INTERNATIONAL SYMPOSIUM ON LOGISTICS

Proceedings of the 24th International Symposium on Logistics
(ISL 2019)

Supply Chain Networks vs Platforms: Innovations, Challenges and Opportunities

Wurzburg, Germany
14th – 17th July 2019

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Supported by: **The Institute for Advanced Manufacturing, The University of Nottingham, UK**

Website: **http://www.isl21.org managed by The University of Nottingham, Nottingham, UK**

Registration coordination: **Mejimedia.com**

Front cover: **Würzburg, Germany**

ISBN: **ISBN- 9780853583295**

Published by: **Centre for Concurrent Enterprise, Nottingham University Business School, Jubilee Campus, Wollaton Road Nottingham, NG8 1BB, UK**

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INTRODUCTION

We are delighted to welcome our friends and colleagues, both old and new, to the 24th International Symposium on Logistics in the historic location of Würzburg, Germany. Würzburg offers a special mix of culture and ambiance, of world heritage and wine festivals, of modern and classical music, of avant-garde and age-old traditions, of sciences and party atmosphere that make this city popular. The stunning historical architecture provides the perfect setting for everything Würzburg has to offer: The Residenz Palace, a UNESCO World Cultural Heritage Site, the view from the Fortress Marienberg across the many towers rising above the city – the cathedral, the Marienkapelle, the town hall, and the Käppele. Quaint restaurants and traditional wine taverns offer local products (Würzburg is one of the best wine-growing regions in Germany). It is also home to about 36,000 university students. Wilhelm Conrad Röntgen once taught here and discovered X-rays that have transformed our lives. Over the years, 14 Nobel prize laureates studied and carried out research at the University of Würzburg. Considering the location and the historical significance of the city for scientific discovery and innovation, the chosen theme for ISL2019 is "Supply Chain Networks vs Platforms: Innovations, Challenges and Opportunities". The 24th ISL aims to provide a forum for both academics and practitioners to discuss the current and future research in the area of logistics and supply chain management. The papers in this book proceedings represent the latest in academic thinking, as well as case examples of successful implementations. The 24th ISL, also presents an opportunity to engage in various discussions and debates during the course of the event and see how our models, concepts and findings are pushing the frontiers of knowledge in the area of logistics and supply chain. Equally, it is important to explore how our cumulative know-how in our discipline can be successfully applied to develop the next generation of experts through our teaching and curriculum development as well as helping the practitioner community to enhance the competitiveness of industry.

For us as event organisers, it is especially gratifying to see that this year's symposium will once again be a truly international event, having attracted submissions from across the globe. This, together with the healthy balance of participants who have contributed regularly to the symposium over the years, combined with many first time participants who inject new ideas and points of view into the community, promises to make the event an enjoyable and valuable experience.

A particular strength of the ISL community is the enthusiasm of the participants. As the number of parallel sessions during the programme is kept low, many participants value the personal touch and community feeling that this engenders. Having the opportunity to receive personal feedback during the formal sessions, coupled with discussions and debates at the many informal setting that the symposium offers, invariably results in a memorable experience.

As in previous years, all abstracts and/or full papers were reviewed by two or more academic experts from the field of Logistics and Supply Chain Management. This book of proceedings containing the accepted papers, has been organised according the following categories:

- General issues in supply chain management
- Applications of ICT in supply chains
- Transport and distribution
- Food and cold chain supply chain management
- Inventory and warehousing
- Supply chain performance assessment
- Complexity, risk and uncertainty
- Sustainability in logistics and supply chains

To date ISL has been held in Europe, Africa, Australasia and Asia (see full list below). Following last year's successful event in the exotic and breath taking settings of Bali, Indonesia, we are very much looking forward to meeting you all at this year's symposium in historic and beautiful Würzburg, Germany.

Last but not least we would like to take this opportunity to express our sincere thanks to all the presenters, delegates, reviewers, Advisory Committee members, organising team, invited guest speakers, sponsors, partner International Journal of Logistics Management's editor Professor Britta Gammelgaard and local organising team for their excellent and valuable contributions. Finally, our special thanks go to Mrs Maeve Rhode, and Jimo Ajeseun for their support throughout the event, as well as Mengfeng Gong for her help in preparing the proceedings.

Professor Kulwant S Pawar, Dr Andrew Potter, Professor Helen Rogers and Professor Christoph Glock – July 2019.

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Session 1: General Issues in Supply Chain Management

IMPLEMENTATION CHALLENGES OF THREE-DIMENSIONAL PRINTING (3DP) IN MEDICAL DEVICE MANUFACTURING SUPPLY CHAINS

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Abstract
Purpose of this paper- The aim of the study is to investigate the implementation challenges of 3DP and explore the level of difficulties in overcoming these challenges.

Design/methodology/approach- We develop a conceptual model by employing the technology-organisation-environment-cost (TOEC) based framework of technology adaptation (Yeh and Chen, 2018; Baker, 2012, Tornatzky and Fleischer 1990). To identify and prioritise the implication challenges of 3DP manufacturing, we conduct case study interviews with 3DP experts. The participants of this research are senior executives of 3DP product firms, and 3DP research and development experts.

Findings- Analysis reveals that the critical implementation challenge categories are predominantly technology (production), and cost related. The major challenges are related to quality of products in terms of surface finish, standard, strength and colour. Furthermore, requirement of new skills in designing the products and cost of raw materials are found to be major challenges.

Originality/Value- This research contributes to both manufacturing management and advanced manufacturing literature. Through literature review this study develops a framework to conceptualise implementation challenges of 3DP manufacturing.

Practical implications- This research will help guide firms using 3DP for manufacturing to identify challenges in implementing 3DP.

Research Limitations –This study is conducted from the one manufacturer's and two research and development organisation perspective. Therefore, further investigation is necessary for other manufacturer involved with 3DP.

Keywords: 3DP, Implementation challenges, Supply chain management.

INTRODUCTION

Three-dimensional printing (3DP) is additive manufacturing based digital technology where products are manufactured on layer by layer basis by adding materials based on digital 3D computer aided design file (Khajavi et al. 2014; Nyman and Sarlin 2014; Attaran 2017b). Earlier in 80's, additive manufacturing technology has been predominantly used to prepare moulds for casting along with preforms (Cotteleer and Joyce 2014; Attaran 2017b). Recent advancement of 3DP is ground breaking and considered disruptive with other emerging manufacturing technologies of Industry 4.0 (Despeisse et al. 2017; Durach et al. 2017).

Unlike traditional manufacturing, 3D printing manufacturing is a tool-less manufacturing system (Attaran 2017b). It uses digital design of products from open/close source (Laplume et al. 2016), utilises special raw materials, dedicated printers for manufacturing the product at a convenient locations and suitable time. The primary advantages of 3D printing are: rapid, customised and low cost production, minimum inventory turnover, low to no material waste, and speed to market (Khorram and Nonino 2017).

It is being suggested that the adoption of 3DP technology shifting the current manufacturing paradigm from mass production to mass customisation and personalisation, and bringing manufacturing close to customer (Attaran 2017a). These changes has the potential to transform the existing business models which may inflict striking impacts on supply chain members such as machine vendors, material manufacturers, software providers, logistics operators, and research centers. Hence, it is imperative to comprehend the effects of 3DP on manufacturing (Nyman & Sarlin, 2014).

3D printing has already adopted by some industries. Among those industries, remarkable sectors are manufacturing of rubber and plastic products, manufacturing of non-metallic mineral products, manufacturing of machinery and spare parts, manufacturing of jewelry, toys and puzzels, dental and medical devices, low-turnover replacement parts and sports items (Berman 2012; Laplume et al. 2016). The 3DP has potential and the global market for 3DP-based business is estimated to hit $23.79 billion by 2025 (GlobalMarketInsights 2018) (Grand View Research, 2018). 3DP market in Australia is also promising. In Australia, labour cost is very high which led many of the manufacturing offshoring. Moreover, the country is remote from rest of the world and geographically disperse/large, therefore international and domestic logistics costs are high, lead time is longer and inventory level is high. 3D printing can minimise most of the existing issues of manufacturing and can support the sector to be more affordable and competitive in the local market. 3DP lies under advanced manufacturing and medical technologies sectors and are the major two industries of Australian Federal government strategic priorities (Aus-Govt 2018).

In spite of its huge potential impact of 3DP, we realise there are anticipated challenges of implementing 3DP. Hence, our objective is to investigate challenges of implementing 3DP and difficulties of overcoming these challenges.

LITERATURE REVIEW OF 3DP CHALLENGES

Various authors worked on identifying the challenge categories that influence 3DP implementation. Mellor et al. (2014) suggested the factors as external force, technological factors, organisational factors, strategic factors, operational factors and supply chain. Attaran (2016), identified implementation challenges under broad categories such as technology, cost, government regulation, and material. Weller et al (2015) identified technological and economic factors of manufacturing firms are critical challenge of 3DP implementation. On the basis of technology-organisation-environment (TOE) framework and cost factors, Yeh and Chen (2018) further proposed TOEC model of challenges. It appears that TOEC model previous does not emphasis the supply chain challenges related to technology. Moreover, technology issues need further break down such as 3DP technology itself and technology management and adaptation issues. Considering the previous research on technology transfer and 3DP we propose the following five categories of challenges of 3DP implementation: (i) technology (production), (ii) technology (adaptation), (iii) supply chain management, (iv) business environment, (v) cost.

Technology (production): 3DP technology is still not well developed to use a wide variety of raw material to produce varieties of products in faster like mass production.

Table 1: Operational definition of technology (production) related sub-challenges

Terms	Brief explanation	Source
Slow speed compared to mass production	Because of the slow speed of 3DP manufacturing, when it needs mass production 3DP is relatively slow to produce large volume of items	Rengier et al. (2010), Berman (2012)
Quality of products	3D manufacturing is producing products layer by layer. Hence there are issues of surface finish, use of different types of colour, product strength, printing precision, and limited materials which further restricts 3D printing utilization, confining it to very particular situations.	Berman (2012), Holmström et al. (2010)
Limited availability of raw materials	3DP technology is still limited to use certain raw materials such as resin and plastics. This limits 3DP to make the variety of the products.	Holmström et al. (2010)

Technology (adaptation): Since 3DP is an emerging technology, there are issues in adapting the new technology by firms, and required new skills to use the technology and related supply chain.

Table 2: Operational definition of technology (adaptation) related sub-challenges

Terms	Brief explanation	Source
New skills for design and production	Due to the adaptation of new 3DP technology in manufacturing, new skills are required in the form of product design, materials development and sourcing, and to work in new orientation of supply chain. There is a demand for the new skilled workforce who can design, model, and manufacture different products. Educating designers and engineers about the potential uses and benefits. Needs significant training as most of the non-expert owners don't have a printer (home printing).	Weller et al. (2015), Ford and Despeisse (2016)
Infrastructure readiness	3DP is basically an implementation of new manufacturing technology which needs firms' capabilities of digital infrastructure to use of CAD software, as well as digital imaging technology to produce goods	Yeh and Chen (2018)

Supply chain management: The supply chain of 3DP is considered as a demand chain and is consisted of processes such as plan and acquisition of design or images, post-processing of images by Computer-Aided Design (CAD), sourcing raw materials, manufacturing of 3DP products, and finally delivering the product to customer. 3D printing processes relies on the intersection of two supply chains: the supply chain of a machine and materials vendor and the supply chain of the company intending to purchase the tools that allow them to 3D print products (Mellor et al. 2014). 3DP has the potential to change the tradition supply chain structure of manufacturing firms. As a challenge of future growth, firms need to redesign and establish relationship with the new supply chain partners in new digital business environment.

Table 3: Operational definition of supply chain management related sub-challenges

Terms	Brief explanation	Source
Last-mile delivery design/planning	New manufacturing technology is bringing the manufacturing near to the point of consumption. There is a tremendous decrease in transportation of finished goods which will change the existing distribution system, hence new last-mile delivery design is required	Mckinnon (2016), Manners-Bell and Lyon (2012)
Organisational readiness	Business organisations are not ready yet to adopt the changes necessary to implement the 3DP. Organisations need to view 3DP as a strategic move and then support and deploy resources such as top-level management support, and technical capabilities and financial resources.	Yeh and Chen (2018), Liu et al. (2013)
Supply base reconfiguration	3DP production technology is changing the existing supply chain structure of raw materials sourcing and supply. The raw materials are only consumed at downstream supply chain, mostly purchased items will be raw materials and CAD. The digital raw materials chain (source digital	Waller and Fawcett (2014), Berman (2012), Kietzmann et al. (2015)

	design) will create disruption in traditional part supply.	
Business relationship	Because of new supply chain structure, business relationship between the supply chain partners are changing and need to re-establish. Integration and relationship of activities across designers, makers, and movers of goods, digital platforms will have to be established.	(Campbell et al. 2012)

Business environment: Consideration of the business environment of 3DP is important to implement the new technology. There needs to have relatively sufficient market demand for 3DP products, to regulate the piracy or intellectual copy right issues government policy and regulation should be in place, and lastly, a healthy market competition is required for 3DP implementation. Details of the business environment related challenges are shown in Table 4.

Table 4: Operational definition of business management related sub-challenges

Terms	Brief explanation	Source
Regulatory issues	Consumers can purchase designs from online market and then build products at home. No control on personalisation and printing could result in easy access to the products such as firearms, weapons etc. This freedom introduces challenges of counter freight products, making illegal products, and there will be issues of intellectual property rights of design.	Long et al. (2017), Schniederjans and Yalcin (2018)
Competitive pressure	Competitive pressure positively influences the start of 3DP business. Influenced by competitive pressure to deliver customised goods and services some firms are forced to implement 3DP.	Srai et al. (2016)
Market readiness	The market for different types of 3DP services has, not yet stabilized, with frequent market entrances and exits. Moreover, customers are not ready yet to choose for a 3DP products when they have other alternatives.	Rogers et al. (2016)

Cost: Cost of production is an impeding factor for the success of 3DP implementation. Business organisations still reconsiders the fixed costs of printing services, raw materials cost and cost of high volume of products. The summary of the cost related challenges is shown in Table 5.

Table 5: Operational definition of cost related sub-challenges

Terms	Brief explanation	Source
Production volume related cost	3DP takes time to produce a large volume of products hence for mass production the 3DP facility is still not cost effective	Long et al. (2017), Berman (2012)
Printer cost	3D printers are an expensive investment. Hence, the cost of investment is high for small quantity of products	Long et al. (2017), Huang et al. (2013),
Cost of raw material	The raw materials used by 3DP are much more expensive than their conventional manufacturing equivalents. Materials for 3DP manufacturing 'can be 53 to 104 times more expensive than plastic materials for injection molding.	Huang et al. (2013), Wohlers and Caffrey (2013)

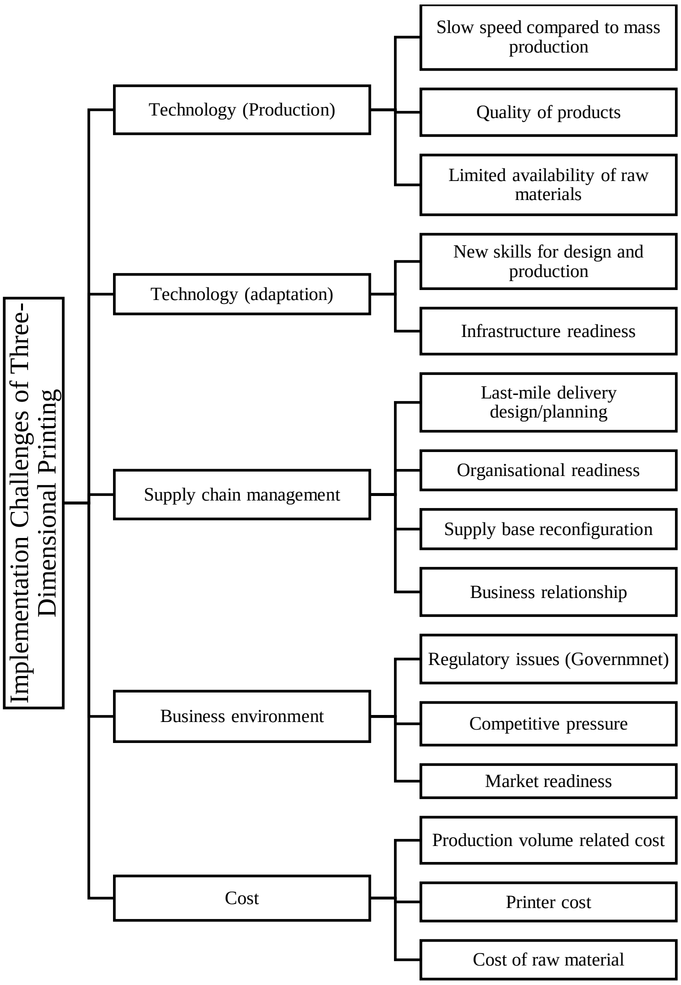

Figure 1: A conceptual framework of 3DP challenge-categories and sub-challenges

METHODOLOGY AND RESULTS

This study employs the analytic hierarchy process (AHP) methodology for analysis. AHP is a multi-criteria decision making approach that helps in breaking down a complex, unstructured situation into components in hierarchical structure (Saaty 1990). There are three main construction steps of AHP: hierarchy construction of criteria, compilation of decision-makers' opinions, and synthesis of normalized priority weights and consistency verification (Saaty 1990). Considering the features of the AHP approach and nature of our research problem, we find AHP an appropriate method for identifying critical challenges of 3DP implementation.

Case study and respondents

To prioritize the implications challenges of 3DP and to find the level of difficulties to resolve the issues, we conducted case study interviews with 3DP experts in the field. We investigate three case studies and conduct structured interview with the 3DP experts of each case.

Participants of these case organisations are selected by using a purposeful sampling and snowballing techniques. Selection of respondents were based on their position, current role in 3DP, work experience and background knowledge. We visited websites of organisations related to 3DP, identified key professionals and approached them though telephone, email and LinkedIn. Upon confirmation of their participation, prior to the structured interview we sent the AHP questionnaires to participants to give a prior idea of the interview questions. After approaching several potential participants, we confirmed interviews with three participants.

Case 1 is an independent R&D organisation conducts research and support local industries through 3DP related services. The organisation is servicing industries such as mining, medical device, sports, defence, and providing 3DP services such as R&D and printing services. The organisation is involved in 3DP related activities for more than 10 years. Case 2 is a manufacturing organisation in Victoria, Australia. The organisation is involved in 3DP business for more than four years and serving the sports industry through 3DP design, R&D, and printing services. Case 3 organisation is a tertiary research institute based in Melbourne, Australia. The organisation conducts additive manufacturing and 3DP related research to manufacture high value complex products for the mining and medical device industry for more than 9 years.

Respondents of the above three cases are manager (case 1), engineering director (case 2), and technical director (case 3) of 3DP product manufacturing and research and development organisations in Melbourne, Australia. Respondents requested to keep their identity anonymous. The work experience of these executives varies between 15-37 years in the field of manufacturing and 4-9 years in 3DP.

Identification of critical challenges using AHP

We develop a two-part questionnaire for data collection. First part of the questionnaire focuses on collecting respondent demographic information and their organization profile. Second part of the questionnaire is based on the Analytical Hierarchy Process (AHP) framework (Satty and Vargas 1990) where respondents will be asked to pairwise compare the challenges and impacts within five attributes: equal (scale 1), moderate (scale 3), strong (scale 5), very strong (scale 7), and extremely strong (scale 9). The data collection procedure using the AHP methodology lasted over 60 minutes for each respondent. Following AHP we rank critical impacts and challenges of 3DP. The process of AHP involves three steps:

Step 1- Identification of key challenges and AHP structuring: The first step involves identification of key challenges for 3DP implementation. We considered five major challenge-categories and 15 sub-challenges for implementation of 3DP (shown in Figure 1). In this study, the problem was structured as goal (Level1), challenge-category (Level 2), and sub-challenges (level 3) at three hierarchical levels (see Figure 1).

Step 2- Pair-wise comparison of challenges and determination of local priorities of sub-challenges: In this step, challenges in each level are compared pair-wise in terms of their importance to a challenge in the next higher level. The scale used for pair-wise comparisons in AHP is called a one-to-nine scale and is based on five attributes equal (scale=1), moderate (scale=3), strong (scale=5), very strong (scale=7), and extremely strong (scale=9). We asked participants to judge the relative importance of the five major challenge-categories, and sub-challenges under each category. In total six matrices were generated: one for challenge-categories at level 2 and five for sub-challenges at level 3 of the hierarchy.

Local priorities of sub-challenges under each challenge-category are determined by considering only level 2 and corresponding 3 challenges. In this step of the AHP, the preference matrices generated were translated into the largest eigenvalue problems. Next, eigenvalues were solved for unique and normalised vectors of weight to criteria in each level of the hierarchy. Following this process, we generated the local priority weights of respondents for each of the challenge categories and sub-challenges. The results of the local priority weights for each case are shown in Table 6.

The calculated relative priorities of sub-challenges are discussed for each challenge categories. For example, under the technology (production) category, R&D and manufacturing organisation consider quality of product is a major challenge, tertiary research institute considers slow speed compared to mass production is a major challenge of implementation. Under the supply chain management category, all the respondents consider organisational readiness is a major challenge. Regulatory issues (government) is the main challenge under the business environment category. For the technology (adaptation) all the respondents consider new skills for design and production is a major challenge. Lastly, under the cost, the critical sub-challenges are cot of raw materials and production volume related cost.

Table 6: Local priority weights of sub-challenges

Challenges/Sub-challenges	Case		
	R&D organisation	**3DP service provider**	**Tertiary research institute**
1. Technology (production)			
1.1 Slow speed compared to mass production	0.201	0.066	0.594
1.2 Quality of products (surface finish, standard, strength, colour)	0.730	0.785	0.249
1.3 Limited availability of raw materials	0.060	0.149	0.157
2. Technology (adaptation)			
2.1 New skills for design and production	0.900	0.900	0.833
2.2 Infrastructure readiness	0.100	0.100	0.167
3. Supply chain management			
3.1 Last-mile delivery design/planning	0.049	0.047	0.062
3.2 Organisational readiness	0.584	0.616	0.400
3.3 Supply base reconfiguration	0.101	0.196	0.207
3.4 Business relationship	0.266	0.140	0.331
4. Business environment			
4.1 Regulatory issues (Government)	0.637	0.333	0.731
4.2 Competitive pressure	0.258	0.333	0.081
4.3 Market readiness	0.105	0.333	0.188
5. Cost			
5.1 Production volume related cost	0.189	0.053	0.594
5.2 Printer cost	0.120	0.474	0.249
5.3 Cost of raw material	0.691	0.474	0.157

Step 3- Determination of critical challenges and consistency of judgements: In the third and final step of AHP, the overall weights of the challenges are determined by aggregating the local priority weights throughout the hierarchy. The AHP analysis also provides a direct measure of consistency of judgment elicited by the respondents or decision makers. Saaty (1990) demonstrated inconsistency ratio (CR) as the degree to which decision-makers adhere to the rank order specified and measures the extent to which an established preference is kept. A CR≤0.1 is considered acceptable (Saaty and Kearns 1985). Based on AHP principles and using the Expert Choice® Software we calculate the overall CR of the model for each respondent's judgement, CR with respect to the goal. For each respondent, global priority weights are calculated with respect to goal by synthesizing all the weights and relative priorities of second and third hierarchy level. Details of respondent's judgment CR, global priority weights of sub-challenges are presented in Table 7.

From Table 7, it appears that critical challenge categories of 3DP are related to technology (production), cost, and business environment. Respondents of two case organisation (R&D organisation and 3DP service provider) ranked technology (production) as the most critical challenge category. Cost is considered as another important challenge category, respondent from tertiary research institute considers cost as the most critical challenge and 3DP service provider considers cost as second most important challenge. The judgements for the three cases are consistent with CR ≤ 0.1.

Considering the overall priority ranking of sub-challenges for three respondents, R&D organisation ranked top four sub-challenges as: quality of products, new skills for design and production, slow speed compared to mass production, and regulatory issues. 3DP service provider considers top four sub-challenges as: quality of products, new skills for design and production, cost of raw materials, slow speed compared to mass production, and printer cost. From the global priority of tertiary research institute respondents, top four sub-challenges are: production volume related cost, regulatory issues (government), printer cost, and cost of raw materials. Considering all the three cases, we can conclude that quality of products (surface finish, standard, strength, colour) and new skills for design and production are the two top two sub-challenges of implementing 3DP manufacturing.

Table 7: Overall priority ranking of the challenges

	Level of overcoming difficulties		
	Case		
Challenges/Sub-challenges	**R&D organisation**	**3DP service provider**	**Tertiary research institute**
CR	**0.10**	**0.08**	**0.08**
1. Technology (production)	**0.561**	**0.479**	**0.094**
1.1 Slow speed compared to mass production	0.113	0.032	0.056
1.2 Quality of products (surface finish, standard, strength, colour)	0.415	0.377	0.023
1.3 Limited availability of raw materials	0.034	0.071	0.015
2. Technology (adaptation)	**0.133**	**0.12**	**0.137**
2.1 New skills for design and production	0.120	0.108	0.114
2.2 Infrastructure readiness	0.013	0.012	0.023
3.Supply chain management	**0.043**	**0.139**	**0.040**
3.1 Last-mile delivery design/planning	0.002	0.006	0.002
3.2 Organisational readiness	0.025	0.084	0.016
3.3 Supply base reconfiguration	0.004	0.027	0.008
3.4 Business relationship	0.011	0.019	0.013
4. Business environment	**0.174**	**0.037**	**0.241**
4.1 Regulatory issues (Government)	0.111	0.012	0.176
4.2 Competitive pressure	0.045	0.012	0.020
4.3 Market readiness	0.018	0.012	0.045
5. Cost	**0.089**	**0.228**	**0.488**
5.1 Production volume related cost	0.017	0.012	0.290
5.2 Printer cost	0.011	0.108	0.122
5.3 Cost of raw material	0.061	0.108	0.077

Overcoming the challenges and sub-challenges

We further investigate the difficulties of overcoming the challenge categories and sub-challenges. We ask the respondents to scale the difficulties as high, medium and low grade. In Table 8, we summarised the scales provided by the respondents. Out of five challenge categories, all the three respondents ranked technology (production) and cost are highly difficult to overcome. Among the sub-challenges, organisational readiness and new skills for design and production are considered to be highly challenging to overcome. All the respondents ranked quality of products, printer cost, and cost of raw material as the second difficult category level (two respondents ranked them high and one as medium).

Table 8: Difficulties in overcoming challenges

Challenges/ Sub-challenges	Level of overcoming difficulties		
	Case		
	R&D organisation	**3DP service provider**	**Tertiary research institute**
1. Technology (production)	High	High	High
1.1 Slow speed compared to mass production	Low	Medium	High
1.2 Quality of products (surface finish, standard, strength, colour)	High	High	Medium
1.3 Limited availability of raw materials	Medium	Low	Medium
2. Technology (adaptation)	Medium	Medium	Medium
2.1 New skills for design and production	High	High	High
2.2 Infrastructure readiness	Low	Low	Medium
3. Supply chain management	Low	Medium	Medium
3.1 Last-mile delivery design/ planning	Low	Low	Medium
3.2 Organisational readiness	High	High	High
3.3 Supply base reconfiguration	Medium	Medium	Medium
3.4 Business relationship	High	Medium	Medium
4. Business environment	Medium	Low	High
4.1 Regulatory issues (Government)	High	Low	High
4.2 Competitive pressure	Medium	Low	Medium
4.3 Market readiness	Medium	Low	Low
5. Cost	High	High	High
5.1 Production volume related cost	Low	Medium	Low
5.2 Printer cost	Medium	High	High
5.3 Cost of raw material	High	High	Medium

DISCUSSION

AHP analysis indicate the critical challenge categories of implementing 3DP are related to technology (production), cost and business environment. While considering the sub-challenges then the top critical challenges are related quality of products (surface finish, standard, strength, colour) and new skills for design and production. Other critical challenges are regulatory issues (government), cost of raw materials and printer cost.

Quality of products is a challenge due to the new technology related issues such as the lack of printing precision, colors, surface finishes, stability of product parts, and limited materials (Berman, 2012). The materials used for 3D printing (like liquid polymers, powder comprised of resin or plaster) lacks material strength. Early adopters are experiencing the disruption effect of new technology. Among those industries, remarkable sectors are manufacturing of rubber and plastic products, manufacturing of non-metallic mineral products, manufacturing of machinery and spare parts, manufacturing of jewellery, toys and puzzles, dental and medical devices, low-turnover repair or replacement parts and sports items (Berman 2012; Laplume et al. 2016). Plastic beads or large-sized particles create a rough and ribbed surface. This creates an uneven and unfinished look to the end product (Huang et.al., 2013). As the parts are created on layer by layer basis the strength is not uniform. Furthermore, often the parts from different machines will have varying properties (Campbell et. al, 2011).

In the new 3DP market where the competitive landscape is rapidly shifting, dynamic capability needs to be developed in terms of developing skills of 3DP design. To adopt with the new 3DP technology, new skills related to new technology needed to be developed. There are demands for the new skilled workforce who can design, model, and manufacture different products for 3DP. Educating designers and engineers about potential uses and benefits of 3DP also necessary (Ford and Despeisse 2016).

Cost is also another crucial aspect for the success of 3D printing. We identified an important challenge of 3DP under cost category is high cost of raw materials. Unlike other manufacturing process, 3D printing uses raw materials such as plastics, alloys and resins that are readily available from small number of vendors (Waller & Fawcett, 2014).

CONCLUSION

This study proposes the 3DP implementation challenge framework based on TEOC model. Furthermore, using AHP methodology through case study interview, we identify critical challenges of implementing 3DP. Among the major challenge categories, technology related to production is critical. Respondents perceived that it will be highly difficult to overcome the quality issues soon. It is expected that 3DP technology would continue to improve this challenge related to quality. For a new technology such as 3DP more research and development is necessary to improve the quality of the product in terms of precision, strength and aesthetic view. Second important challenge category is business environment. Market demand for 3DP products is not enough for sustainable business. Moreover, government policy and regulation should be in place to stop piracy or intellectual copy right issues. Capability or lack of skills are also hindering the implementation of 3DP. Organisations need to be equipped with new skills and dynamic capability needs to be developed in terms of developing skills of 3DP design, running the manufacturing operations. This research employed case study interviews with a limited sample. Further research may employ either case study method with higher number of case studies or use survey technique with a large sample size.

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THE IMPACT OF ADOPTING ADDITIVE MANUFACTURING ON THE PERFORMANCE OF A RESPONSIVE SUPPLY CHAIN

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Abstract
Purpose
Matching supply with demand is the primary concern of supply chain management. Uncertainty in demand, however, is detrimental to performance as it leads to cost in the form of backorders, low capacity utilisation and avoidable inventory. This paper investigates the value of adopting Additive Manufacturing (AM) technology for the performance, and flexibility as a performance-related metric, of a supply chain with uncertain demand, taking into consideration the cost of inventory and backorders.

Design/methodology/approach
This paper implements an inter-process comparison by simulating a supply chain based on data collected from a plastic products manufacturing company that produces pipe fittings using injection moulding technology. The used dataset was combined from company information and AM specific data form the University of Nottingham. The investigated simulation model is built for both scenarios, with AM and with injection moulding, using the Arena software package.

Findings
By incorporating the cost of inventory and backorders, injection moulding still showed lower unit cost compared to AM. While AM exhibited higher levels of supply chain flexibility both in mix and new product introduction, injection moulding presented higher volume and delivery flexibility.

Value
This paper addresses a gap in current knowledge by systematically examining the value of employing AM in mass manufacturing environments with uncertain demand. These findings will shed light on the broader benefits of AM adoption by investigating its impact in a wider supply chain context

INTRODUCTION AND LITERATURE

One important aspect in the managing of supply chains is the matching of supply and demand. As recent research has shown, the costs of both holding large amounts of inventory and not being able to fulfil orders due to insufficient inventory, referred to as a 'stockout', must be carefully traded off (Christopher, 2016). As demonstrated by Donaldson (1977), this trade off can be managed with a strategy of optimisation in environments where demand is certain and deterministic inventory management policies are employed. The contrasting situation occurs if demand is uncertain: in this case, it is likely that excess inventory and stockouts lead to relatively high costs. Such costs are effectively the result of a binary decision to either produce in batches or not to produce at all. Hence, they are driven by the logic of economies of scale in which average unit costs decrease as the produced quantity increases by spreading fixed costs across higher production volumes (Zipkin, 1986).

The concept of economies of scale has been challenged recently through the emergence of Additive Manufacturing (AM) technology, also referred to as 3D printing in a wide range of industries including automotive, aerospace, jewellery and pharmacy (Ben-Ner and Siemsen 2017). As a process that does not require dedicated tooling, such as moulds, cutting implements or dies, there are no tooling costs that are amortised over production runs (Weller, Kleer and Piller 2015). This has led to claims that in AM, average unit cost does not benefit from an increase in total production quantity.

To establish the feasibility of adopting AM technology in commercial manufacturing applications, it is normally necessary to compare the unit costs of AM against conventional manufacturing technologies (Tuck et al., 2008). Such comparisons are frequently constructed as break-even analyses contrasting the unit cost functions of AM and conventional manufacturing. This has allowed researchers to identify quantity-thresholds beyond which conventional tooled processes are more cost effective than AM for a given product (Ruffo et al., 2006). In comparisons of the cost performance of AM against injection moulding, which is one of the most widely adopted technologies in mass manufacturing of polymer components, two broad scenarios have been proposed to establish the commercially feasibility of AM. First, Mellor et al. (2014) have shown that where production runs are limited to small quantities, AM adoption might be beneficial from a unit cost perspective due to the absence of sunk tooling costs. Second, Sasson and Johnson (2016) proposed that AM forms a cost effective approach in applications in which demand is volatile and infrequent. In such cases, AM and conventional manufacturing systems can be run alongside each other, with conventional technologies used to serve predictable and regular order flows and AM being used to cater for volatile demand elements resulting in irregular orders. The spare parts industry, for instance, has been suggested as a production environment in which AM is proven to be cost effective (Liu et al., 2014) due to demand uncertainty and low order quantities.

Traditionally, the costing literature distinguishes between two types of manufacturing costs (Son, 1991): well-structured costs incurred through predictable aspects such as material purchases, machines and operators, and ill-structured costs which are hard-to-predict costs arising from aspects such as quality, process failure and inventory. Although a considerable body of literature investigates the performance of AM in terms of well-structured cost models (e.g. Ruffo et al., 2006) few AM cost models include ill-structured cost variables (e.g. Baumers and Holweg, 2016). Baumers and Holweg (2016) have argued that realistic cost models should be used as a basis for the statement of cost-quantity relationships in AM and should reflect ill-structured elements. To date, no studies have addressed the cost effectiveness of AM in mass production environments while accounting for inventory-related costs and the opportunity costs resulting from stockouts.

This article is therefore in line with the move towards increased realism in the investigation of the commercial aspects of AM through the inclusion of the cost impact of inventory and stockouts. This is further supported through a complementary investigation of the effects of supply chain flexibility. As discussed in the supply chain literature, supply chains that face demand uncertainty benefit from being more responsive (Fisher, 1997). To measure such responsiveness, the flexibility of the supply chain has been suggested as a core performance metric (Reichhart and Holweg, 2007) while cost is characterised as a market qualifier (Roh, Hong and Min, 2014). To address these issues, this paper develops an extended cost model including inventory carrying, order and stockout costs and employs it in a simulation approach featuring uncertainty in demand. Additionally, this paper applies four flexibility metrics to the model to evaluate the flexibility yielded through the adoption of AM in mass production environments.

This paper is organized as follows: Section 1 describes the research methods. Section 2 presents the findings. Section 3 presents and discusses the results reached. The final sections presents as summary and lists identified limitations of this study.

METHODOLOGY

An inter-process comparison between AM and injection moulding is constructed by simulating a supply chain based on data collected from a plastic products manufacturing company that produces pipe fittings in Saudi Arabia. In a preliminary step, the products manufactured by the company were surveyed and data on the demand for each product was collected. The demand volatility level, known as Coefficient of Variation (*CV*), was estimated using the method proposed by Olhager (2003) to establish the level of volatility in demand faced by each product. Following this assessment, one product with a *CV* value in excess of 40% (based on the threshold value identified by Halawa et al., 2017), was chosen for the study. The selected product is a PVC Pipe tee joint ¾" as shown in Figure 1.

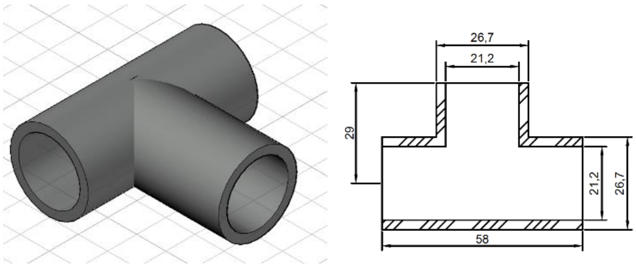

Figure 1: CAD drawing of the part selected as a case study: Pipe tee joint ¾" (dimensions in mm)

Pertaining to this product, additional process time and cost data were collected, including changeover durations and lead-times. The specified cost model is based on the structure proposed by Atzeni et al. (2010) for the comparison of polymeric AM versus injection moulding. Additionally, a set of historical sales data have been collected from the host company for a period of 49 months.

The simulation models

In the following step of the investigation, the system behaviour of the supply chain of the host company was simulated using the Arena software package (version 15.1). Based on the information provided by the company, a basic process model for the current production line using injection moulding was specified, as summarised in Figure 2. In this process, the company initially receives orders from customers which are either rejected or accepted based on the availability of sufficient stock in the inventory. If accepted, an order is processed and shipped. If the order is declined, the process ends with no additional action taken. New production activity is initiated on the basis of inventory data using a continuous review inventory model. The stated inventory reorder point is 11,600 parts with a target stock of 13,800 parts.

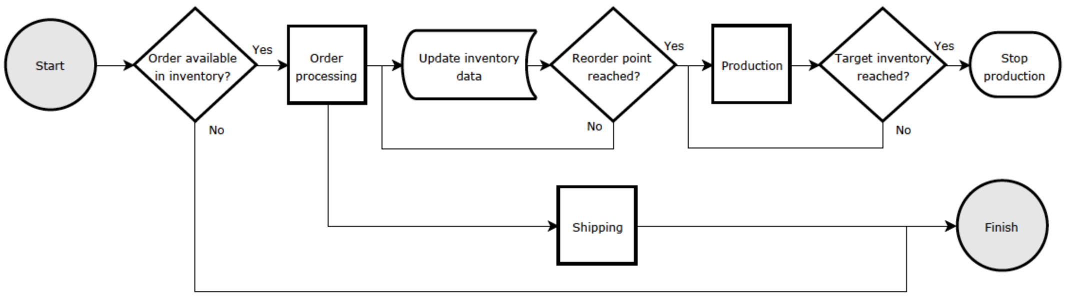

Figure 2: Flowchart of the current supply chain configuration of the manufacturing company

Through its continuous review inventory model, the host company implicitly takes into account demand and market characteristics. Where a quantity in excess of the currently available inventory level is requested by the customer, and hence cannot be served out of existing stock, the customer will usually contact competing companies motivated by the long lead-time needed to fulfil the order. Due to a normal level of capacity utilisation of the available injection moulding equipment, resulting from the manufacture of products featuring predictable and continuous demand, the lead time for the production for other products exceeds two weeks in most cases, which is deemed too long for a reactive Make-to-Order approach.

The collected historical sales data were used to specify an inter-arrival time-quantity distribution using the Input Analyzer Tool in Arena. The least square error, which is the total sum of squared discrepancies between the frequencies in the histogram of the sales data and those in the fitted distribution, was used to select the type of distribution best representing the collected data. This resulted in time between arrivals that follows a Weibull distribution while demand volume with each arrival is represented by a Beta distribution.

The following step in the investigation was to construct a corresponding process model for the AM pathway. As shown in Figure 3, the replacement of the conventional injection moulding process by AM technology significantly altered the structure of the model. Based on the maximum expected demand, five AM machines were allocated in the simulation to ensure the availability of sufficient machine capacity to cover the investigated demand levels. The AM system selected for this simulation is the EOS P770 system, which is a polymeric laser sintering system featuring a relatively large nominal of build volume of 700 mm x 580 mm x 380 mm (EOS GmbH, 2019). Using the total build time estimator proposed by Ruffo et al. (2006), the time required to manufacture a full build of the investigated product is estimated at 30 hours for each build. A raster-type model of build volume packing was used to estimate that each AM build could accommodate a quantity of 1,400 units of the tee joint at full capacity. Since activity-based cost models of this type require the statement of a depreciation period for the AM system, it was possible to simplify the overall modelling approach by setting the simulation time span and the depreciation periods for both the injection moulding and AM processes to 5 years (as done by Atzeni et al., 2010).

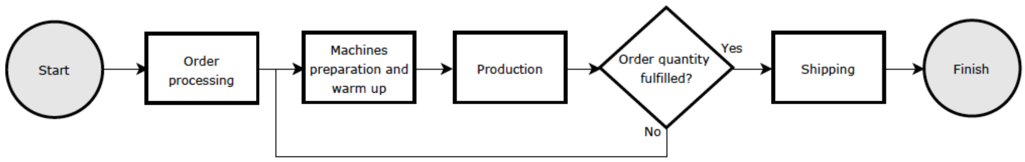

Figure 3: Flowchart of the supply chain configuration with AM

To better understand the performance of both supply chain simulations implemented in Arena, the models were executed for a pre-specified period (five years) and an extended period (ten years). Additional validation of the modelling approach was sought through the review of the models and the results with the executives from the host company.

Manufacturing cost parameters

The unit cost models developed for both the AM and the injection moulding pathways are based on the general model structure for inter-process comparisons proposed by Atzeni et al. (2010). The material used to produce the part using injection moulding is PVC procured as a feedstock at a price of €16/kg. Since PVC cannot be processed with the investigated variant of AM technology, laser sintering, the corresponding material employed in the AM supply chain is a Nylon 12 type material (PA2200) procured at a cost of €54/kg. The part volume of the product shown in Figure 1 is 2.27 cm3. Due to the characteristics of proposed AM technology, sacrificial support structures are not needed in the AM route and degraded raw material is the only form of waste. Labour costs entered the AM pathway in the form of direct cost of €0.23/part. The purchase price for each AM system (EOS P770) is estimated at €668,475, based on Hasan (2017), with assumed useful life of five years (as stated above). A depreciation cost of €133,695 per year therefore has been estimated in this study following a straight-line depreciation technique.

For the injection moulding pathway, the most significant cost element is the tooling expense, estimated by the host company at €30,000; this cost was amortised over the manufactured quantity. The tooling features four mould cavities, allowing the concurrent processing of four units in the moulding cycle, with each moulding cycle taking 74 seconds to complete. The operator cost per part for injection moulding, arising as a direct cost, is €0.009/part. The injection moulding machine (Haitian MA 5300) price is estimated at €110,000 with assumed service life of five years. This results in a depreciation cost of €22,000 per year.

Inventory, order and stockout costs

The total supply chain cost model was obtained by combining the manufacturing cost estimate with three additional elements: inventory costs, order costs and stockout costs. An order cost estimate of €44.22 per order was obtained from interviews with operations managers in the host company. It is assumed that the order cost is identical for both the AM and injection moulding pathways. An inventory holding cost estimate was obtained by applying an inventory carrying cost factor of 0.25 reported in the literature (Brolin, 2015) to the manufacturing cost estimate. Finally, the stockout cost incurred by the company is modelled as an opportunity cost incurred via profit loss resulting from unmet orders. Thus, the total supply chain cost was established using the following model:

Total supply chain cost = Inventory holding cost + Inventory order cost + Inventory stockout cost + Manufacturing cost (1)

Flexibility metrics

To assess the impact of AM adoption on flexibility characteristics alongside estimates of unit cost, this paper investigates four relevant flexibility metrics (Reichhart and Holweg, 2007). These are: mix flexibility, volume flexibility, delivery flexibility and new product flexibility. This section briefly introduces each.

1. *Volume flexibility*

Volume flexibility can be defined as the range of possible manufacturing volumes a company can produce in response to demand. Based on this, Beamon (1999) characterises volume flexibility (F_v) as the probability of the quantity demanded being within a certain interval:

$$F_v = P\left(\frac{O\,min - \overline{D}}{\sigma} \leq D \leq \frac{O\,max - \overline{D}}{\sigma}\right) \quad (2)$$

Where D represents the instantaneous market demand as a random variable with an approximately normal distribution with mean $\overline{D}$. O_{min} denotes the minimum profitable production volume a company can produce in specific period of time and O_{max} refers to the maximum profitable production volume within the same period. For both supply chain models it is assumed that profitability is constrained by the maximum time a customer can wait, which is estimated at two weeks based on the information provided by the host company. Using this metric, a high value for F_v represents a low degree of volume flexibility, and vice versa. In both supply chain scenarios $\overline{D}$ was set to 3,240 parts with a standard deviation of 7,530 parts. Additionally, O_{max} for injection moulding was estimated at 134,400 parts and at 78,400 parts for AM. O_{min} was estimated at 200 parts for the injection moulding route (based on the minimum possible quantity a customer can order from the inventory) while 1400 parts was assumed to be the minimum order for the AM route to ensure adequate capacity utilisation.

2. *Mix flexibility*

The concept of mix flexibility represents the range of different product types that can be produced throughout a specific period of time. This aspect can be captured by considering the changeover time as a metric. The mix flexibility, hence, was calculated for each supply chain model by linking it to the changeover time T_{ij} from product family i to product family j, which basically represents the set up time in this study. Mix flexibility therefore is estimated as follows (Beamon, 1999):

$$F_m = T_{ij} \quad (3)$$

3. *Delivery flexibility*

The main purpose of the delivery flexibility metric is to reflect the ability to shorten a production lead-time to accommodate rush orders. Therefore, delivery flexibility is expressed as the share of slack time in lead-time. The delivery flexibility metric proposed by Beamon (1999) is based in the assumption that the supply chain produces more than one product, which is not the case in this model. Therefore an adapted delivery flexibility equation is used:

$$F_D = \frac{L - E}{L} \quad (4)$$

where L is the due time (or last possible time to deliver the product) and E is the earliest time the product can be delivered. As specified in the above, a two week maximum lead-time window is assumed.

4. *New product flexibility*

The flexibility of new product, F_n, measures the ability to add new products to the current manufacturing processes. This can be reflected using Beamon's (1999) model, in which C refers to the cost required to add new product to the system:

$$F_n = C \quad (5)$$

RESULTS AND DISCUSSION

The execution of the models of the injection moulding and AM pathways in Arena allowed the estimation of manufacturing quantities for each technology. The injection moulding model estimates the production of a total of 378,841 parts in the investigated 5 year period. For the same time period, the AM model predicts a total production quantity of 239,400 parts. Despite all orders being met in the AM route (unlike the injection moulding route), our model suggests that the overall output of the AM supply chain is lower than that of the injection moulding supply chain in four out of five years. The main explanation for this result is that in the injection moulding model initiated is initiated for batch production. This leads to the accumulation of buffer inventory, while with AM only ordered quantities are produced.

Table 1 compares the main model results for both pathways occurring over the investigated five-year period. As can be seen, the model suggests that the overall output quantity of the injection moulding pathway is larger (378,012 units) than the quantity generated in the AM pathway (239,400 units). Additionally, injection moulding benefits from the amortisation of tooling expenses across the manufactured volume of products, leading to a lower manufacturing unit cost of €0.78 versus €2.06 in AM. We note that the observed cost level is broadly in line with the cost performance reported by Atzeni et al. (2010). As per the model specification, inventory and stockout costs do not occur in the AM pathway – the model suggests, however, that these costs are not great enough to outweigh the manufacturing cost advantage of injection moulding, as shown by the total supply chain unit cost estimates of €2.07 for AM and €1.03 for injection moulding. The model thus indicates that, on a cost basis, the conventional injection moulding route is more attractive than the adoption of AM, especially if it assumed that the sales price for the investigated component is independent of the used technology.

Table 1: Comparison of cumulative model results after five years

Model element	Unit	Additive Manufacturing	Injection Moulding
Production volume	pcs	239,400	378,012
Manufacturing unit cost per part	€	2.06	0.78
Total manufacturing costs	€	418,069	295,440
Inventory holding costs	€	-	14,080
Order costs	€	2,122	1,724
Stockout costs	€	-	78,861.10
Total supply chain cost	€	420,191	390,105
Total supply chain unit cost	€	2.07	1.03

Further insight into the performance of both technologies is obtained from comparing the estimation of the four supply chain flexibility metrics (i) volume flexibility, (ii) mix flexibility, (iii) delivery flexibility and (iv) new product flexibility. As evident from Table 3, the supply chain employing injection moulding shows greater volume and delivery flexibility with 65.6% and 92.8% compared to 59.6% and 91% for AM, respectively. This is due to the existence of buffer inventory in the injection moulding supply chain which gives the ability to fulfil orders with volume as low as 200 and instant shipping of parts from the warehouse. This is unlike the AM route which requires at least 30 hours of production to process any order. AM, on the other hand, shows lower changeover time and cost of new product introduction to the system, which is indicated by the greater mix and new product introduction flexibility. This is explained by the lack of tooling that characterises AM.

Table 2: Comparison of the flexibility metrics

Flexibility metric	Unit	Additive Manufacturing	Injection Moulding
Volume flexibility	%	65.6	59.6
Mix flexibility	h	0.33	5
Delivery flexibility	%	92.8	91
New product flexibility	€	0	30,000

CONCLUSIONS

The model constructed for this investigation is based on the assumption that the adoption of AM in place of injection moulding permits the elimination of some supply chain costs, including the opportunity costs resulting from stockouts. Despite this cost reduction, the total supply chain costs estimated in this paper suggest that the lower unit costs of injection moulding (chiefly the result of the amortisation of tooling expenses and hence a form of economies of scale) make injection moulding a more cost effective process.

As such, this investigation yields insight into the relative magnitude of supply chain costs compared to manufacturing costs which has been ignored in previous cost models of AM. On a general level this shows that inter-process comparisons of the commercial performance of different manufacturing processes can be made more realistic by including such aspects. Especially if the differential in pure manufacturing cost is smaller than in the investigated case (€2.06 versus €0.78), order costs, carrying costs and stockout costs may form a decisive part of the overall case for or against the adoption of AM.

In the supply chain literature it has been emphasized that managing manufacturing systems should incorporate flexibility as a core objective along with cost and productivity (Slack, 1983). The results of this study provide some tentative quantification of these aspects. Despite the current narrative about AM, an AM supply chain without inventory seems to be relatively ineffective in responding rapidly to different demand volumes. However, due to the lack of tooling, AM provides more flexibility in producing a wide range of products and in introducing new products to the system.

This paper would be incomplete without a brief appreciation of its limitations. First, the model of stockout costs is limited in that it ignores aspects such as the loss of goodwill for instance (Schwartz, 1966). Second, the manufacturing company will in reality cater for different types of customers, including stockists and wholesalers, which was ignored in the model. Had this diversity been taken into account in the simulation, different outcomes related to flexibility measures might have been observed. Third, from a technical point of view the paper is limited in that it assumes that the two investigated processes and their materials can simply be interchanged. This ignores knock-on changes in post processing and quality assurance which are likely to affect the overall adoption rationale.

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PARTICIPATORY DIGITAL TRANSFORMATION: HAPTIC ACCEPTANCE CATALYST FOR THE EMPLOYEE-CENTERED DESIGN OF CHANGE PROCESSES

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Abstract
Purpose
The successful digital transformation requires employees to be sensitized to innovations and to take them along on the path of organizational change. New technologies can only develop their full potential if the employees, as process experts and essential interfaces, are integrated into the design of the digitized processes. According to an empirical study by ZIEMENDORF, the causes of resistance are less to be found in rational decisions than in emotional aspects of "fear", "shyness", "helplessness", "inertia", "anger" and "power", which are increasingly attributable to insufficient participation of people in processes of change (cf. ZIEMENDORFF 2009). The digital transformation therefore needs an integrated management that considers technological and IT process innovations in equal measure, as well as the changing role of employees and the associated development of the entire organisation. (HENKE et al. 2018)

Design/methodology/approach
The paper presents the approach of designing a discussion space with a haptic demonstrator as the core, as an acceptance catalyst for change processes in the company. The demonstrator pursues the approach of creating a haptic interface between the digital and analog world on the one hand and between employees and planned future work processes and objects on the other.
The demonstrator concept "haptical" was already developed in the science year 2018 for science communication and showed first successes in stimulating constructive discussions based on an example of intralogistics. In this example, the information flows between the autonomous machines in the Internet of Things, which will shape the working world of the future, were visualized via intelligent objects that determine their position in space, via corresponding projections in the environment of the real objects in a virtual environment. The research approach is to transfer this concept to the participation processes in corporate transformations.

Findings
First application scenarios of the demonstrator have shown that this interactive way of presenting future scenarios for working environments promotes the active critical examination of this scenario and stimulates constructive and creative suggestions as a transfer of the experience knowledge of the employee to the future situation.
Technology integration scenarios are often supported by laboratory environments in which the technology is usually made available to employees for the purpose of learning to try it out. In digital transformation, which is characterised by changes in the provision of information, work processes and interaction with automated or even autonomous machines, such processes have so far not been modelled in a way that can be touched and experienced. The depiction in virtual spaces is slowly gaining relevance in practice, but here the discursive contribution of a group is already technically excluded. The WING project (BOES et al. 2017) shows first results which show the keys for an acceptance-

promoting effect of innovation spaces as a physical realization of the participation possibilities of the employees in transformation processes.

Value
The paper presents the technical possibilities of the demonstrator concept and explains the scenario already realized. The question to what extent the already indicated experience gained with comparable approaches from VR and technology-focused laboratory environments can be transferred is discussed and possible application scenarios described.

Research limitations/implications
In future case studies with companies, the aim will be to prove the acceptance catalysing effects. As a practical implication, however, the positive effect of internal discussion and laboratory environments in transformation processes on the acceptance by employees and their active participation can already be derived from this state of the investigations.

INTRODUCTION AND PURPOSE

The successful digital transformation requires employees to be sensitized to innovations and to take them along on the path of organizational change. New technologies can only develop their full potential if the employees, as process experts and essential interfaces, are integrated into the design of the digitized processes. According to an empirical study by ZIEMENDORF, the causes of resistance are less to be found in rational decisions than in emotional aspects of "fear", "shyness", "helplessness", "inertia", "anger" and "power", which are increasingly attributable to insufficient participation of people in processes of change (cf. ZIEMENDORFF 2009).
This impairment for the transformation process exists first and foremost when resistance takes place undercover and no appropriate handling of barriers takes place because the causes are not clearly recognisable.
In this context, the emotional acceptance of transformation processes is described as the central problem. This usually leads to resistance on the part of the employees concerned during the transformation process.
The most common form of resistance here is the hidden resistance (CACACI 2006). Therefore, in the context of organisational transformation and learning, the anticipation of barriers is demanded in order to be able to deal with resistances by means of suitable measures in such a way that the learning of employees in organisations as well as the further development of the entire organisation is positively influenced (ZIEMENDORF 2009).
The most frequently stated reasons for barriers to change relate both to the emotionality and attitude of the employees and to the type of internal project management, with the emphasis on aspects of a participative project approach and the communication structure. In this respect, a participatory project approach is almost unanimously considered to promote change. Communication is a decisive factor in ensuring continuous transparency about concrete process changes. This primary importance of communication can also be found as a prerequisite for organisational learning. In theory, this results in optimal conditions for the implementation of change projects as well as the successful implementation of process change in organizations in a logistical environment. However, these theoretically optimal conditions are no guarantee for a smooth course of the project in operational practice. Rather, dealing with a multitude of possible resistances is part of the everyday practice of change projects. This once again shows that people are the central drivers of change.
The digital transformation therefore needs an integrated management that considers technological and IT process innovations in equal measure, as well as the changing role of employees and the associated development of the entire organisation. (HENKE et al. 2018)
The paper presents the technical possibilities of the demonstrator concept and explains the scenario already realized. The question to what extent the already indicated experience

gained with comparable approaches from VR and technology-focused laboratory environments can be transferred is discussed and possible application scenarios described.

"HAPTICAL" DEMONSTRATOR

The paper presents the approach of designing a discussion space with a haptic demonstrator as the core, as an acceptance catalyst for change processes in the company. The demonstrator pursues the approach of creating a haptic interface between the digital and analog world on the one hand and between employees and planned future work processes and objects on the other.
The demonstrator concept "haptical" was already developed in the science year 2018 for science communication and showed first successes in stimulating constructive discussions based on an example of intralogistics. In this example, the information flows between the autonomous machines in the Internet of Things, which will shape the working world of the future, were visualized via intelligent objects that determine their position in space, via corresponding projections in the environment of the real objects in a virtual environment. The research approach is to transfer this concept to the participation processes in corporate transformations.

Technical development

Basically the technological development of haptical is based on the technology of HTC (HTC 2019) and Valve (VALVE 2019). Under the brand name HTC Vive ©, these companies distribute virtual reality glasses with corresponding sensor technology, which enables an indoor positioning system (IPS) with accuracy to the millimetre. The principle of this IPS is adapted within the scope of haptical in a self-developed system. The base stations and the corresponding sensors, which are also applied in HTC Vive, are used to create "smart objects" with the help of a 3D printer. The base stations generate an infrared signal which can be evaluated with the use of the sensors and analyzed for exact position determination. The computing capacity for this is guaranteed by an Arduino MKR1000. Specially developed for IoT applications, this microcontroller already provides necessary functions such as WLAN connection, battery electronics and digital inputs and outputs. The program code was developed with the Arduino development environment distributed by the microcontroller manufacturer.

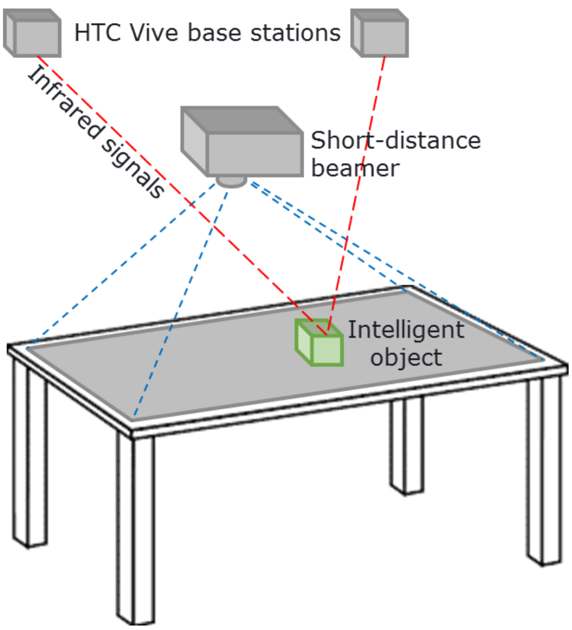

Figure 1: Schematic representation of the demonstrator

The integration of the electronics into individually produced 3D-printed objects leads to "intelligent objects" which are necessary for the realization of a haptic interface to digital and complex scenarios. In contrast to existing solutions, this approach works with infrared based sensor technology, while others use image recognition software or ultrasound for position determination. The precise position calculation opens up completely new possibilities and ways of interaction. That can be used, for example, to interact with virtual content on a table using a (beamer) projection (see figure 1). Thus, a tangible and yet digital interaction environment is made possible which, for example, displays information or material flows via a projection in real time and reacts to the changes in position of the intelligent objects.

Realized Scenario
Through the integrated electronics in individually configurable 3D models in combination with indoor localization technology, a degree of interaction with simulation environments is hereby accomplished, which is implemented in this form for the first time. Haptical can create a significant added value, especially in the representation of complex information, since the human stimulus system is addressed extensively by physical components and thus an enhanced environment promoting interaction is created. For the implementation of a first demonstrator, a scenario in the field of warehouse logistics is developed (see figure 2).

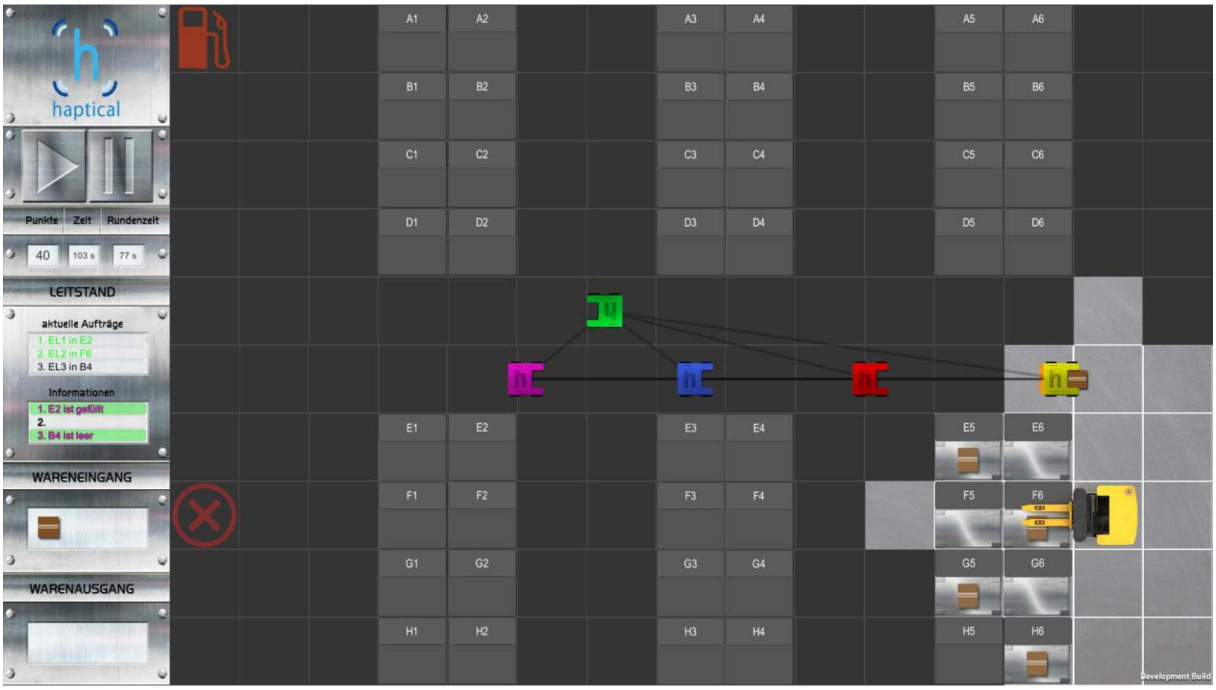

Figure 2: Implemented scenario for executing tasks in a warehouse

Generally, the scenario is based on a warehouse layout with incoming and outgoing goods, a control center and several racks. The main objective of the scenario is to move the goods correctly to and from the storage area with as little effort as possible. There are three different levels:

Level 1: The player uses the smart object to control a forklift truck. He gets new orders from the control center, such as to store goods in a certain rack. If the order is accepted, the player first manoeuvres his forklift truck to the goods receiving area to pick up the goods. The goods are then transported to the appropriate rack coordinate. Errors can occur here, such as when a previously advertised rack space is already occupied. In this case, the player must first drive back to the control station in order to report the error and be assigned a new rack space.
Level 2: In addition to the tasks and conditions from level 1, the player is now supported by autonomous transport systems. The autonomous system takes orders on its own,

stores and retrieves them automatically, but does not interact directly with the player. This can lead to conflicts, e.g. when autonomous systems block the shortest transport route because there is no communication with the player.
Level 3: In addition to levels 1 & 2, an interaction between the player and autonomous machines is now possible. For example, the autonomous transport systems detect errors in the allocation of racks, so that the player does not need to drive to the rack to store goods if the system has detected an already occupied position. In addition, information flows are visually displayed in order to provide the player with maximum transparency in autonomous (machine) communication. The behaviour of the autonomous systems (such as recharging, certain routes) can thus be better understood by humans. The interaction with the systems also makes it possible to highlight the supporting effects.

FINDINGS

First application scenarios of the demonstrator have shown that this interactive way of presenting future scenarios for working environments promotes the active critical examination of this scenario and stimulates constructive and creative suggestions as a transfer of the experience knowledge of the employee to the future situation.
Technology integration scenarios are often supported by laboratory environments in which the technology is usually made available to employees for the purpose of learning new processes or to try the technologies out. In digital transformation, which is characterised by changes in the provision of information, work processes and interaction with automated or even autonomous machines, such processes have so far not been modelled in a way that can be touched and experienced. The depiction in virtual spaces is slowly gaining relevance in practice, but here the discursive contribution of a group is already technically excluded. The WING project (BOES et al. 2017) shows first results which show the keys for an acceptance-promoting effect of innovation spaces as a physical realization of the participation possibilities of the employees in transformation processes.

In order to fulfill the purpose of an acceptance catalyst, the technological demonstrator environment must show the planned changes in the concrete corporate environment. The planned target state of the work area must be virtually represented with a focus on the work process of the employees and the interaction processes with the technology. In this way, the change of the work process can be experienced through the haptic interaction with the physical intelligent objects in connection with the virtual representation of the new work environment.
The demonstration environment must be actively used for discussion within the company. For this purpose, different workshop rounds with the employees directly affected by the planned change can be arranged. But also other employees who are not directly affected should be able to use the demonstrator and make suggestions and raise concerns. The demonstrator thus becomes an integral part of internal communication, and thus of the change process, and should be designed accordingly. In the workshops, the objective of the digital transformation of the company should be clearly communicated and a real opportunity for employees to participate should be offered. Active participation in the change processes and the planned use of technology can directly address and weaken the aforementioned barriers to change among employees. On the other hand, the process knowledge available to the employees who execute the processes operationally can be integrated into the planned future workflows and point out further optimization potential. The haptic demonstrator serves as a basis for discussion but also for understanding the future work process which is experienced. This way, employees already uncover work steps and special cases that have not been taken into account during the planning phase and reduce later correction loops or even misinvestments.
Several rounds of workshops are necessary to integrate the employees into the change process and to promote acceptance. On the one hand, workshops are limited in their number of participants. On the other hand, the planned future working environment develops further with the concretisation of the planning. It is of course crucial that the comments, suggestions and concerns of the employees from the workshops are taken up and if possible and practical considered. Therefore, it is essential that those responsible

for planning participate in the workshops. The demonstrator is thus constantly evolving and becomes an image of the company's digital transformation process. The employees can thus get used to the future processes and the barriers to change are further reduced. The field of application of the demonstrator is therefore not limited to logistics, but it is especially the overall understanding of processes, which is very important in logistics, that can be promoted with a representation of cross-departmental order processing processes. A great potential of digital transformation lies in the continuous digital support of processes that integrates new technological developments such as autonomous systems or artificial intelligence. Thus it can be useful and necessary to illustrate a scenario of the future work process, which affects several departments. Thus, the responsible persons from these departments should of course also participate in the workshops. In this way, in addition to the acceptance of digital change, cross-departmental cooperation can also be promoted.

RESEARCH IMPLICATIONS

In future case studies with companies, the aim will be to prove the acceptance catalysing effects. As a practical implication, however, the positive effect of internal discussion and laboratory environments in transformation processes on the acceptance by employees and their active participation can already be derived from this state of the investigations.

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ENHANCING CUSTOMER SERVICE THROUGH FOCUSED SUPPLY CHAIN RISK MANAGEMENT AND PERFORMANCE METRICS

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Abstract
The southern African mining industry has faced many trials in recent times, with decreasing profit margins due to declining commodity prices and increases in critical cost drivers (Mining Weekly, 2018; Crowley & Biesheuvel, 2017). Profits have been further affected by loss of production due to augmented mining regulations that increase the frequency of production stoppages (Mining Weekly, 2013), which cost the sector approximately R4.8 billion in 2015/16 (Lead to Business, 2016). This has placed pressure on mines to contain costs to improve or just maintain their profit margins in a depressed market (Deloitte, 2017; Frost & Sullivan, 2017). As mines concentrate on profitable production (PwC, 2017), there is an increased focus on the reliable supply of cost-effective input materials such as explosives. Cost is a large determinant in the choice of explosives, thus cost leaders are bound to have a greater market share (Crowley & Biesheuvel, 2017). The decreased profitability in the southern African mining sector, compounded by increased competition in explosives supply, has created a need for better supply reliability, cost containment, and general customer service quality to increase organisations' competitive edge. Not only are explosives an element of the cost of production, but the timely supply of explosives has a direct impact on the production output of a mine and therefore profitability. Both the cost and quality of service delivery are therefore important. Given demand and supply issues such as remote mining sites, sporadic demand, limited storage capacity at the mines and regulations that limit the delivery of explosives, this study seeks to determine the impact of the explosives supply chain's performance in servicing mining customers and to describe how explosives suppliers can use the information to improve their competitive position. The explosives supply chain was selected as an industry that is highly regulated, has high risk operations and is very price sensitive, thus providing where even small risks are likely to have large performance impacts and thus, major customer service implications. Thus the study assessed the effects of reduction of supply chain risk elements to increase supply chain performance to improve the customer service experience. While various studies explore supply chain risk, supply chain performance and customer service in isolation, this research aimed at creating a framework which links these to illustrate the cause and effect relationship of risk to supply chain performance.

LITERATURE REVIEW

Globalisation has amplified competition in the marketplace (Daultani, Kumar, Vaidya & Tiwari, 2015) and altered customer behaviour (Caridi, Moretto, Perego & Tumino, 2014; Lockamy & McCormack, 2004). Customers are now more demanding (Yu, Xiong & Cao, 2015), expect lower prices, faster responsiveness (Varzandeh, Farahbod & Zhu, 2016) and are no longer satisfied with mediocre service delivery, as substitutes are readily available (Kalaiselvi, 2016; KPMG, 2016; Efros, 2015). This leaves companies with a dilemma of differentiating themselves from the rest (KPMG, 2016). Researchers have found that there is limited competitive advantage that can be derived from cost strategies (Naoui, 2014) and technological differences (Kulyk et al., 2017) as they can be replicated by competitors over time. Thus, many have opted to differentiate themselves by enhancing the value to the customer (KPMG, 2016; Varzandeh et al., 2016), which is derived from the optimisation of the various elements in the supply chain (Yu et al., 2015). Risk and uncertainty can however greatly affect the performance of the broader supply chain (Sreedevi & Saranga, 2017) and, thus, the customer's experience (Patil et al., 2012).

Supply chain risk and uncertainty

Supply chain risk refers to any activities that can hinder the company's supply chain performance (Patil et al., 2012) and lead to reduced financial performance and reputation (Sreedevi & Saranga, 2017; PwC & MIT, 2013). Reducing uncertainty in the organisation necessitates understanding the root cause inherent in each area (Manuj & Mentzer, 2008). Typically, there are four key sources of risk. Globalisation has introduced lower-cost suppliers and improved technology that allows a firm to reduce input costs and focus on its core competencies (Myerson, 2017; Lui, 2012), but implies increased risk (Kumar et al., 2010) due to longer supply chains (CIPS, 2016), higher levels of complexity (Li et al., 2017b; Rangel et al., 2015), and increased vulnerability to exchange rate fluctuations and natural disasters (Chen et al., 2013; Kumar et al., 2010). *Sourcing risk* is defined by Kumar et al. (2010) as the deviance in the supply of goods in quantity, quality, or time, which results in an incomplete order. *Operational risk* is defined by Chen et al. (2013) as a mismatch of supply and demand due to failed processes, therefore the failure of one supply link may affect the efficiency of another supply chain partner(Daultani et al., 2015). *Outbound logistics* is defined as the processes used to move and store products and the necessary information flow from production output up until the end customer (Paragon Films, 2015). According to Jones (2008), customers do not have tolerance for goods or services that are not delivered on time, thus outbound logistics play a critical role in customer satisfaction. *Demand uncertainty* is where customer behaviour is unpredictable (Negahban & Smith, 2016) and manifests as a fluctuation in product mix and order quantities (Daultani et al., 2015). An underestimation of demand may lead to lost sales, while overestimation leads to surplus inventory (Daultani et al., 2015; Kumar et al., 2010).

Customer service and satisfaction

Philosophically, customer service is achieved by the whole organisation committing to ensuring customer gratification with superior customer service. Since the prevailing driver of corporate endeavours is top management commitment (Barve, 2011), management needs to buy into the customer service philosophy in order to ensure buy-in from the rest of the organisation. Customer satisfaction is a key measure as it dictates whether customers will return. When a company falls short of meeting a customer's expectation, this influences the retention of the customer and future purchasing behaviour (KPMG, 2016). Continuously exceeding expectations by the supplier may equate to customer loyalty (Adil, Ghaswyneh & Albkour, 2013; Nguyen, Chaipoopirutana & Combs, 2011).

Supply chain performance models

Service quality is a measure to determine how well the customers' expectations are met (Ghotabadi, Feiz & Baharun, 2015; Yarimoglu, 2014; Adil et al., 2013; Gupta & Singh, 2012). Offering a good quality service is a strategy that will ensure that any organisation continues to compete successfully in the market (Adil et al., 2013; Ramseook-Munjurrun, Lukea-Bhiwajee & Naidoo, 2010) as it will have the ability to attract new customers, retain existing customers, develop relationships, reduce costs, and increase market share (Ucenic & Ratiu, 2017; Adil et al., 2013; Poliakova, 2010). Many models to measure service quality have been created (Ghotababadi et al., 2015; Gupta & Singh, 2012). The *Grönroos* model is based on the requirement that business operators understand the perception that customers have of the services provided (Grönroos, 1984). Two dimensions of service are analysed; technical (the outcome) and functional (the process) (Gupta & Singh, 2012). These perspectives are joined to form the corporate image, which is determined by the customers' perception of the brand as a whole (Ghotababadi et al., 2015). The *SERVQUAL* model seeks to establish the gaps between customers' experience and the actual service quality delivered to the customer (Parasuraman, Zeithaml & Berry, 1988). Five service dimensions are measured, namely reliability, assurance, tangibles, empathy, and responsiveness. When an organisation aims to drive certain behaviour by regularly measuring progress or lack thereof, metrics are used. Metrics are characterised by being measurable, visible, easily understandable, and supporting required behaviour (Coyle et al., 2013). *Ucenic and Ratiu* (2017) categorised the most used indicators of supply chain performance into five categories, namely reliability, financial, cost competitiveness, responsiveness and quality. *Coyle et al.*'s (2013) supply chain performance metrics assess the customer service elements and corresponding metrics in SCOR. These are reliability, responsiveness, flexibility, costs and assets. *Equbal et al.* (2017) adapted SCOR risk assessment and developed performance measures for supply (sourcing), company (operations) and delivery (outbound logistics). These measures are grouped as effectiveness, efficiency, quality and productivity. The *Aberdeen Group (2005)* identifies measures to assess supplier performance and include on-time delivery, quality of goods/services, service capability, price competitiveness, compliance with contract terms, responses, lead times, technical capability, environment health and safety, and innovation. The most recurring elements in the above models are reliability, responsiveness, quality, availability and cost competitiveness and are thus key to assess customer service.

Supply chain performance metrics

Supply chain performance was defined by Ucenic and Ratiu (2017) as a company's ability to deliver the right product at the right time to customers at minimum logistic cost. Supply chain *reliability* is defined as the probability that a system will perform flawlessly over a defined period of time (Taghizadeh & Hafezi, 2012). Reliability is critical as it affects the customer's operations. On-time delivery (Ucenic & Ratiu, 2017; Coyle et al., 2013; Mandal, 2012; Aberdeen Group, 2005); perfect order fulfilment (Taghizadeh & Hafezi, 2012) and process variability (Coyle et al., 2013) are typical measures of reliability. *Responsiveness* is defined as the speed at which the supplier provides goods to customers and includes flexibility, which is the speed at which a supplier responds to market changes to maintain or improve competitiveness (Coyle et al., 2013). Process time and customer response time are typical metrics (Ucenic & Ratiu, 2017; Coyle et al., 2013; Mandal, 2012; Taghizadeh & Hafezi, 2012). Others are flexibility and adaptability (Ucenic & Ratiu, 2017; Taghizadeh & Hafez, 2012) and new product development cycle time (Taghizadeh & Hafezi, 2012). *Quality* relates to the quality of the material as well as the calibre of the service rendered by the supply chain. This includes measures such as order accuracy (Coyle et al., 2013; Ucenic & Ratiu; 2017), dependability (Coyle et al., 2013), customer service (Kulyk et al., 2017; CIPS, 2016), quality of delivery documentation (Ucenic & Ratiu; 2017), supplier rejection rate (Equbal et al., 2017, Ucenic & Ratiu, 2017), and innovation (Equbal et al., 2017, Ucenic & Ratiu, 2017). *Availability* determines whether a required item is available for procurement by the customer and identifies whether the required goods are always available or if customers are given an opportunity to seek an alternative supply (Coyle et al., 2013; Wilkins, Thakur-Weigold & Wagner, 2012). Typical elements are product availability (Mandal, 2012; Wilkins et al., 2012) and order fulfilment (Ucenic & Ratiu, 2017; Coyle et al., 2013; Mandal, 2012) The supply chain cost to service the customer is a large percentage of the charged price. Some of the performance measures used to assess the *cost competitiveness* consider inventory cost (Mandal, 2012; Taghizadeh & Hafezi, 2012), product value (Ucenic & Ratiu, 2017) and the cost to serve (Coyle et al., 2013). Table 1 thus summarises all the supply chain risks found in literature with all the supply chain performance metrics used to assess the performance of the various customer service (CS) attributes. This model is then applied to the explosives supply chain.

CS attributes	Supply chain performance measures	Supply chain risk			
		Sourcing	Operational	Outbound logistics	Demand
Reliability	On-time delivery	**Raw material availability**	**Manufacturing process**: • Flow & lead time variability • Over-production of unwanted products • Production capacity **Operational disruptions:** • Set-up & change-over times • Machinery breakdown **Labour disruptions**: • Labour unrest / Rising labour cost/ Absenteeism **Waste:** • Defective/ out of spec goods • Excess inventory	**Outsourcing:** • Loss of control of service delivery • Poor performance of logistics suppliers **Transportation:** • Delay & logistics capacity • Increasing transportation costs **Environmental risks:** • Infrastructure quality • Operational inefficiencies **Labour relations**: • Skills shortage • Absenteeism **Labour unrest**: • Transport strikes, truck torching **Restricted storage:** • JIT delivery	**Demand and forecasting inaccuracy:** • Under-/over-estimation of demand • Demand fluctuation • Late orders • Delayed demand signals • Baulking behaviour / Bullwhip effect/ supplying to distributors **Lost production:** • Rainfall **Economic factors:** • Exchange rate changes • Legislation instability
	Perfect order fulfilment				
	Process variability				
Responsiveness	Process time				
	Customer response time				
	Flexibility and adaptability				
Quality	Order accuracy or shipment errors				
	Dependability				
	Customer service				
	Customer satisfaction				
	Quality of delivery documentation				
	Supplier rejection				
	Innovation				
Cost	Product value				
	Inventory cost				
	Cost to serve				
Capability	Skills shortage				
Availability	Product availability				
	Order fulfilment				

Table 1: Critical performance measures and customer service attributes

RESEARCH METHOD

This research sought to investigate the impact of supply chain risk on supply chain performance and service delivery to explosives customers. Since little information exists on explosives supply chains, Leedy and Ormrod (2010) suggested that, in such instances, a qualitative research approach will help to define what is important. A single case study was used as this research explored a phenomenon that few have considered before (Saunders et al., 2016).

The research design was based on a critical realism philosophy, which recognises that there is "the real" world, which is characterised by mechanisms and structures. These result in events that may or may not occur, which is known as "the actual". The actual is formed from factors in the real domain that act together to formulate causal changes in the actual domain (Clark, 2011; Easton, 2010). The actual then leads to the events that are experienced –"the empirical". Critical realism believes that the world is an open system composed of simple parts in the real world. In this study, the simple parts include the various supply chain risk elements such as forecasting and production capacity under operation risk, demand fluctuation in demand risk, supply fluctuation in sourcing risk, and safety stock in outbound logistics risk. Therefore "the real" is represented by the supply chain risk elements, while "the actual" is represented by the supply chain performance, and "the empirical" are represented by the customer service experience. A deduction theory of development was used and this then asserts that if supply chain risk is reduced, this should lead to an increase in supply chain performance; and if an increase in supply chain performance leads to an enhanced customer experience; then it follows that a reduction in supply chain risk should lead to an improved customer experience.

To determine this, interviews were conducted with explosives supply chain experts to determine the risks that are relevant in their supply chains. A total of 14 interviews were conducted with respondents representing the full explosives supply chain. Respondents comprised customers, sales representatives, supply chain experts, and explosives production personnel. Three production persons gave perspectives of sourcing risks as they affect production operations, as well as operational risks in the supply chain. Three supply chain personnel provided perspectives of how operational risks affect supply chain operations, as well as outbound logistics risks. Five sales representatives provided views of how operations risks and outbound logistics risks affect customers' operations and what demand risks are inherent in the system. Finally, three customers provided information on demand risk and perceived customer service levels. This highlighted various angles of the explosives chain to formulate a single case study.

Semi-structured interviews were used because limited information is available about the current state of explosives supply chains and these could ensure that data collection was not too rigid and allowed for additional information to surface. Appointments were made with interviewees, and questions were based on themes identified in the literature, particularly sources of supply chain risk and uncertainty, supply chain performance and theories on customer service delivery to determine how the elements affect practices in the explosives supply chain and ultimately the customer experience. Data were therefore collected through interviews and recorded on a device and later transcribed from the recordings. Common themes were taken from all the interviews to determine the greatest issues that customers experienced and draw conclusions about the state of the supply chain and how the supply chain elements affect the supply chain's performance.

Trustworthiness of the data was achieved by ensuring that perspectives from different parts of the supply chain were obtained and compared. The sample size was also sufficiently large to ensure that data saturation was reached. Bias was also eliminated by checking for constancy of information from the various interviewees.

DISCUSSION OF RESULTS

Critical customer service attributes

Customer service attributes were researched and eight were found to be consistent across the literature reviewed. These were, in order of the level of occurrence, reliability, quality/innovation, availability, responsiveness/flexibility, tangibles, cost competitiveness, and safety. As tangibles are defined as the appearance of the physical facilities, products, and equipment, and this research mainly focused on the service performance of the supply chain and not the physical products, the tangibles were included as a theme under quality, as the physical features of interest are those that affect delivery defects, delivery rejection, overall customer satisfaction, customer complaints, and the quality of delivered products. A summary of the main findings of all the customer and sales representative interviews is shown in Figure 2. This figure shows the aggregated interviewee responses for each of the customer attributes, and the supply chain performance measures which affect them.

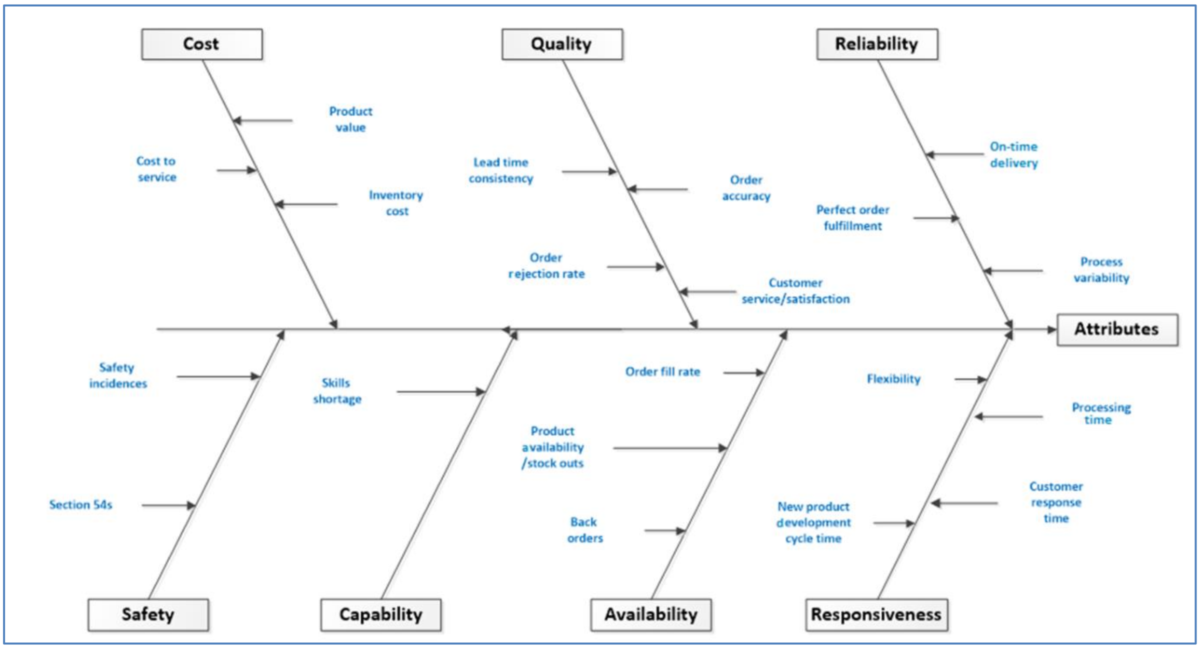

Figure 4: Influence of metrics on service quality attributes

Causes of supply chain risks

According to literature, typical supply chain risks originate from four areas within the supply chain, namely sourcing, production operations, outbound logistics, and customer demand.

In interviews, *sourcing risk* was not as pronounced as in the literature. Thus, further study of secondary data was done to ascertain whether the raw material availability was indeed not a concern. This was done by assessing the raw material inventory and whether there was buffer stock in the system. The five main raw materials were investigated; four of which were found to be warehoused with a minimum three-month stock level. However, one material was delivered on a JIT basis and was considered to a big risk. Another material that emerged as a risk was packaging, of which there was a single supplier. A strategy was given to use dual sourcing to reduce the risk. The old and the new supplier are now used simultaneously and thus the risk is managed. The current sourcing of explosives raw material is done in-house and is not outsourced, and is thus not perceived to be a risk.

The *operational and outbound logistics risk* can lead to major supply chain performance constraints. An analysis of the results shows that the following percentage of interviewees indicated these operational risks in the production of explosives, including production capacity (56%), production scheduling (36%), operational disruptions such as machine breakdowns (36%), labour disruptions such as labour unrest (29%), operational risk (7%) and introduction of new technology (7%). Production capacity was influenced by elements such as shift duration and multiple SKUs, which cause increased time wastage (reduced production output) in the form of change-over time and setup times. Machine breakdowns were also identified as a major source of material unavailability. Labour unrest was a smaller concern as there had only been three production strikes in 30 years at one of the customers, however protests not only affected operations but also outbound logistics as there is a safety risk of setting the trucks alight, which will cause an explosion.

Outbound logistics risks found in literature included outsourcing of the individual outbound activities, such as warehousing and other logistics activities. Unlike the sourcing component, which was performed in-house, some of the activities in the supply chain were outsourced, such as transportation to remote areas. There were conflicting views from the interviewees, which showed the varying performances from service providers. The explosives supply chain is heavily regulated and requires many activities that cannot be managed by a non-logistics specialist. Thus, the activities were managed better when

executed by a good logistics service provider. Transportation capacity was also found to be a great risk (Mogre *et al*., 2014) as multiple deliveries exposed the trucks to delays.
Customer *demand* was the last risk to supply chain performance within the scope of this research. Demand and forecasting accuracy was cited as a risk, which includes demand changes and forecasting errors, and the delay in demand signals, which manifested as late orders. This is typical in the mining environment, which is plagued by changes in production due to labour productivity, mine geographical changes, and production stoppages due to safety incidents. Demand fluctuations were also noted as an issue that affects stockholding and lowers suppliers' responsiveness to orders. Lost production was also indicated as a risk. The mines frequently plan for less than 100% production as they often experience absenteeim and labour unrest. Other economic factors noted in the literature, such as exchange rate changes and legislation issues were only mentioned once in a single interview by a customer who was experiencing credit issues.
Therefore, current supply chain issues that cause supply chain risks can be summarised as single sources of supply and JIT delivery that cause sourcing risk, production capacity and production interruptions that cause operational risks, outbound logistics planning and truck capacity that cause outbound logistics risk, and finally, mine demand uncertainty and delayed demand signals that cause demand risks.

Impact of supply chain risk on supply chain performance
Reliability featured prominently in the literature as well as during the interviews. This is due to the regulated delivery times and how the mines' productivity relies on the on-time delivery of explosives. Availability is another attribute that was strong in the literature and the interviews. The availability of explosives is closely linked to reliability, as unavailability of the product will cause delivery issues and the products will first have to be manufactured, which causes further delivery delays. Availability was also considered critical as customers have storage constraints at the mine, which means limited buffer stock, thus requiring the supplier to have stock available for faster responsiveness.
An attribute that was not particularly significant in the literature and yet emerged strongly during interviews was safety. The explosives supply chain produces and moves hazardous material, thus safety is critical as a low levels can bring mining operations to a halt. Safety is critical in mining; so much so that there are dedicated departments that are responsible for mining safety and tenders are also awarded according to suppliers' safety standards.
Quality was a key attribute in literature and in interviews. This was due to the implications of incorrect deliveries to business operations. The packaged explosives' concentration and size are chosen due to the required strength of the precious metal being mined and the rock strength. If an incorrect size is delivered, it does not fit into the holes and cannot be used for blasting, thus is as good as a non-delivery. If a lower strength is delivered, it has lower productivity, while a higher strength will affect the integrity of support walls, which can cause rock falls and fatalities. Therefore, quality affects other attributes like safety.
The responsiveness attribute was stronger in the interviews than in literature. Mining production is characterised by much uncertainty, there are constant changes in demand, thus there is a significant need for a supplier to be responsive to the changing demand.
The cost competitiveness occurrence was similar in the literature as in the interviews. While the customers need the costs to be competitive, the product needs to be safe first, available, and have a reliable supply before its price is even considered.
The capability and skills shortage of the staff were not raised as a concern, although this could have been due low knowledge levels of personnel issues as respondents are focused on product deliveries and not the skills shortages that may be causing delivery issues.

Customer service improvement
The research also tested how supply chain performance can be improved to increase customer service. Table 2 summarises the risks identified from the literature and interviews and their impact on customer service. The table indicates the frequency of occurrence from the interviews. The high (primary) risks show that more than 40% of the interviewees indicated the element a supply chain risks. The medium (secondary) risks

were indicated by between 10% and 39% of the interviewees. The rest were either not indicated or there was weak feedback on those elements during the interviews.

Supply chain risks		Supply chain performance metrics	Customer service attributes
Primary risk	**Secondary risk**		
• Customer production breakdowns • Mining labour unrest • Absenteeism (14%)	• **Late orders (64%)** • Demand uncertainty (36%) • Forecasting inaccuracy (36%)	• Customer response time • Flexibility and adaptability • New product cycle time	**Responsiveness**
• Raw material availability	• **Production output variability (50%)** • Production scheduling (36%)	• Product availability • Order fulfilment	**Availability**
• Processing time • Shift numbers and duration • Multiple SKUs • Change-over and setup times		• On-time delivery • Perfect order fulfilment • Process variability	**Reliability**
• Machine breakdowns (36%) • Production labour unrest (29%) • New technology			
• Truck capacity constraint • Community protests (21%)	• **Multiple deliveries (50%)** • **Standing time (43%)**		
• **Road conditions (50%)**	• **Truck breakdowns (50%)**		
• Skills shortage (14%) • Fatigued employees (29%)	• Poor transport planning (21%) • Loading errors (36%) • **Document errors (43%)** • Incorrect delivery (29%)	• Customer service • Customer satisfaction • Quality of delivery documentation • Supplier rejection rate, innovation • Order accuracy or shipment errors • Dependability • Safety incidences • Inventory cost • Product value • Cost to serve	**Quality** **Safety** **Cost**

Table 2: Relationship between measures, risks and customer service

MANAGERIAL IMPLICATIONS

Critical customer service attributes

The identified customer service attributes are critical to management as they highlight the elements used by the customer to assess the service. This research showed that while safety is not frequently cited in literature, it is imperative in mining as the inability to operate safely will halt business operations. Many mines are threatened with closure as workers believe their lives are at risk due to repeated safety incidences. Together with compliance requirements, this implies that safety is the most important attribute and management should ensure that their service always prioritises safe operations. Availability was ranked as the next most important attribute as it affects reliability (which was the top customer service attribute in both literature and interviews), responsiveness and cost competitiveness and indirectly affects quality through reliability. The model thus allows for the determination of those customer service attributes that are most likely to affect the customers' service perception, thus indicating focus areas for management interventions.

Supply chain performance

The selection of supply chain measures is complex, thus it is important to ensure that performance measures are targeted at those aspects that are most likely to impact customer perceptions. The performance measures which impact the key customer service attributes, in this case are, firstly, the measurement of safety incidences. This will assist management in addressing safety concerns before they affect the customer. To ensure that the customers are not tempted to seek alternative supplies from competitors, management should prioritise product availability and order fulfilment. This is imperative as availability impacts reliability. This model allows for the identification of performance measures that enhance the customer experience and therefore their retention.

Supply chain risk

Safety risks were not explored in detail in the research process, as the focus was on the risks which hinder the supply chain performance efficiency and effectiveness. The model can therefore be enhanced by the inclusion of this element, which is currently not adequately covered in the literature. Availability and reliability risks were identified as being greatly enhanced by reduced production output. In this research, the process showed that management could improve supply chain performance by increasing shift duration and machine capacity to increase production output and renewing machinery to reduce breakdowns. The research also showed that outbound logistics poses risks to reliability and dependability. Managers therefore need to assess fleet management processes. The research process indicated that management can implement supply chain risk management to address specific risks and ensure improvements in key supply chain performance areas and thus critical customer service attributes.

FUTURE RESEARCH

This research is based on a single case study of a supplier that serves multiple customers. This implies that the research is not necessarily generalizable as risks could be unique, thus additional research is required which incorporates additional suppliers. In addition, the research should be applied in alternative industries to determine the generalizability of the model. This research also only includes sourcing risks from suppliers, internal risks and demand risks from customers. However, information systems risks were not included in the scope of the study. Further study is required which assesses how customer demand signals can be linked to suppliers in highly regulated and volatile supply chains to allow for more rapid responses to changes in demand. In addition to the above, the research focused on risks identified by the interviewees when responding to the supply chain risks which affect supply chain performance and could thus only report on perceptions. Further research should focus on the quantification of the probability of the risk occurrence and the impact of that risk on supply chain performance.

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Available on request

GROWING UP AND MATURING: EVALUATING SME GROWTH PHASES USING THE QUICK SCAN APPROACH

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Abstract

Purpose

Although there is disagreement as to the number of stages, sequencing, and progression, literature suggests that Small/Medium sized Enterprises (SMEs) go through several growth phases, each with distinct challenges (Kazanjian and Drazin, 1990). When such organisations begin to expand there is typically the need for increasing formalisation (e.g. processes, strategy, structure) (Lewis and Churchill, 1983). The Quick Scan Methodology (QSAM) assesses the performance of an organisation's supply chain and reflects on maturity related factors to suggest improvements (Childerhouse and Towill, 2011). However, QSAM has predominantly been applied to larger organisations. Hence, the purpose is to investigate the supply chain maturity and growth phases in manufacturing SMEs via the application of the QSAM.

Design/methodology/approach

A consolidated categorization of SME growth stages is established, and this is integrated with supply chain maturity and QSAM concepts. We then undertake a cross case analysis of QSAM data from three manufacturing SMEs (Naim et al., 2002). For each case, we utilized interviews, process mapping, root cause analysis, analysis of archived systems data, and vector scoring. Case 1 (ModuleCo) is a manufacturer of modular building elements (70 employees). Case 2 (LiftingCo) is a manufacturer of specialist lifting equipment (35 employees). Case 3 (TestingCo) is a producer of specialist testing equipment (120 employees).

Findings

A framework that incorporates SME growth phases and supply chain maturity concepts is developed. In doing so, it is possible to gather a more complete picture of how manufacturing SME operations and supply chain develop and mature, and what is appropriate in different phases. Growing pains identified include lead time issues, sensing customer requirements, quality control, information and communication, and establishing formalized procurement processes.

Value

The study adds to our understanding of supply chain maturity in the context of growing manufacturing SMEs. By integrating knowledge relating to growth phase models for SMEs,

the QSAM is enriched and methodological advances are made, and the understanding of supply chain maturity in the context of growing SMEs is more complete.

Research limitations/implications
Further work is needed to explore micro/larger medium sized companies, which in turn would increase the generalisability of the findings.

Practical Contribution
A set of practical guidelines are developed for manufacturing SMEs enabling them to establish their current position within the growth stages framework, the potential route forward, and general challenges that may be faced as the firm develops.

Introduction

The Quick Scan Auditing Methodology (QSAM) is a widely published (Childerhouse and Towill, 2003; Childerhouse and Towill, 2004, 2011; Naim et al., 2002; Towill et al., 2002) approach to assess the performance of an organisation's supply chain, and reflects on maturity related factors to suggest improvements (Childerhouse and Towill, 2011). It is grounded in systems engineering tools, techniques and thinking to analyse a production system, and uses systematic approach to consider improvements. However, QSAM has predominantly been applied to larger organisations (Boehme et al., 2007), and in this paper we consider its relationship to Small and Medium Sized (SME) organisations (which form the majority of organisations in the UK). In the entrepreneurship domain, scholars have sought to characterize and document the factors behind the evolution and growth of firms (Kazanjian and Drazin, 1990; Penrose, 1959), notably drawing on the idea of dynamic capabilities that evolve as forms grow (Branzei and Vertinsky, 2006; Penrose, 1959). However, there is a disciplinary interface between the Operations/Supply Chain literature and the entrepreneurship literature, which leads to ineffective transfer and development of opportunities between the domains (Shepherd et al., 2013). Hence, the purpose is *to investigate the supply chain maturity and growth phases in manufacturing SMEs via the application of the QSAM*. A consolidated categorisation of SME growth stages is established, and this is integrated with supply chain maturity and QSAM concepts.

Literature Review

Stages of Firm Development and Theories of Growth
In 1959 Penrose published her landmark book, which developed a general theory of the growth of firms, focusing on the processes leading to growth (Penrose, 1959). It highlighted internal and external forces propelling growth, as well as the limits and constraints to expansion. Penrose (1959) characterised the firm as a collection of physical and human resources, which interact with 'productive opportunities'. Hence, expansion is partly governed by expertise in managing and acquiring resources for growth opportunities. Management, internal resources and productive services, and opportunities, interact in a dynamic exchange. Expansion, she argued, may also occur through diversification, as well as acquisition and merger.

This seminal work established a key foundation for a theoretical view of the firm that emphasizes specific capabilities and assets in the form of resources (Peteraf, 1993; Teece, 1984). This was later developed to incorporate the idea of dynamic capabilities, whereby combinations of competences and resources, both internal and external, are 'developed, deployed and protected' in response to changing environments (Teece et al., 1997). Dynamic capabilities, however, will need to take into account life stage of a firm (Helfat and Peteraf, 2003). The capability lifecycle is characterised by a founding stage, a development stage, followed by a maturity stage. Once maturity is reached, then capability progress may branch out using different approaches: retirement, retrenchment, renewal, replication, redeployment, and recombination (Helfat and Peteraf, 2003).

Stage of growth models have been developed with a view to characterizing organisational creation and growth process. Although there is disagreement as to the number of stages, sequencing, and progression, literature suggests that Small/Medium sized Enterprises (SMEs) go through several growth phases, each with distinct challenges (Kazanjian and Drazin, 1990; Lester et al., 2003; Lewis and Churchill, 1983). For example, building on insights from the technology sector Kazanjian and Drazin (1990) propose four stages: conception and development, commercialization, growth, and stability. Structural features of the organization such as centralization and formalization, and functional specialization, will change according to the stage. Centralization of decision-making was found to decrease as a firm moved to higher stages, whereas formalization of decision making increased in higher stages. This latter point is also supported by Lewis and Churchill, who argue that when organisations begin to expand there is typically a need for increasing formalisation (Lewis and Churchill, 1983). Specialization of roles in the functional areas also increased by stage (Kazanjian and Drazin, 1990). Building on the above literature, figure 1 summarises typical development stages.

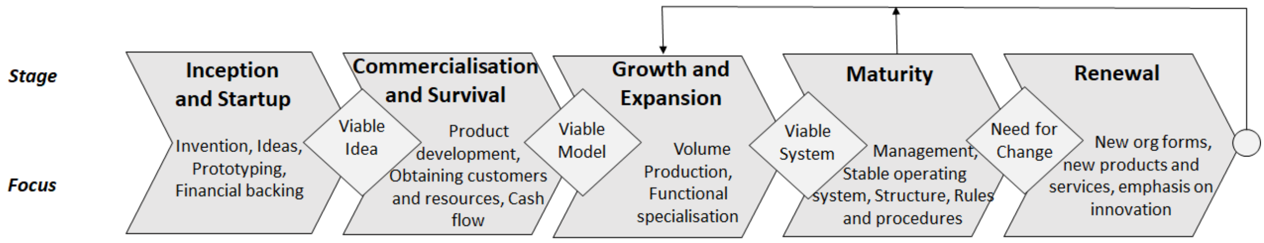

Figure 1: Characteristics and Challenges of Growth Stages. Synthesis based on: (Lester et al., 2003; Lewis and Churchill, 1983)

Supply Chain Maturity and the Vector of Change Revisited: The Intellectual Foundations

The rationale and approach for the QSAM were originally articulated in Naim et al's (2002) paper, which focused on using the QSAM approach to determine the 'vector of change' in terms of the operations and supply chain management practices. They also explained the data collection and analysis protocols, and the key principles for the approach: team based ethos, triangulation of data types, and a manufacturing systems view. This was followed by the publication of a range of findings related to the QSAM (e.g. (Childerhouse and Towill, 2003; Childerhouse and Towill, 2004, 2011).

Figure 2 summarise the intellectual foundations of the QSAM approach, and how this is operationalized within a QSAM analysis. The first foundation is the reduction of supply chain uncertainty. This argument rests on the assumption that uncertainty propagation through a system makes a significant contribution to the underperformance of supply chains, and management effort and adopting good practice can significantly and systematically reduce it. Uncertainty in the QSAM approach is characterized through interactions between supply, demand, control, and process system elements, and if it is not managed effectively, there will be a 'flywheel effect' (Childerhouse and Towill, 2004). Hence, the QSAM seeks to score and classify uncertainty using the uncertainty circle and Euclidean norm scoring system (Childerhouse and Towill, 2003).

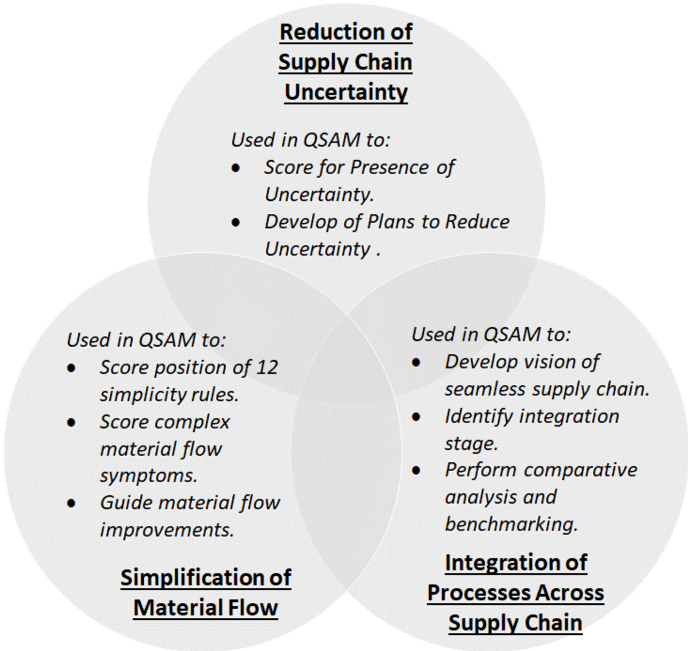

Figure 2: The intellectual foundations of the Quick Scan Approach

The second foundation is the simplification of material flows. This builds on pioneering work in systems dynamics and material flows to develop a set of principles to guide the design and operation of supply chains in order to reduce complexity (Gosling et al., 2015; Towill, 1997a). Towill (1999) further developed the principles to create a series of 12 simplicity rules to operationalise the principles, and then 24 symptoms of complex material flow organised into dynamic, physical, organisational and process based factors. These have been used as the basis for a complexity scoring toolbox in the QSAM approach (Towill and Childerhouse, 2006).

The third foundation is the integration of processes across the supply chain. Towill (1997b) proposed the seamless supply chain as a vision for all actors involved to 'think and act as one'. The QSAM uses Stevens (1989) model of integration as a reference framework, moving from baseline through to external integration and the seamless ideal. Childerhouse and Towill (2011) established a typical path for integration, starting with internal integration, followed by upstream streamlining and then finally downstream integration. Hence, there is a strong link with supply chain maturity running through many of the QSAM papers. As a supply chain matures, it is expected to display uncertainty reduction, simplification of material flows, and closer integration of processes (Childerhouse and Towill, 2003; Childerhouse and Towill, 2011; Towill and Childerhouse, 2006; Towill et al., 2000).

Our propositions with respect to QSAM intellectual foundations and SME growth stages are summarised in figure 3. Through the remainder of the paper, we explore the interaction of the QSAM intellectual foundations, and the growth stages of manufacturing SMEs.

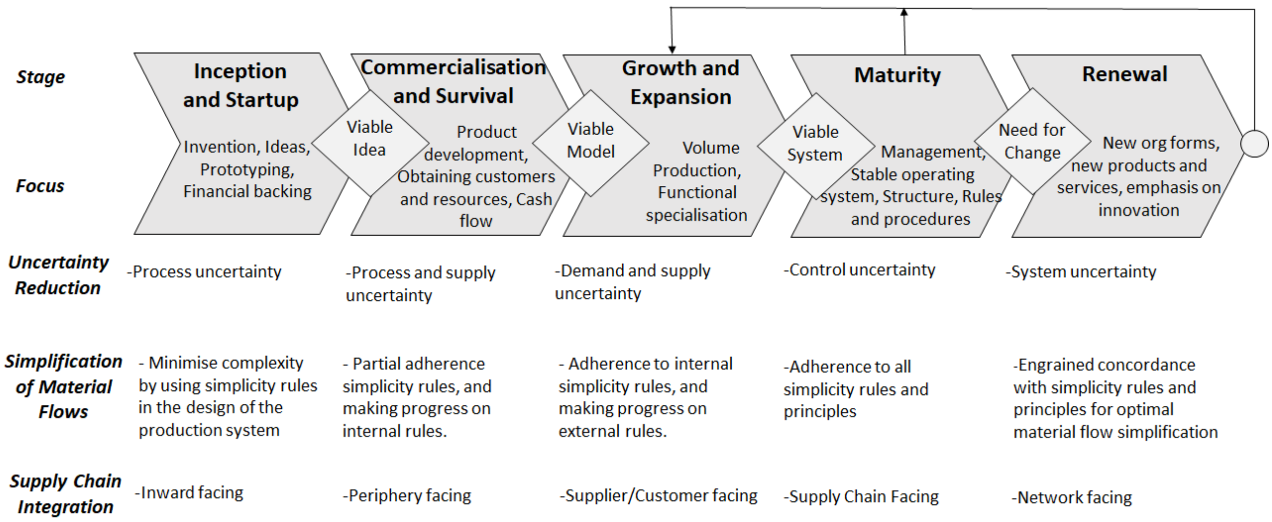

Figure 3: Linking the intellectual foundations of the Quick Scan Approach and SME growth phases

Research Methods

The empirical phase of the study is based on Quick Scan activity with 3 different manufacturing SMEs in South Wales. Case 1(ModuleCo) is a manufacturer of modular building elements, employing 70 employees. Case 2 (LiftingCo) is a manufacturer of specialist lifting equipment, which at the time of the QSAM employed 35 employees. Case 3 (TestingCo) is a producer of specialist testing equipment, employing 120 employees. Data collection was undertaken in line with the QSAM approach (Naim et al., 2002), utilizing interviews, process mapping, archival data. Data was analysed using root cause analysis, analysis of archived systems data, and vector scoring. To capture investment plans, we also asked each company about critical incidents that have shaped the company and investment plans and strategies regarding the future. We then undertook a cross case analysis of QSAM data. The specific methods for each case are summarised below:

Case 1 (ModuleCo) – A core team of 2 researchers and 2 company representative conducted a wide range of interviews across company functions. Value stream mapping was undertaken for 2 different product families, which was enabled by factory tours and 'walking the process'. In depth process mapping was also conducted for customer touch points. The team analysed Sales and Inventory data, lead time data, as well as On Time In Full measures. Cause and effect was analysed using a fishbone diagram, and vector scoring was undertaken by the team.

Case 2 (LiftingCo) – A core team of 3 researchers and 1 company representative conducted a wide range of interviews across company functions. Value stream mapping was undertaken for 1 product family, which was enabled by factory tours and 'walking the process'. The team analysed Inventory data, as well as On Time In Full measures. Cause and effect was analysed using the 'five whys' approach, and vector scoring was undertaken by the team.

Case 3 (TestingCo) – A core team of 4 researchers and 1 company representative conducted a wide range of interviews across company functions. Value stream mapping was undertaken for 1 product family, which was enabled by factory tours and 'walking the process'. In depth process mapping was also conducted for the entire Order Fulfilment Process. The team analysed On Time In Full measures The team analysed Inventory data, as well as On Time In Full measurement data. Vector scoring was undertaken by the team.

Analysis and Findings

Table 1 summarises the current position of each of the case companies. It is possible to see that different critical incidents have shaped the outlook of each case. All 3 cases are at pivotal points in their growth (hence, their association with research projects).

	Case 1 - ModuleCo	**Case 2 - LiftingCo**	**Case 3 – TestingCo**
Critical Incidents	- A factory fire led to a new factory, re-organisation of processes and priorities, as well as new health and safety procedures.	- Market leader of a niche product, but competition replicating products.	- Sudden growth in orders and demand. - Installation of an ERP system. - Company takeover
Current Position and Constraints to Growth	- Heavy investment in a new technology/ process. - Revisiting approach to NPD and innovation. - Constrained through knowledge and people. - Productivity constrained through tech investment.	- Niche expertise starting to be compromised and needs to find new ways to compete. - Outgrowing premises and processes. - Difficulty meeting due dates and loosing big customers as a result. - Constrained through knowledge, people and capacity constraints.	- Scientific/Technical market leadership - Huge growth opportunities, but this leads to challenges. - Experiencing lead times issues and problems meeting due dates. - Constrained by layout of buildings, turnover of staff, and limited and unchanged supply base.
Investment and Expansion Plans	- Looking at various ways to automate processes through capital investments. - Engaging with universities and knowledge related investments.	- Planned investment in a new site and facilities. - Range of process improvement plans.	- Large recruitment initiative planned. - Investments in new layouts and integration of facilities.

Table 1: Summary of Critical Incidents and Future Investment Plans

Table 2 also gives a summary of the QSAM focus, issues and key recommendations for each of the QSAM cases. By comparing the individual case root causes analysis for each case, we can identify underpinning problems across the focal companies. We identify that all three cases experienced lead time issues as a result of a specific bottleneck or outsourced process. Similarly, all three cases demonstrated problems in the knowledge management. Knowledge is frequently stored as tacit know-how in experienced employees' heads, rather than in codified systems or processes. Access to knowledge is typically through informal channels, and often results in difficulties where the bearer is absent or leaves the company.

Common to all three cases was the 'organic' growth of production and administration systems, and there is a lack of formalised planning systems, standard operating procedures, defined processes or protocols. The approaches employed in our focal cases often showed a strong correlation with the experiences of key employees; for example production managers advocating systems they had previously employed in other companies, or 'local experts' in individual departments setting up their own spreadsheets and databases that were either inaccessible or unknown to the rest of the company. Often IT systems in all cases had developed around particular problems, internal projects or functions, leading to fragmented (and frustrating) patchwork of programs and data repositories. A further related problem is that all cases experienced difficulties with information exchange across boundaries (internal and external).

	Case 1 - ModuleCo	Case 2 – LiftingCo	Case 3 – TestingCo
Focus of QSAM	Customer Service and Information Sharing	Long & Variable Lead Times	Meeting Order Fulfilment Requirements
Factors from Cause and Effect	-Managing Due dates and Delivery dates -Lack of up to date Information Sharing	-Drilling Bottleneck -Delays in Outsourced Processes	-Component shortages -Accommodating needs for servicing -Testing/Inspection Bottleneck -Cross Functional and Business Unit Communication
Main QSAM Recommendations	- New customer interaction processes - Strategic use of purchasing - TQM initiatives - New innovation strategy, structure and processes	- Move to ATO for some products with greater kitting - Detailed Layout Improvements - More strategic and structured use of pacemaker and supermarkets - New outsourcing options	-Re-structuring of supply base -Functional Integration Initiatives - Mini project on Testing Bottleneck - New approach for managing servicing parts

Table 2: QSAM Focus and Recommendations

Figure 4 provides a summary of the QSAM assessments for the three cases. ModuleCo operates in uncertain markets, and has faced significant constraints through its physical location and industry. It is particularly vulnerable to peaks and troughs in the construction market, as levels of Housebuilding rise and fall. It faces high levels of uncertainty through its make to order production model and the project-by-project variation required for customers. Despite this, it performs in line with average dynamic behaviour symptoms, even though simplification efforts have been undertaken, the company were ranked low relative to our QSAM benchmarks. As indicated on figure 4, ModuleCo iterates between survival and growth, depending largely on shifts in the economic cycle.

LiftingCo has a simple product structure in comparison, based on four key variants. It scored well in our uncertainty analysis, being much lower than average benchmarks. The company did not score so well in our simplification analysis, ranking high against benchmarks in dynamic behaviour symptoms and low in its simplification efforts. LiftingCo is ambitious in its growth plans, and is in a period of 'managed growth'. TestingCo had a more rounded profile in our analysis. It scored in line with our average benchmarks in uncertainty and simplification efforts. However, dynamic behaviour indicators were higher than our benchmarks, suggesting that some improvements are possible. TestingCo is iterating between growth and maturity phases, seeking to formalise systems and processes, while at the same time recruit people and keep up with accelerating demand.

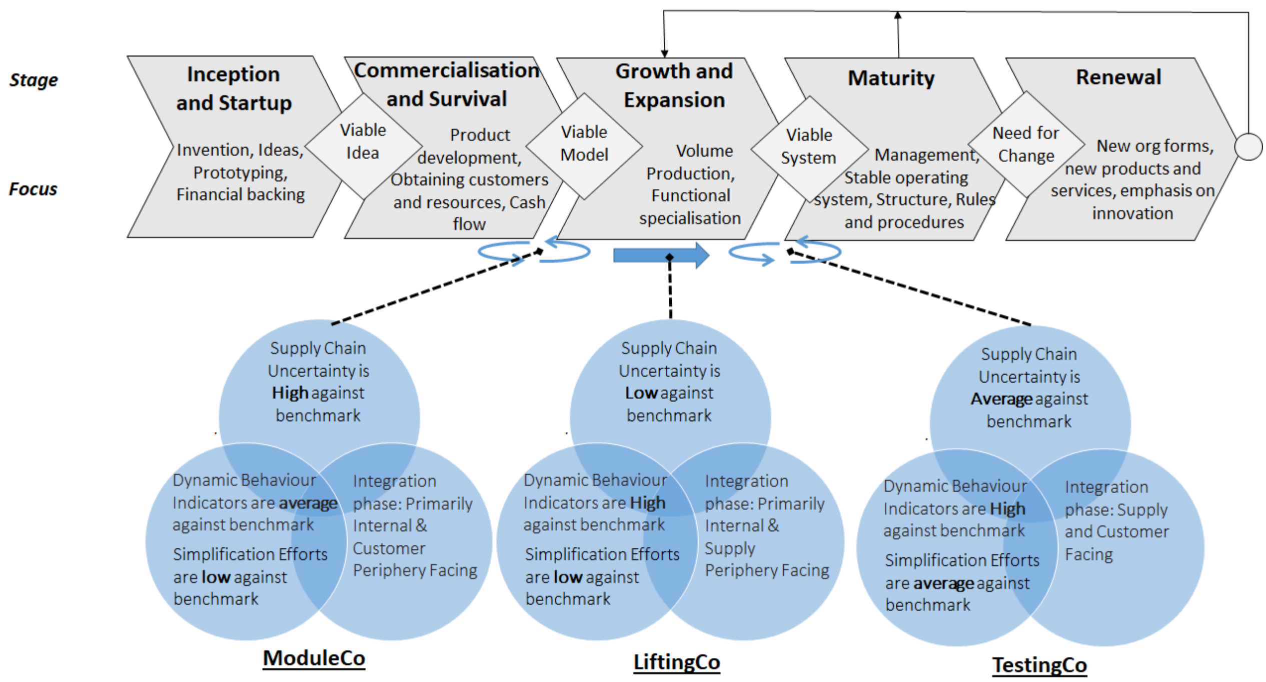

Figure 4: Summary of QSAM findings integrated with growth phases

Conclusion

The aim of this paper was to investigate the supply chain maturity and growth phases in manufacturing SMEs via the application of the QSAM. In doing so, we developed a consolidated categorisation of SME growth stages, and considered the linkages with intellectual foundations of the QSAM. As-yet both research and exploitation of QSAM has omitted the growth phases of firms, and so by integrating knowledge relating to growth phase models for SMEs, the QSAM is enriched and the understanding of supply chain maturity in the context of growing SMEs is more complete. Three case studies applying the QSAM within SME manufacturing firms provide the basis for the empirical work. Through the integration of concepts and models developed, it is hoped that manufacturing SMEs are better able to establish their current position within the growth stages framework, and so can better plan the potential route forward with their operations and supply chain development. As a result of this research it is therefore possible to gather a more complete picture of how manufacturing SME operations and supply chain develop and mature, and what is appropriate in different phases. However, we recognize that to enhance the generalizability of this work an increased number of cases would be beneficial, both in terms of the firm size (i.e. micro and larger SME) and the position within the lifecycle.

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OPTIMAL SHIPPING STRATEGIES FOR ELECTRIC POWER LOGISTIC NETWORKS IN TAIWAN

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Abstract
Purpose
The vehicle routing problem (VRP) is widely studied in freight transportation and distribution fields, which aims to minimize the total system routing costs for covering demand requests while considering the limited loading space and shipping vehicles. This study examines the existing shipping patterns of electric power logistic networks in Taiwan, and jointly optimizes order frequencies and shipping patterns to improve the system efficiency.

Design/methodology/approach
Simulated annealing (SA), an improved K-means TSP approach, and other heuristic approaches will be examined in this study, to find a suitable shipping pattern of the studied network.

Findings
Optimal parts order frequencies and best shipping plans of the studied multi-modes and multi-commodities freight networks will be conducted in this study, while also considering the nonlinear-based transportation fare schemes.

Value
This paper specifies a mixed integer nonlinear programming problem for assisting electric power system operators in Taiwan to determine the optimal electric power parts order frequencies and the corresponding shipping plans

1. Introduction

In accordance with a series of power outage events on 2016-2018 in Taiwan, it has been significantly affected people's livelihood and industry. Thus, the ability to make the electric power recover in a timely manner is an important issue for the case company, one major electric power company in Taiwan. Whether there is sufficient maintenance materials in each branch will play a key role in whether or not it can quickly restore electricity. Therefore, it is important and necessary to research the logistics network of the case company.

Based on the survey conducted by National Council of Physical Distribution Management (NCPDM), transportation costs account for an average of 44% of logistics costs (Yan Yiru, Zhang Yizhi, 2005.) It reveals that transportation cost is significantly higher than the cost of other logistics activities. If the transportation network is properly planned, it will greatly reduce transportation costs, increase disruption events resilience capabilities, and enhance the competitive advantage of enterprises. This study contributes quantitative-based approaches and several heuristic algorithms to develop optimal material distribution routes of the studied logistics network.

2. LETERATURE REVIEW

2.1 Methodology

There are three common categories of methodology for solving the vehicle routing problem. One is exact algorithm. Another is classical heuristics. The other is meta-heuristics.

Exact algorithm is to build a mathematical model to solve the problem. It search all possible solutions, can guarantee that the final solution is the optimal solution. It is suitable for solving small-scale problems. P. Kabcome and T. Mouktonglang[11] build a mathematical model to solve the VRP with soft time window ,deliver multiple types of products.

Classical Heuristics and Meta-heuristics solve the VRP by specified logic and criteria. The well-known classical heuristics include savings algorithm[3], K-Opt exchange [9],sweep algorithm[5],λ-interchange[10].The famous Meta-heuristics include genetic algorithm[7,13], tabu search[1],simulated annealing[2,14].Although these two categories of methodologies cannot guarantee that the final solution is optimal, it can get an approximate solution in a reasonable time. It is suitable for solving the large scale problem.

2.2 Clustering first, routing second

The vehicle routing problem (VRP) has been proved as a NP-hard problem. (Lenstra and Rinnooy Kan, 1976). As nodes increase, the computation time increases. In order to solve this problem efficiently, decrease the total computation time, many researchers decide to cut this complex problem into some small problems. The common simplified method is "Clustering first, routing second".

Boonsam et al.(2011) handle the VRP with 3 depots and 377 nodes. Firstly, an assignment algorithm is proposed to divide the service range of each logistics centre. According to the distance between the 377 nodes and 3 logistics centres, nodes are assigned to the nearest logistics centre for distribution. The second part, the sweep algorithm is used to cluster nodes for each logistics centre. Finally, establish the route with the nearest neighbor method.

Kwangcheol and Sangyong (2011) proposed a three-stage method for solving the VRP with homogeneous fleet. In the first stage, authors came up with a clustering method to cluster nodes. It choose the node which is the farthest node from the depot as the first seed in the first cluster, add the nearest node from the first seed as the second seed, calculate the geometrical centre of a cluster, and the node closest to the cluster centre is sequentially added without violating the limitation of the vehicle capacity. If there is a new node is added to the cluster, it will recount the geometrical centre of a cluster. The second phase is to adjust the nodes in the clusters. The third stage is to construct the route of the cluster, and treat each cluster as TSP to solve.

Comert et al. (2017) also used the strategy of "Clustering first, routing second" to solve the problem of supermarket goods distribution. In the first phase, all retail stores are clustered by using K-means, K-medoids, and DBSCAN. Due to consider the capacity restriction in the first phase, the problem is viewed as Travel Salesman Problem to establish the route. Finally, compare the results of different clustering methods and find that the target value of K-means is better.

In this paper, we also use the strategy of "Clustering first, routing second" to solve the homogeneous/heterogeneous vehicle routing problem. A four-step method include cluster model is proposed. We will take the solomon benchmark (RC101) for example, to test the feasibility of cluster model. Then use the four-step method to solve the real case problem (Electric Power Company in Taiwan).

3. PROBLEM DECRIPTION AND METHODOLOGY

3.1 PROBLEM DECRIPTION

The logistic network of the Electric Power Company presents as a 3-level network. The first level is warehouse. There are two warehouses in Taiwan. The warehouse A is located in the north of Taiwan, store the heavy-weight material, and ship the heavy-weight order to branch which is belonged to the second-level. The warehouse B is located in the middle of Taiwan, store the light-weight material, and ship the light-weight order to branch which is belonged to the second-level. The second-level are branches which are located in every county in Taiwan, the number of branches are 30 .The third-level is business office which disperse in every county, the total number of business office is around 300.Currently, the shipment task of material from first-level to second-level is outsourcing, the shipment task of material from second-level to third-level is shipped by the business office own vehicle.

In this study, we focus on the material shipment work from warehouse to branches.(The second-level to The third-level)

After analyzing the transportation data of the case company, it is found that the long-distance distribution ratio is relatively high, and the transportation cost increases due to long-distance distribution. Therefore, this study will adjust the logistics distribution network from the first level to the second level and re-plan the current distribution model to improve the transportation cost.

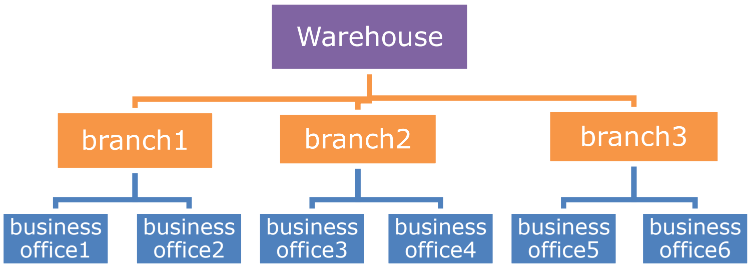


Figure3-1 the logistics network of the case company

3.2 METHODOLOGY- PROPSED FOUR-STEP METHOD

3.2.1 .Divide the Service Range of Each Logistics Centre

According to the distance from the 30 number of branches to the two warehouses, regardless of the type of materials, such as light-material or heavy-material, the material distribution task in a certain branch is handed over to the nearest warehouse.

3.2.2 Cluster Construction

This study refers to the ideas of Comert et al. (2017) and Kwangcheol and Sangyong (2011) to propose four clustering models to solve the homogeneous/heterogeneous vehicle routing problem. In this part, we will just take one model to introduce.

Step1 set the vehicle type randomly

*there are separately two types of vehicle for two warehouses

Step2 choose the nearest branch as the initial seed in the cluster

Step3 add the branch that is the nearest branch from the initial seed in the step1 to the cluster, calculate the geometrical centre of a cluster

$$* \text{ geometrical centre of a cluster} = \left(\sum_{j=1}^{n} v_j^x / k \ , \ \sum_{j=1}^{n} v_j^y / k \right)$$

* let Ei={v1,v2,⋯,vn}，Ei stands for branches which are in the cluster i

v_j^x , v_j^y stand for the longitude and latitude of branch j separately

Step4 calculate the distance between the remaining branches and the geometrical centre of a cluster, sort the remaining branches from short distance to long distance, these remaining branches are viewed sequentially as candidates of the next seed in the cluster

Step5 Check whether the demand of the candidate point plus the demand of all seeds in the cluster exceed the capacity of vehicle or not. If it is not exceeded, the candidate point is taken as the next seed of the cluster; if it exceeds, the next candidate point is continuously checked.

Step6 recalculate the geometrical centre of a cluster

Step7 repeat step4, step5, step6, until finish the cluster

Step8 choose the branch that is the nearest to the warehouse from the unclustered branches as the initial seed of the next cluster

Step9 repeat step3~step7

Step10 repeat step8~9, until all branches have been clustered

3.2.3 Cluster Adjustment

After finishing the second phase, it will get the clustering result. In this part, it is necessary to check whether the total travel time plus the total service time of each cluster is exceeded the time restriction (8 hours) or not. If it is exceed the time restriction, the cluster must be adjusted. In order to adjust the cluster, the adjustment algorithm is proposed to solve this problem.

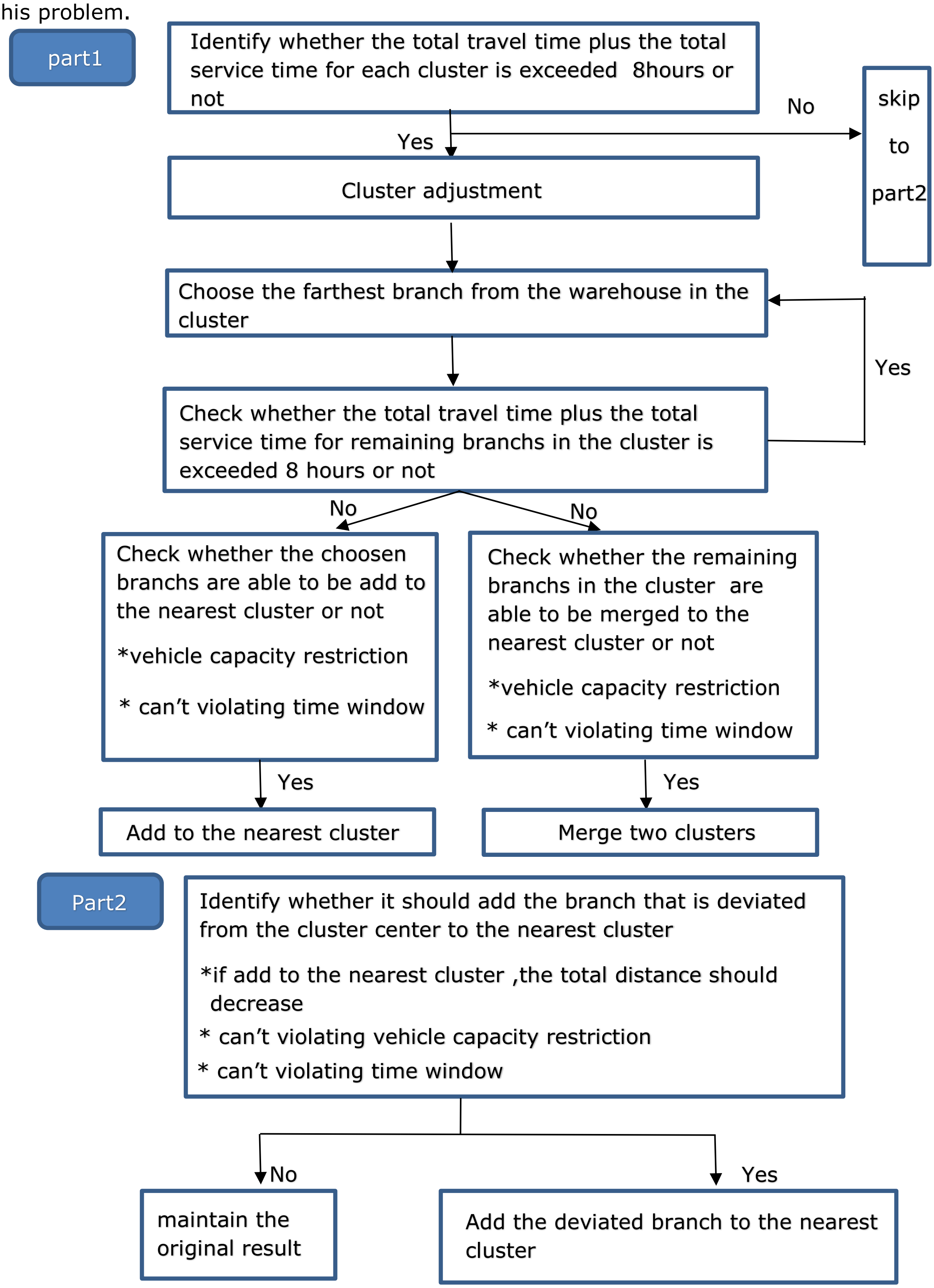


Figure 3-2 the flow chart of adjustment algorithm

3.2.4 Route Construction

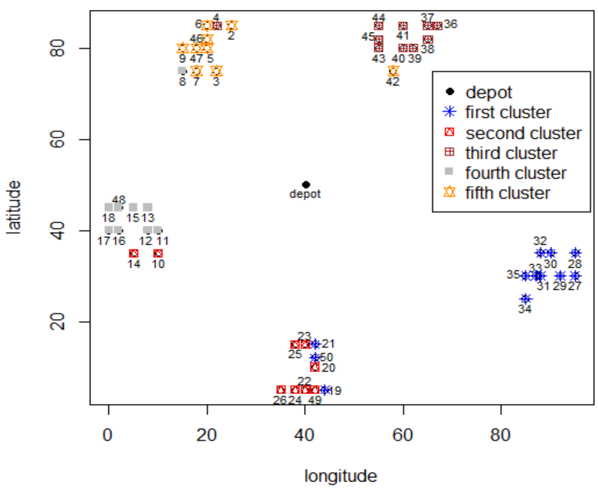
After adjusting the clusters, we get the clustering result that satisfies the time window, and the capacity restriction. Due to it has considered the capacity restriction in the second phase and the third phase, we can view the route establishment work as Travel Salesman Problem (TSP) to establish route for each cluster.

4.RESULT

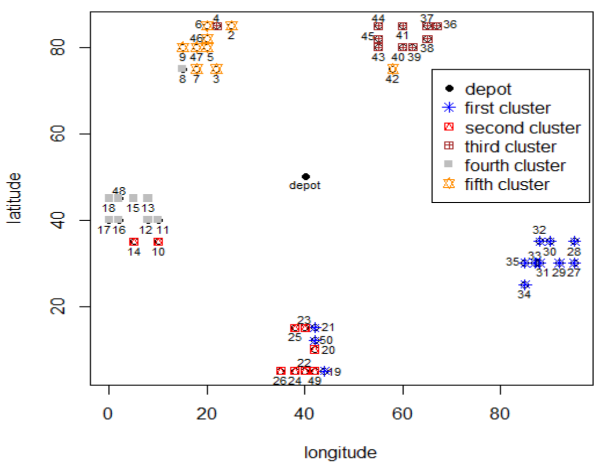
In this study, we examine the routing results of 50 nodes (i.e. one depot with 49 branches) within the studied network.

Table4-1 the result of 4 clustering model

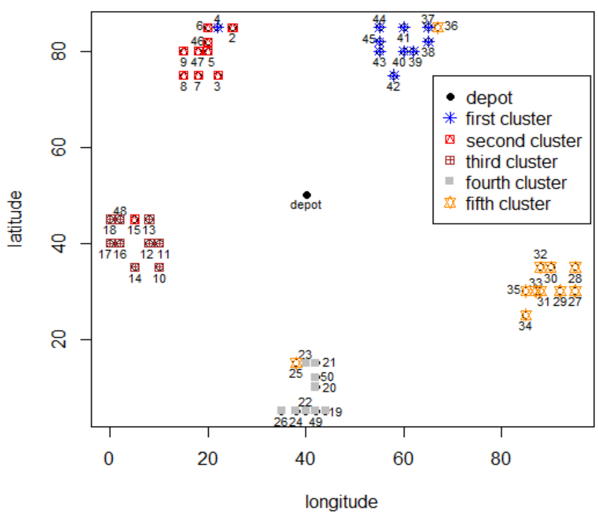
	Clustering model1	Clustering model2	Clustering model3	Clustering model4
the variance of load rate (%)	2.56	2.56	2.56	2.56
the variance of travel distance	378.12	378.12	441.17	441.17
average load rate (%)	66.2	66.2	66.2	66.2
Total travel distance	557.92	557.92	546.65	546.65
Number of vehicles	5	5	5	5

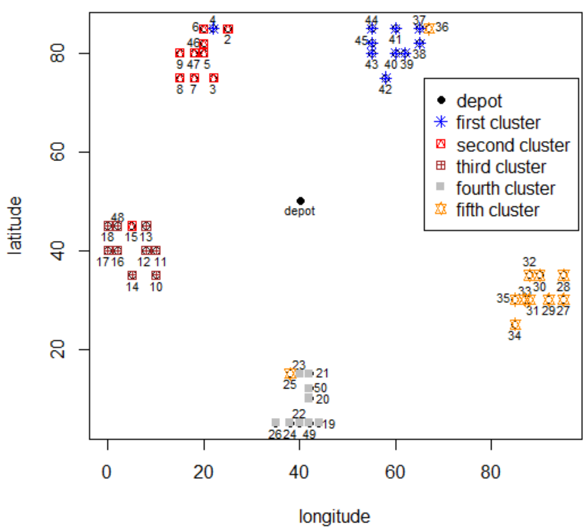


Model 1



Model 2





Model 3 Model 4

Figure 4-1 the result of 4 clustering models

As we can see on the figure 4-1, the result of model 1 and 2 are the same; the result of model 3 and 4 are the same. As a result of the total distance, model 3 and model 4 is better than model 1 and model 2. Due to the similar demand of customers in this case, it is hard to see the difference between four clustering models in this case. Overall, these results are almost meet with our expectations: the close customer points are divided into the same group. It proves the feasibility of these four clustering models.

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B2B SUPPLY CHAIN PROCESSES LACKING BEHIND THE B2C DEVELOPMENTS – A CO-OPERATIVE PLATFORM APPROACH FOR JOINTLY REALIZING COMPETITIVE ADVANTAGES

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Abstract
With the presented paper, a conceptual approach for creating a co-operative and discrimination-free Business-to-Business (B2B) retail platform is demonstrated. The investigation of the approach highlights, which long term business- and market-success factors can be realized by following the Business-to-Consumer (B2C) example in terms of rapid growth due to the use of new technologies and platform solutions that meet customer expectations and needs at its best. The retail industry, mainly in the B2C market, is constantly adopting new technical solutions and digital services. The development of e-commerce solutions in this context enable the rise of new transaction types and sales channels, e.g. online-shopping platforms, that have been established successfully due to comprehensive fulfilment of end consumer needs and offering a high convenience level. In the B2B market, the usage of online tools, just as e-procurement applications and advanced supplier integration has also become a common practice over the last years. Nevertheless, in terms of adopting digital technologies that enable B2B actors to optimize processes and to gain competitive advantage is linked to certain market-specific barriers – mainly related to single actor`s capabilities and the complexity of buyer-supplier relationships. Transaction cost savings that can be derived due to close cooperation within the market would offer high potentials to reduce process complexity by additionally creating high transparency. Major players – just like Amazon - from the B2C market have already recognised the potential to enter the B2B market with their expertise and capabilities to bring new solutions to the market. It is questioned, if the B2B market should stay in the "wait-and-see" position, or to progressively counteract the loss of control that is initiated by market leading actors of the B2C retail segment.
The decisive factor in establishing an efficient, resilient and flexible platform solution is an agreement of existing B2B players on common goals and objectives by not losing control or facing risks on the other hand. Nevertheless, business relations are built on "trust", "balanced power" and "relation quality". Even if all actors involved benefit from a co-operative approach, e.g. due to know-how exchange and increasing process and transaction transparency, the development of an organizational as well as a regulatory framework is irreplaceable. Within a status quo analysis of the B2B and B2C retail market, the use of digital platforms and online services together with the identified transaction cost impacts and theories of business relations are elaborated. Based on the findings, an exemplary framework for B2B retail platform solutions is created, using the approach of the Institutional Role Model (IRM). The conceptual approach demonstrates a basic framework for efficient stakeholder cooperation in the B2B market. It allows to adopt to a constantly changing eco-system. The investigations are limited to the presentation of a conceptual approach but pave away the further elaborations of a concrete framework construction and operation model development. with respect to new technologies. Future research should use this conceptual framework as a basis to apply it in practice. The next step is to address the identified stakeholders by presenting the approach.

INTRODUCTION

Globalization and the use of digital technologies enable retailers to distribute products and services via new channels (Gelderman et al., 2011). In this context, convenience and transparency are significant drivers for business success. E-commerce and especially platform solutions such as *Amazon* can be classified as "game changers" in consumer behavior. Business-to-consumer (B2C) retail is in this field way ahead of the business-to-business (B2B) market. B2C e-commerce platforms are standard practice and steadily increase their market share (bevh, 2018). In turn, the B2B market faces a variety of internal and external barriers, such as supply chain integration and long-term buyer-supplier relationships. B2B retailers who want to position themselves for future challenges need to become pioneers in the field of digitization and innovation to be able to implement new ideas and adapt to customer requirements quickly (Spryker, 2018). The development and use of digital technologies, such as marketplace platforms, is indispensable to stay competitive. Additionally, new market entrants increase pressure on existing stakeholders by entering into existing buyer-supplier cooperation in the B2B market. A suitable infrastructure needs to be in place to provide, inter alia, flexible process structures, high transparency, and less organizational complexity. Macro trends, such as globalization and global interconnectedness demonstrate that the pressure on the B2B market to adapt to the digital environment is increasing. Market leading companies such as *Amazon* via its B2B marketplace platform *Amazon business* already identified the B2B market as new growth potential. Dominant B2C market players enter the B2B market and have the chance to become future market leaders. In the future, B2B retailers might lose control over their business activities since core business activities might be under control of the action of dominant B2C companies. Actors in the B2B retail market should be prepared to face the newcomer threat and to improve business processes jointly. A central aspect in this context is to eliminate challenges that are related to the enforcement of the single participating partner`s interests, power struggles of established or dominant market actors and newcomer integration. By implementing a co-operative, system-open and declination-discrimination-free platform approach with a joint commitment on common rules, a solution can be established that is adaptable in terms of disruptive occurrences effects and adaptable for changing market conditions. The paper presents a systematic methodological approach for the B2B platform solution. Based on a comparative status quo analysis of the B2B as well as the B2C market, the authors identify significant challenges and opportunities by focusing on platform solutions. In addition, a framework for the implementation of a B2B retail transaction platform is developed using the methodological approach of the Institutional Role Model (Schulz et al., 2011; Schulz & Wieker, 2016).

STATUS QUO ANALYSIS

The B2B market has extensive information requirements, which need to be provided, among other things, via the website concerning product properties or payment methods (Zhou et al., 2018). However, larger players do not necessarily consider smaller customers' needs, and requirements since smaller players might not have sufficient bargaining power. Collaboration between stakeholders via a platform pools their interest. Furthermore, small retailers are enabled to have access to technological innovation, e.g. to explore web technologies, and the possibility to develop their online B2B relationships (Nieto & Santamaría, 2010). Manufacturers form an important group of supply-side customers with longer-term potentials for the electronic marketplace (EMs) platforms due to the internet's disintermediation effect. However, manufacturers face serious barriers to sell their products online, which need to be addressed by EMs. EMs might, among other things, provide online training or offer data services to build product databases for efficient and effective online content publishing. These services add value to the relationship and promote customer loyalty (Wang & Cavusoglu, 2015). The ability to implement digital transformation in a company depends on resources, skills and digital know-how and therefore might not be conducted without external advice. This might not only be the case for specific aspects just as e-commerce, but the general methods used and the ability to create an agile working environment (Graf et al., 2018). In this context, it is indispensable to consider the digital transformation in the retail segment. New challenges arise continuously by the introduction of new technologies about changing consumer behaviors that force all stakeholders to adopt strategic business processes accordingly. With the development of dedicated platform solutions, the B2B retail actors across industries should be able to realize increasing process efficiency and productivity within a cooperative framework. Creating trust and transparency in this context is a crucial success factor and efficiency lever. To enhance the essential elements of the workable business network, the B2B and B2C market characteristics are assessed, followed by a review on their effects on operations efficiency, transaction costs and business relations.

Market Characteristics
In table 1, characteristics have been identified to delimitate B2C and B2B market. While the B2B market targets a smaller number of larger customers, B2C market provides products and services to end consumer. Therefore, B2B market delivers products and services as part of the value chain and involves a wide range of stakeholders. Consequently, purchasing processes comprise of highly complex buying sequences with larger transactions and consecutive processes. In the B2B market, the value proposition focuses on a technical proposition and incorporates a significant component of economic value (Lilien & Grewal, 2012).

Characteristics	Business-to-Consumer (B2C)	Business-to-Business (B2B)
Supply Chain Section	Market to end of chain	Market to value chain
Value proposition	Perceptual proposition	Technical proposition
Value added	Value in brand relationship	Value in use, quantifiable
Customers	Large customer segments	Small number of customers
Transactions size	Smaller-unit transactions	Large-unit transactions
Transaction type	Transaction linkage	Process linkage
Sales process	More direct purchase	Complex buying sequences
Decision-Maker	Consumer decides	Web of decision participants

Table 1: Key differences between B2B and B2C markets (adopted from Lilien & Grewal, 2012, p. 4)

The use of payment methods in e-commerce is one example reflecting the differences in the status of digitization between B2B and B2C market. The B2B market has not yet adapted towards up-to-date payment methods, as checks still have a market share of 51% of B2B payments executed worldwide (AFP, 2016). Changing the internal organization is one of the major challenges due to the complex manual and established processes that have existed for many decades. In turn, the B2C market already uses solutions based on new technologies for example via mobile payment or wearable. In the B2C retail market, the use of new payment methods increases significantly and thereby replaces traditional payment types, just as cash and checks (Statista, 2019). B2C e-commerce has mostly grown up to an ecosystem, which involves current stakeholders and created new shopping concepts. The development has been significant since Book Stacks Unlimited launched the first online marketplace in 1992. Revenue of the German B2C e-commerce has grown from € 1.1 bn in 1992 to € 48.9 bn in 2018 (HDE, 2018). B2B e-commerce is still lacking behind the B2C market in terms of development and growth. The "Contractual-Relationship Dominant" condition is an established framework, which describes how developed companies sell products and services to each other in industrialized countries. The BuyGrid model (Robinson et al., 1967) has proven to be adequate during the last five decades. However, the environment in which the B2B market is working has changed due to, inter alia, demographic change in the professional field of buyers. More than half of all B2B buyers are younger than 34 years old and millennials have grown its share in the B2B market from 27% in 2012 to 46% in 2014 (Snyder & Hilal, 2015; Spryker, 2018). As the new generation of employees in the B2B market has grown up with digitization media usage patterns differ respectively. Grewal et al. (2015) recommend an update to the BuyGrid model since they observed the increase of buyer-seller interdependence. Various stakeholders have recognized opportunities in the B2B e-commerce industry and pay extra attention to realize early mover advantages. One of the first marketplaces was established in 2012 by *Amazon*, with the launch of *Amazon Supply*, which solely featured the so-called order fulfillment service. In 2015, *Amazon Supply* was replaced by *Amazon Business*, which is a platform for B2B e-commerce, offering additional drop shipping. Retailers and manufacturers need to focus on how, when and where their customers shop and optimize the user journey instead of solely focussing on a comprehensive product catalog (Spryker, 2018). By using the B2C e-commerce market as a model, the B2B market can close the gap to meet customer needs and business partner related requirements.

B2B Transaction Costs

B2B transaction costs for electronic integration and digitalization have not been investigated sufficiently, as most articles are published about 10 to 18 years ago, mainly deal with the implementation of Electronic Data Interchange (EDI), the potentials of online marketplaces and using the web for B2B transactions to realize transaction cost savings (Garicano & Kaplan, 2001; Berthon et al., 2003; Bunduchi, 2008). The review of B2B transaction cost effects, therefore, is limited to the definition of costs and savings potentials related to digitization of B2B transactions. The presentation of measurable effects at this moment is not included, as the framework conditions since then have changed significantly and the available data and related effects are not likely to be representative for the B2B market status quo. The role of EDI will evolve but demands a business process redesign, as, by the time of their study in 2002, the role of EDI is limited to localized applications (Mukhopadhyay & Kekre, 2002). Their future projection, therefore, can be applied to the high potentials, which are ascribed to the various application areas of web-based services and online platforms accordingly. Pavlou (2002) in this context states, that institution-based structures and inter-organizational trust are an indirect driver for transaction success in B2B marketplaces. The efficiency leverages linked to financial success (benefits) considering the significant types of transaction costs and how the internet (or the Web) affects transaction cost savings are presented in Table 2. Internet-based solutions might realize cost saving potentials as outlined in Table 2, which demonstrates one benefit the digitalization of business processes.

Cost Type	Impact
Search Costs	Reduced time effort for ordering products, services, solutions and potential buyers and suppliers, e.g. via search engines.
Information costs	Learning more about products and product availability.
Bargaining costs	Replacing individual negotiations by intelligent agents who act on behalf of customer or online bidding systems, which can cut bidding processes.
Decision costs	Comparative websites facilitate the decision on suppliers or products.
Policing costs	Online ordering and billing allow buyers to check statements in real time.
Enforcement costs	Chat lines, bulletin boards and on-line media facilitate the enforcement of contractual rights at low costs by "making suppliers listen".

Table 2: Types of transaction costs and effects of the Web (adopted from Berhton et al., 2003)

Nevertheless, the integration of electronic services and applications, just as mobile payment, requires business processes and structures to be redefined considering stakeholders of the value chain network. This can only be achieved if all relevant market participants have a common agreement on process development and integration. It is not a question of whether electronic integration into B2B processes is beneficial and profitable for each party, but how processes can be designed and executed to achieve long-term increases in efficiency and profits. To answer this question and to develop a suitable approach, theories of business relations and their impact on performance are examined.

Theories of Business Relations

Regarding the uncertainty of online transactions, digitalization forces market actors to create institutional structures that support inter-organizational exchange relation. By reviewing the literature on business relations, the impact factors "*relationship quality, power, trust and transaction costs*" have been identified as being most likely to influence the decision of B2B actors to strengthen inter-firm cooperation. The relevance of relationships in various forms also besides standard business contracts like joint ventures or supply agreements is addressed. Beside those, networks and cross-sector partnerships are of high relevance when it comes to relationship forms as an instrument for creating and maintaining competitive advantages (Gölgeci et al., 2018; Parmigiani & Rivera-Santos, 2011). Three aspects - power-based behaviour, relationship quality, trust – represent a set of impact factors that influence efficient interactions and transactions within the B2B retail supply chain environment. All aspects are closely linked to each other, whereby it can also be assumed, that relationships are shaped by the status of power and trust. Furthermore, firm's behaviors and strategies are based on power effects, the risk of being affected by the partner`s capabilities and perceived power symmetries or asymmetries (Bastl et al., 2013; Nyaga et al., 2013; Tate et al. 2013). Some firms are then focusing on demanding conformance and others strive for balanced power and the engagement of partners for cooperatively facing problems and finding solutions. The interplay of both reactions then is shaping supply chain relations (Hingley, 2005). To be able to realize efficient co-operations between all stakeholders in B2B online retail, conceptual approaches need to eliminate or at least lower barriers, e.g. the negative effects on relationships that occur when partners are enforcing power as a form of a control mechanism which on the other way around negatively influences trust and relationship quality. Therefore, Institution-based structures help to create inter-organizational trust and transaction success (Pavlou, 2002). Finding a suitable methodological approach for the creation of efficient platform solutions can be a starting point for eliminating negative effects on business relationships and thereby enable efficient cooperation of partners along the supply chain.

METHODOLOGICAL APPROACH: THE INSTITUTIONAL ROLE MODEL (IRM)

The Theory of the Institutional Role Model is applied to ensure efficient coordination of the involved actors with their different interests (Schulz, 2011; Schulz & Wieker, 2016). In the following the investigation scope and methodological background of the IRM approach will be presented and will then be applied on the example of B2B retail for creating a conceptual framework for cross-sectoral and cross-industrial transaction platform. For the development of a workable platform solution, besides the identification of the major actors and stakeholders it must be identified, which actors in context of the "action system" (e.g. individuals, company divisions or as a whole) are capable and willing to take over specific economic and technologic roles, that are fulfilled with respect to the "regulatory system" (Schulz & Wieker, 2016). Based on the presented IRM approach (Figure 1), a 360° assessment (self-assessment, partner assessment, and expert assessment) is used to identify the partner specific role perception. The evaluation is conducted by all partners (actors) involved. The rating scheme ranges from (1) *Partner is not capable of taking over the role* to (5) *Partner wants to or should take over the role, as the partner has a competitive advantage or unique position in this field* (Schulz & Wieker, 2016). Considering the theoretical background on business relations and their effects on profitability of market actors and the business segment, the IRM approach is regarded as one suitable solution for the development of an efficient, co-operative B2B network with common objectives and strategic alignment for achieving a consistent and workable solution.

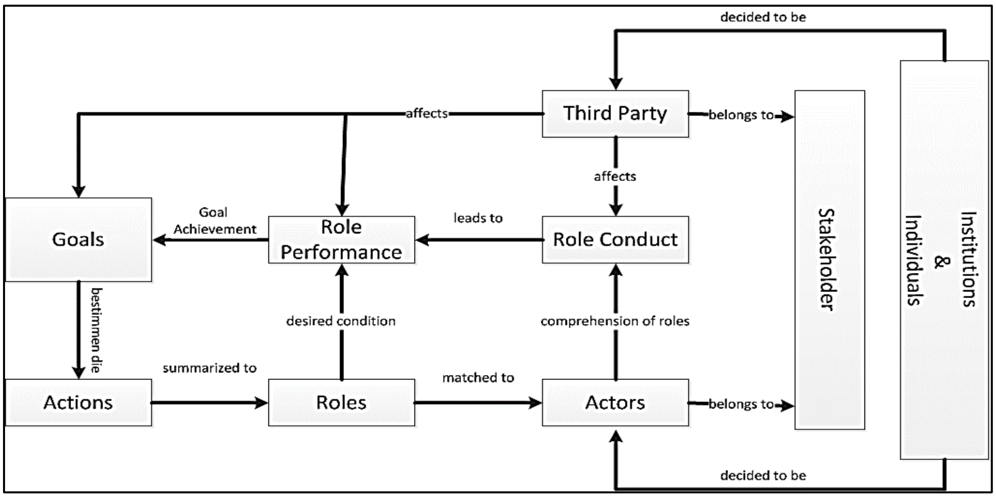

Figure 5: The Institutional Role Model Approach (Schulz, 2015, p.93)

To be able to evaluate the economic feasibility of the presented approach, an assessment of role performance related to the capabilities of institutions as "role owners" must be conducted. Performance represents an important evaluation criterion, as not only internal but also external economic effects are caused by actions taken by single actors in the business environment. The suggested evaluation criteria are presented in Table 3.

Internal impact	Operability of the process: An actor's willingness to take over a certain role, which can be identified and clearly defined. The execution of actions hereby depends on the actor´s capabilities.
	Cost efficiency: An essential part of the economic assessment is to distinguish between static efficiency and dynamic efficiency effects.
Internal & External impact	Transaction Cost Saving: An increasing efficiency of processes within the system has an impact on transaction costs. These savings represent the overall profit that can be allocated to the partners. Transaction cost savings are applicable for all meta-roles and economic effects are only applicable on those who are providing revenues, whereby the one does not exclude the other.
External impact	Economic Effects: The generation of benefits for consumers, users or the whole society (profitability for businesses, macroeconomic benefits).

Table 3: Economic effects of Role Performance (adopted from Schulz & Müller, 2016; Schulz & Wieker, 2016)

Application of the IRM Approach

For developing a platform approach, the classical roles of platform solutions have been assessed to define suitable meta-roles. Subramaniam and Shaw (2002) presented a framework for web-based procurement from the technical perspective. However, before being able to implement a technical solution the organizational framework must be defined by considering economic roles to gain a common understanding of cooperation in terms of taking over general tasks. As a starting point, the authors consider the approach of Alstyne et al. where they defined the roles within the ecosystem of platforms, enhanced by the definition of community roles by Roskos (2011). Figure 2 demonstrates that the classical interpretation of platform roles is not sufficient for the aim to develop a discrimination-free solution which ensures equality, fair conditions and a high level of transparency for all actors. Therefore, roles with moderating and member managing functions which incorporate an independent and neutral position should be included in the B2B platform ecosystem. With the defined roles, the minimum requirements for the creation of co-operative platform solutions can be met. As mentioned before, the interactions and behaviour of single actors with their business partners are crucial influencing factors, as a co-operation always is built on trust and commitment – regardless contractual obligations that ensure the fulfillment of tasks, as those are more a control mechanism for relational agreements than an expression of relationship value (Liu et al. 2010; Gölgeci et al.; 2018; Parmigiani & Rivera-Santos, 2011). Since the evaluation of a B2B platform specific construct can only take place within the evaluation process, only assumptions about the roles and institutions to be involved can be made by the status quo and the literature analysis. The baseline concept is described in Figure 3.

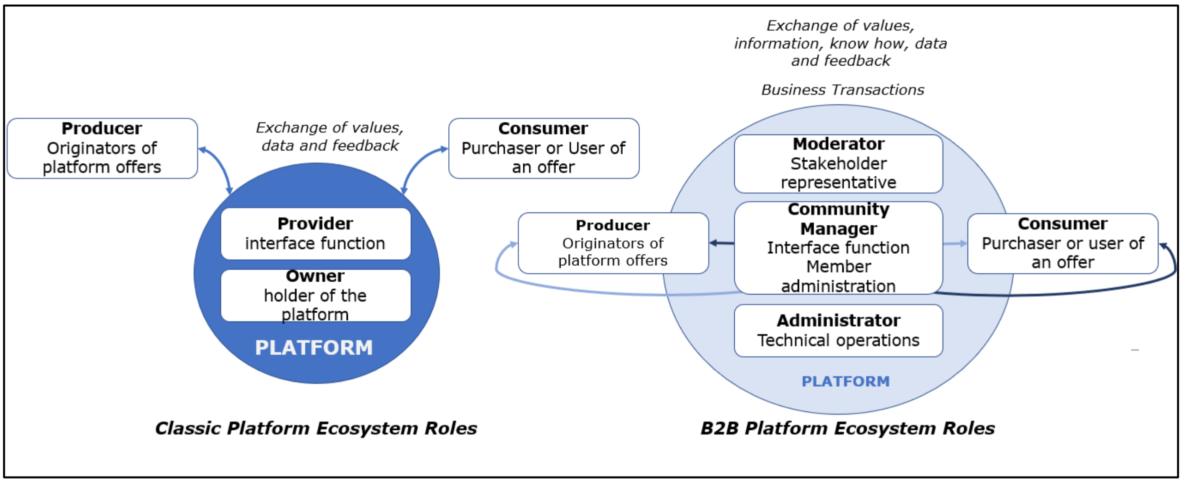

Figure 6: Platform Ecosystem Roles (own illustration, based on Van Alstyne et al., 2016; Roskos, 2011)

Platform Operation		
Meta Roles	**Sub Roles**	**Tasks**
Moderator	Stakeholder Position Assessment Code of Ethics Code of Conduct Negotiations	**Fairness** Coordination of interests with regard to rules, regulations, fair conditions and power balance.
Community Manager	Communication Member Application and Integration Contracting	**Relationship management** Central administration for lowered complexity and increasing transparency.
Administrator	Technical Integration Service Management Member and Service Linkage	**System Operation** Central platform application decreases the complexity of lacking technological know-how, member and innovation integration
Quality Management	Process Screening Supply Chain Management Risk Management Audit Regulatory Framework	**Control Mechanism** Lowering the complexity of market and supply risk identification and management by continuous screening processes.

Supporting Business Process		
Meta Roles	**Sub Roles**	**Tasks**
Sales	Service Portfolio Member Akquisition Contract Management Market Research Customer Account Management	**Business Development** Identification of new members, entrants, market dynamics and new business opportunities. Operational community development management.
Procurment	Ressources management Demand Management Order Management	**Resources Management** Demand and market oriented management and allocation of available resources.
Financial Management	Opertation Cost management Transaction Management Invoice Management Payment Tracking	**Accounting** Managing internal financial contributions, capital and transactions.
Controlling	Cost Projection KPI Reporting Solvency Check Pricing	**Performance Control** Measurement of internal business performance and strategic planning.

360° Assessment of Role Fulfilment

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Chamber of Industry, Trade and Commerce	Federation for Wholesale, Foreign Trade and Services	Wholesaler B2B/B2C	Retailer B2B/B2C	Customer B2B/B2C	Manufacturer	Producer	Processing	Advocacy and Consultancy	Insurance	Transport Operators	Logistics Service Providers	Customs	Supervisory authority	Consumer Protection
Associations and Trade Unions		**Supplier/Buyer**			**Industry**			**Service Providers**				**Legal Entities and Quality Insurance**		
Exemplary Institutions														

Figure 7: B2B Platform Baseline Concept and Roles (own illustration)

CONCLUSION AND OUTLOOK

The literature review and the comparative investigation of current B2C and B2B markets operations methods have shown a significant development gap. The B2B market is characterized by linearity and lack of transparency around the demand situation, which creates reactive behavior to demand changes. In a changing environment, the B2B market questions whether this existing supply chain is still adequate going forward. Supply chain collaboration and the use of a shared platform seem to be a vehicle, which enables an effective network model. The IRM is a suitable method to create a sustainable framework regarding effective stakeholder cooperation via a platform solution with defined roles, tasks, rules. The approach supports the consideration of the elaborated impact factors trust, relationship quality as well as power bias, that are embedded in a workable environment for granting positive effects and output for all involved partners accordingly. The application of the IRM approach for creating a co-operative B2B platform approach is not limited to a certain field of application. Once the platform has been successfully implemented, the approach enables continuous development in a changing ecosystem. The integration of new actors is simplified by a high level of transparency and a low level of complexity due to the IRM process and the 360° assessment for role allocation. To exploit the full potential of B2B platforms, the next step is to evaluate specific empirical data on applicability and practical concept assessment. As the presented approach is limited to the framework setup and the identification of economic roles, technical requirements, related roles and tasks, such as backend system development and the use of technological solutions, were not examined.

In this context, data safety and security are likely to be important for potential actors, also considering aspects like trust, power, and long-term relations. The presented approach must be elaborated in terms of concrete framework construct and operator model development and the application of the latest technological solutions. By using the IRM methodology, we apply a conceptual framework building solution that has already proven within former research projects (e.g. CONVERGE; Schulz, 2015). The presented approach at this point must be regarded as a baseline concept and orientation base for developing a cooperative platform solution for B2B retail. Therefore, the next step is to address the identified stakeholders by presenting the approach for further evaluation and identifying actor specific needs that must be fulfilled by the inclusion of dedicated roles and tasks. By conducting IRM specific stakeholder interviews, economic and technical white spots will be identified that have to be included in the IRM by specifying further institutions and roles. The evaluation of actual case study data is part of our forthcoming research.

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CRITICAL SUCCESS FACTORS FOR ADDITIVE MANUFACTURING ADVANCEMENT IN INDUSTRY

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Abstract
Researchers have outlined some significant conceptual operations benefits associated with the adoption of Additive Manufacturing (AM) processes for low-volume applications in a number of industry sectors, however uptake levels still appear to be low (Ghobadian et al., 2018). There is also a dearth of empirical exemplars profiling the successes and failures of AM implementation. This is evidence of the gap between research and practice regarding the application of the manufacturing process in contemporary manufacturing and service operations (Braziotis et al., 2018). This paper analyses the AM implementation cases of Suppliers operating in three industries to identify the supply chain factors that supported or militated success. This is in order to highlight the critical success factors necessary for the advancement of AM in manufacturing and service supply chains.

Design/methodology/approach
This paper follows a case study approach, focusing on AM implementation projects and AM SCs as the unit of analysis. Semi-structured interviews are employed to explore the experiences of different stakeholders involved in successful and failed AM implementation projects undertaken by suppliers. A purposive sample of 4 firms was selected in application sectors namely aerospace, automotive and power. A conceptual framework, underpinned by SC configuration theory and a structured approach to the make-or-buy decision, was used to develop the case study protocol, exploring the themes of strategy, structure and environment in the process (Cánez et al., 2000).

Findings
This paper outlines the determinant combination of triggers for AM adoption and the critical supply chain factors to be considered during the process of AM implementation.

Value
This paper highlights critical supply chain dimensions necessary for the advancement of AM, taking a particular focus on failed and successful implementation projects. The findings provide elaborates on generic prescriptions for AM adoption and SC factors in extant literature. It also provides empirical evidence on the state of AM developments in the manufacturing and service supply chains vs the hype in the conceptual literature.

Research limitations/implications The research explores a few failed and successful cases of AM implementation across diverse industries. Validity of findings and conclusions can be further strengthened by analysing more cases per industry and including other SC tiers.

Practical Contribution
AM is currently in the developmental phase of its lifecycle for end-use parts applications. Highlighting the critical development paths is important for practitioners and policy makers to channel development efforts in crucial areas to accelerate development. Practical guidelines are provided for prospective AM implementation projects

1. INTRODUCTION

Additive Manufacturing processes (AM) have emerged from the background of prototyping to low-volume end-use parts applications in different sectors. The technical capabilities of the process include design freedom and functional integration with empirical examples evidencing the achievement of these capabilities in industrial applications (Petrovic et al., 2011). Operations and supply chain capabilities include tool-elimination, economic low volumes and localisation of production capacity for assembly and repair operations, however with little empirical evidence to substantiate deployment industrially (Holmström et al., 2016; Khajavi et al., 2014). Adoption levels are growing in a fragmented nature and at different maturity levels across sectors such as aerospace, automotive, energy, medical, consumer etc. For example, AM is being used to fabricate non-critical parts such as brackets for airplanes, components for race cars, gas turbine blades, hearing aids, jewellery etc. Compared to Traditional Manufacturing (TM), uptake levels of AM are significantly low (Ghobadian et al., 2018). This is likely due to the overestimation of conceptual capabilities in the AM management literature, without empirical evidence to outline the limitations of the process for industrial applications. This paper analyses AM implementation cases of suppliers to identify the supply chain factors that supported and militated success. The rest of the paper is organised as follows. Section 2 discusses AM adoption and implementation literature to articulate the research gaps. Section 3 articulates the research objectives and presents the theoretical framework. Section 4 presents the multiple case study methodology adopted. Section 5 presents the analysis and findings of the study. Section 6 presents the conclusions and suggestions for future research.

2. LITERATURE REVIEW

Implementation refers to the process of successful adoption of a new technology consisting of three phases namely pre-installation, installation and commissioning, and post-commissioning (Voss, 1988). Pre-installation deals with preliminary evaluation of positive and negative factors that can potentially impact the outcome of the process. It is at this stage that an organisation decides to adopt or reject the technology under investigation. Installation and commissioning deals with the actual deployment of the technology and is completed when technical and utilisation objectives have been met. The final phase is post-commissioning and deals with refinements to improve the technical performance to business success. The first two phases (pre-installation, installation and commissioning) coincide with the content of AM adoption and implementation studies respectively. This also exemplifies the technology lifecycle stage that AM is as manufacturing firms are currently dealing with problems in implementation (Ghobadian et al., 2018). The final phase therefore corresponds to an advanced technology lifecycle stage where AM is refined to improve business performance and is beyond the scope of this paper.

The AM technology adoption literature examines the environmental elements and their influences on management decisions to adopt the technology. Oettmeier and Hofmann, (2016) found that compatibility of AM with firm's processes and demand-side benefits (e.g. decentralising production and increasing customer responsiveness) significantly influence the adoption of AM processes. Relative advantage of AM and performance expectancy have also been identified as significant drivers of AM adoption (Schniederjans, 2017). Rylands et al. (2016) found competition-related factors as significant in a consumer application. Yeh and Chen (2018) identified cost, environment, technology and organisation as significant factors influencing AM adoption. On the other hand, the AM implementation literature examines some of the factors to be considered during the process of adoption. A number of these studies have focused on cost aspects of implementation (Achillas et al., 2017; Baumers et al., 2016; Khajavi et al., 2014). Mellor et al. (2014) identified 5 dimensions namely strategy, supply chain, systems and operations, organisational change and AM technology as important factors to be considered during implementation through a single case study, however lacking explanatory depth on each of the five dimensions. Rylands et al. (2016) highlighted the business impacts of AM implementation from a value stream perspective. Deradjat and Minshall (2017) considered corporate strategy, technological, operational, organisational and external implementation factors from a mass-customisation perspective in the dental sector. Collectively, these AM adoption and implementation studies lack a focus on the supply chain factors and their bearing on AM adoption and implementation decisions respectively. The supply chain dimension is particularly significant because of the proposed radical transformations that AM brings to supply chain management practices (Braziotis et al., 2019).

3. RESEARCH OBJECTIVES

To address the aforementioned research gap, this research adapted an existing framework developed for the make-or-buy decision proposed by Cánez et al. (2000) for the AM adoption decision corresponding to the pre-installation, and installation and commissioning phases of industrial applications. The framework (Fig. 1) is underpinned by SC configuration theory which consists of three elements namely environment, strategy and structure (Singh Srai and Gregory, 2008). The elements of environment activate performance-related triggers for the AM adoption decision. Further, the AM adoption decision has consequences for the structure of the AM SC represented by four dimensions namely SC structure, material flow, information flow and relationship between SC entities, and product value structure. These elements of structure have implications for SC performance represented by the elements of strategy, to measure the level of achievement of targets set by the triggers. Lastly the arrows pointing out from the performance measures indicate that the AM adoption decision is not static as changes in states of elements of environment can necessitate a re-evaluation of the decision.

This paper aims to answer two questions:

1. Why do suppliers consider AM for manufacturing and spare parts SC applications? This question aims to examine the elements of environment, corresponding performance related-triggers and bearing on the AM adoption decision.
2. What are the SC factors to be considered during the process of AM adoption? This question aims to examine the elements of structure to identify SC factors to be considered during AM implementation.

4. METHODOLOGY

A multiple case study approach is adopted for this research focusing on the AM implementation cases of adopters and potential adopters of AM for low volume manufacturing and spare parts applications (Thomas-Seale et al., 2018). The study involves two units of analysis, namely AM implementation projects of suppliers and their respective SCs. Semi-structured interviews, lasting an average of 83 minutes, were used primarily for data-collection with other sources namely site and artefacts observations serving as complements (Yin, 2014). A case study protocol was developed to explore the elements of environment, structure and environment, based on the theoretical framework (Fig. 1). Tables 1 presents a summary of the cases in terms of the SC position, location, industry, markets and respondents. Within-case analysis is carried out on each of the cases. Subsequently, a cross case analysis was carried out and presented in the analysis and findings section

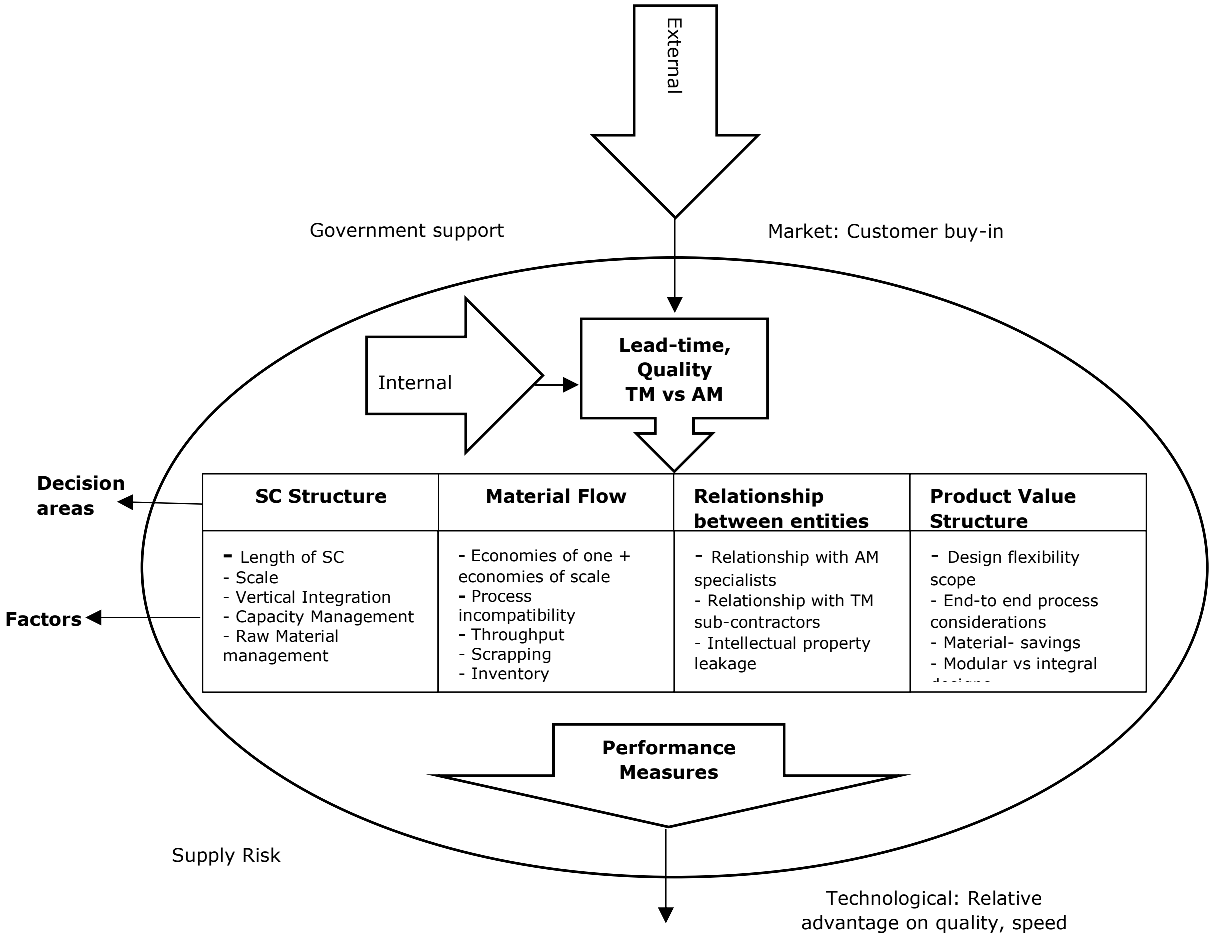

Figure 8: AM adoption triggers and supply chain factors

Table 1: Case company details

Company name	SC position	Location	Market(s)	Interviewee(s)
Tier-2 supplier A (ST2-A)	Tier 2 supplier	UK	Aerospace, motorsport, power	Technology Director (TD)
Tier-2 supplier B (ST2-B)	Tier 2 supplier	UK	Aerospace	Additive manufacturing manager (AMM)
Tier-2 supplier C (ST2-C)	Tier 2 supplier	UK	Aerospace, motorsport, power	Manufacturing development lead (MDL)
Tier-2 supplier D (ST2-D)	Tier 2 supplier	UK	Aerospace, motorsport, medical	Managing director (MD)

5. ANALYSIS AND FINDINGS

5.1 Triggers for AM adoption

A number of external factors in different dimensions influence firms' decisions to adopt AM. In the aerospace sector, supply risk of raw materials and parts represents a significant determinant. This risk can be due to several reasons for example the location of suppliers in politically troubled regions, misplaced or obsolete tooling for spare parts and scarcity of rare materials. This is important for spare parts applications in the aerospace industry where airlines pay huge Aircraft on Ground (AOG) penalties because of lack of spares to keep flights operational. These factors make it difficult for suppliers to meet obligations for quick turnaround applications and AM represents a solution because of tool elimination and raw-material availability. "*There is things like forgings that are made in Russia, I don't* *know if that's a thing at the moment. So there is political risk involved in the sourcing of parts, there is all sorts…. it was just looking after spares and MRO, where you are not worried as much about the final cost if you can add value by having a much shorter lead time than you've got a better business case in such situations"* (ST2B, AMM). For motorsport applications, AM represents a viable solution because of the capability to move rapidly from clean sheet designs to finished parts to meet the requirements of the industry to implement design changes quickly." *So, for the time being, the process as it stands is, the customer designs the part and they going out as a competitive bid, who can deliver these parts on time and if you can deliver on-time, you can almost name your price" (ST2D, MD)*

The relative advantage of AM in comparison to other TM technologies in technical terms still represents a significant trigger for adoption decisions in all the cases studied. For aerospace applications, TM processes are constrained by design for manufacturing rules with the resultant effect that excess material is incorporated into final parts thereby increasing effective weight. AM is attractive because complex geometries can be achieved, eliminating excess material. These AM parts with higher functional performance in terms of light weighting are very attractive for aerospace and motorsport applications to reduce fuel consumption."*But you will certainly struggle to make some of the weight savings using traditional machining" (ST2A, TD).*

In addition to these triggers, some enablers and inhibitors for the AM adoption decision where also identified from the cases. From an external perspective, government support for AM projects has been very instrumental in carrying out R&D projects, without which small suppliers wouldn't be able to participate. *"So, the NATEP programme is to encourage smaller companies to engage in collaborative R&D industry led, and the funding is there to take of the financial barrier, that smaller companies will say that's going to cost too much" (ST2A, TD)*. On the other-hand, government regulations have also been seen to exert influence on the AM adoption decision, as seen from the different regulatory requirements across sectors. For example, the aerospace sector contains very strict regulations for qualification of designs, processes and materials, effectively driving applications towards like-for-like design replacements and clean-sheet designs. Regulations in the motorsport industry are relatively liberal and enable the implementation of design changes.*"Even though the quality demands are probably fairly similar, aerospace will be eager to fit within their current sort of processes, approaches, people, supply chain, stuff like that.. Whereas you get in motorsport, really looking at doing things very different, trying to constantly improve" (ST2C, MDL).* Lastly, from an external perspective, the customer's buy-in is very critical to adoption as supplier parts end up on final products belonging to the OEMs. From an internal perspective, management buy-in is very critical to AM adoption. *"..only that our parent company was interested in learning more about additive because it was, still is a very exciting new technology" (ST2A, TD).*

5.2 Supply Chain Factors

5.2.1 SC Structure

Under this dimension, four salient factors emerged for consideration during AM implementation, namely length of the SC, scale, vertical integration, capacity management and raw-material management.

Several propositions have been made about the capability of AM to shorten SCs (Section 1). Evidence from the cases shows that this vision is currently far from reality because of significant post-processing that is required after the AM build. The amount of post-processing required (in effect, the length of the process chain) is determined by several factors namely, the requirements of the end-application and also the capabilities of the process technology. Some aerospace applications for example are very demanding in terms of fatigue life of parts, therefore require finish-machining, which appears counterproductive to using AM in the first instance. The Electron Beam Melting (EBM) process, doesn't require the stress-relief heat treatment present in laser processes, effectively shortening the length of the process chain. *"…one particular thing about, the EBM is that you don't need to do a number of post-processing steps that you have to do for laser" (ST2D, MD).* Scale considerations are important for make-or-buy decisions for AM. At the initial stage, small suppliers don't have the volumes to justify investment in AM and therefore have to rely on the services AM specialists. These specialists enjoy economies of scale and specialization with the volume of work orders from different customer segments and also the experience to deal with the intricacies of the process. *"So if you are not used to say, handling inert gas and the dangers around that, then you are going to see that as a very big challenge" (ST2C, MDL).*

In a similar manner, suppliers must also consider the experience and scale of sub-contractors for post-processes. This is particularly relevant to vertical integration as some of the post-processes are cheap and others are too expensive to bring in-house. These decisions also have to be balanced against the volume of part orders that flow through those processes. *"It's used a lot in castings. A hip vessel, you are looking at like 10 million pounds. So, you don't want to have that vessel sat there and not used 90% of the time." (ST2, AMM)*

Suppliers need to possess knowledge about the management capacity for AM and post-processes, when dealing with low volumes. This knowledge includes the profile of demand in industry sectors that affect capacity availability in the supply network. For example, the seasonal nature of motorsport races affects AM capacity in the SC. Suppliers also have to be aware of the different AM competencies and also sources of extra capacity without the risk of compromising intellectual property. *"So where you are getting parts from a supplier, all of a sudden, you hit December time and they are just like, well we are not going to talk to you until April. So, all of a sudden, you get that disruption" (ST2C, MDL).*

In the AM SC, suppliers must be aware of the new responsibility for ensuring material quality. In the TM SC, this responsibility rests with the raw-material suppliers, however in the AM SC, the material is created simultaneously with the part therefore there is an extra requirement to ensure that the material has the right properties according to specification. This is particularly significant in aerospace application where rigorous testing is carried out. *"In titanium, it might be 10mm and in steel it may be 5mm or something. I don't know the exact measurements, but I know that there is a problem with inspection, because with additive, you can make very complex parts. How do you know it's okay?" (ST2D, MD)*. The qualification state of AM materials in industry is also a very important SC factor. In the aerospace industry, material characterization programs are mainly focused on expensive raw-materials such as titanium and Inconel, where there is significant scope for material savings with AM. Cheaper raw-materials such as stainless steel are not very attractive candidates for characterization as their TM forms have high availability and are significantly cheaper. That said, regulatory requirements in the motorsport industry do not emphasize material characterization, therefore there is a wider scope for material application. *"So it's a relatively inexpensive raw-material, and in the pecking order of getting the materials fully qualified, you've got people working on the titanium and ...alloys and the more exotic expensive alloys where you get a big saving in raw material costs using additive manufacturing" (ST2A, TD).*

5.2.2 Material Flow

For material flow, SC factors emerged under four dimensions namely economies of one & scale, process incompatibility, throughput and inventory management.

Economic fabrication of small batches has been put forward as one of the superior capabilities of AM, however often ignoring the additional post-processes, some of which are based on economies of scale. Therefore, the flexibility of the AM process in not translated across the process chain, with implications for material flow. Some post processes such as machining and hot isostatic pressing require setups and large batch runs, so whilst the AM build may produce a small economical batch, it has to rely on these economies-of-scale post processes, with implications for cost and lead time. *"You might have to wait for them to have enough material, so if a H.I.P (Hot isostatic pressing)..,for example, that's a good one where, a dedicated vessel could cost you a £1000 plus, to do a run and that vessel could fit in 500 of your parts, but you only want one, so you are paying for that one and the only other option is to wait until they've got other peoples work, put it all in together." (ST2B, AMM).* The capability of AM to fabricate complex designs represents a significant trigger for adoption, however this capability introduces challenges for post-processing and testing further down the chain. This is particularly significant with new complex designs, that haven't been post-processed or tested before. This problem highlights the incompatibilities between AM processes and some of the TM post-processes and testing technologies. *"So because we are operative very much at the cutting edge of some of the components, some of the other processes cannot keep-up" (ST2C, MDL).*

The throughput of AM processes in terms of the number of parts that can be fabricated in a build operation is directly affected by the size of parts, smaller parts being better candidates. Beyond that, this capability is challenged by the variation in quality of parts from the same build that is affected by several factors namely the quantity of parts in a build, build parameters and the AM process capability. EBM processes, for example, make it easier to maximise build envelope height because of the capability to stack parts. This is a challenge with laser processes due to the requirement for substrates and the inability of parts to be built in free space. This limits the throughput of the operation*."So there is flexibility, but with flexibility also comes danger that you may make this part and say well we made this part and it worked and you just move it to a different position and it may not work. So, you have flexibility, but sometimes, it comes at a price" (ST2D, MD).* Suppliers need to be aware of the scope available to apply just-in-time principles to the management of raw-materials, based on reorder levels, because of the generic nature of the raw-material stock. Further, AM parts that are high-value are expensive and therefore there is limited scope for producing excess stock that may end up as waste. That said, the unpredictability of AM as an immature process warrants the production of excess stock in case of part failures. Also, test parts need to be created to carry out trials, especially for new designs and this amounts to generation of scrap and extra costs in the SC.*"Then of course, can we make it physically? We need to look at it and evaluate it. Is this doable with what we know? Because if it is a very complex part, or if it requires a way that we haven't made it before, we may need to do some trials" (ST2D, MD).*

5.2.3 Information flow and relationship between SC entities

The need for collaboration amongst different entities in the AM SC was emphasised in all cases. Firstly, in the area of design, collaboration of supplier's designers with AM specialists is crucial to leverage the benefits of AM for optimised product designs. Otherwise, suboptimal designs result in additional build and processing costs for the SC. Furthermore, this engagement has to occur, early in the product development cycle to maximise AM benefits. That said, AM specialists must prove their design competence to earn the trust of customers before they can be allowed to affect the design process. "*We have to. So we find that when they just push us something and go, "can you build that". It's not going to work" (ST2C, MDL). "For the time being, we don't have much power in terms of affecting the design, because a lot of the parts they do, they are not that brilliantly designed for the process….."(ST2D, MD).* Collaboration between non-competing AM specialists is also crucial because of the availability of capacity. This is particularly important in peak seasons where suppliers require extra capacity to fulfill customer demands. Suppliers may resort to capacity from research institutions as collaboration with competitors risk the leakage of intellectual property. *"So we are working towards building some contingency, in our supply chain. So effectively, working with other people around us that are running machines so that we can go "can we use your machines in the event of needing some contingency" (ST2C, MDL)."They were a bit nervous about getting too close to us in case there was any intellectual property leakage either way, which would compromise them" (ST2A, TD).*

Collaboration with service providers is also very crucial because of less than optimal batch sizes and the need for quick turnarounds for manufacturing and spare parts. In the normal flow of work orders, low-volume parts may be delayed or incur significant costs if the relationship between AM specialists and service providers is at arms-length. "….*because like I've said, they've got the equipment, if in theory it takes ten hours, then they can do it in ten hours, they just have to want to do it in ten hours. So it is just a relationship building, making them aware that this service would be required" (ST2B, AMM).*

5.2.4 Product Value Structure

From a product design perspective, a crucial factor that emerged from all cases was the need to consider the end-to-end processes at the design stage. For post-processes such as machining, it may be necessary to build in excess material for the machining process because of fatigue properties. Furthermore, complex geometries may require the inclusion of supports to hold the AM part during machining. *"It reinforced their understanding that they need to consider the post-processing at the design stage as well" (ST2B, AMM)."If we talk about for the additive process, if this part needs to be machined, and the guys, they are going to take it and put it on their CNC machining, you have challenges sometimes, because you can make complex parts. How do you hold this on your CNC to machine it in the right orientation?" (ST2D, MD).* Secondly, designers must be aware of the characteristics of their parts in terms of sections that wear out frequently vs long life-cycle sections to make the right design decisions. This is because coupling replenishment sections into an AM build may compromise the lifecycle of a lifetime part. That said, there was consensus supporting the fact that components are not replaced as parts, rather as modules. *"So, if we know that something is going to wear and it is a change-out part, then we wouldn't integrate it….but actually, the vast majority of parts these days are not changed" (ST2C, MDL). "…it is very much like an old television, something was breaking and you could change something in. Today, if something breaks in your television, you throw it away and you buy another one. Its the same thing" (ST2D, MD).*

6. DISCUSSION AND CONCLUSIONS

Through the lens of SC configuration theory, the preceding section explored the elements of environment, strategy and structure to identify the salient SC factors to be considered during AM adoption and implementation from industrial cases. Section 5.1 underscores the importance of critical evaluation candidate parts for AM adoption, based on the limitations of TM processes and capabilities of AM. The triggers also suggest candidate SC applications for AM that require speed, providing an extra parameter for evaluation of business cases. Therefore, this paper elaborates on the generic drivers provided by extant AM adoption literature, to specify the determinant triggers for AM adoption (Oettmeier and Hofmann, 2016; Schniederjans, 2017). Additionally, enablers and inhibitors where identified. Section 5.2 extended SC configuration theory to identify the critical SC factors and implications for performance, expanding the narrow discussion on SC aspects, provided by extant AM implementation literature (Deradjat and Minshall, 2017; Mellor et al., 2014). These factors need to be carefully considered during AM implementation projects and provide indications on focus areas to increase the odds of success. Consequently, potential adopters must understand the requirements of end applications, the added responsibilities to ensure material quality and capacity management for effective routing of parts through the SC. Knowledge of scale in the supply network is also crucial to make-or-buy decisions. Adopters must also be aware of the conflicts that arise between economies of one and scale processes to manage the flow of parts, the relationship element being crucial in this regard. Lastly, end-to-end process consideration during product design is crucial to successful implementation. In view of these contributions to AM implementation, the limitation of this paper must be acknowledged. The sample size is limited and therefore limits the external validity of findings. Future studies should broaden the sample size to include entities from other SC tiers and more cases per industry to strengthen the validity of findings. Furthermore, future research should rank and empirically validate the relative importance of these factors across industry sectors.

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EXTENDING SUPPLY NETWORK AND BUILDING CUSTOMER CONNECTIVITY: THE FLIPKART STORY

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ABSTRACT

This study examines the growth path of Flipkart, India's largest e-commerce retailer, to develop a theoretical process model of e-commerce supply chain growth. It found that Flipkart's success was the results of three dynamic logistics capabilities – articulated adaptation, structural realignment and expectation connectivity – which the company used to recruit targeted suppliers and connect with consumers to drive value, increase attractiveness and draw investment to fuel growth and raise further value.

INTRODUCTION

While much has been written about e-commerce operations, little has been documented about the end-to-end processes of e-commerce supply chain operations. Fewer still is how e-commerce supply chains were established and developed over time. With the growing dominance of m-commerce under omnichannel retailing, e-commerce supply chains are on the increase. While models of organizational growth and development abound, few of these models theorize the growth process of an organization's supply chain, let alone that of e-commerce. This study delves into the growth path of Flipkart, India's largest e-commerce retailer with a registered customer base in excess of 100 million. Its objective is to develop a theoretical process model of e-commerce supply chain growth.

E-Business Model

Understanding how businesses grow and develop requires an understanding of their business models. Unfortunately, there is no consensus on the definition of a business model (Zott et. al., 2011). Zott et al. (2011), who conducted a broad and multifaceted review of the literature on business models, found that the literature has been developing "largely in silos" (p. 1020).

In the internet context, Mahadevan (2000) offered a conceptual business model structure comprising three streams - value, revenue and logistical – with three building blocks: portals, market makers, and product/service providers. Focusing on the roots of the business model concept, with a particular bent in the information systems domain, Osterwalder et al., (2005) defined a business model as:

> " ... a conceptual tool that contains a set of elements and their relationships and allows expressing the business logic of a specific firm. It is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value and relationship capital, to generate profitable and sustainable revenue streams" (pp.17-18).

In their attempt to create a common language by identifying the domains, concepts and relationships addressed in the business model field, Osterwalder et al., (2005) placed Mahadevan's (2000) three structural streams of value, revenue and logistics respectively into value proposition, revenue model and value configuration. Osterwalder et al.'s (2005) review, in short, saw logistics as a process of value configurations, which is the key to value creation in e-commerce.

Mahadevan (2000) argued that the robustness of the value stream of an internet-based e-commerce business drives both the revenue stream and the logistical stream. The portal is central to the value creation process. It creates a virtuous cycle of benefits generation arising from the richness and reach of the web, reducing product search cost and transaction cost for buyers, thus leading to an increased customer base for suppliers, and attracting more suppliers in the process. The result is buyers seeing more product choices while suppliers experience a growing customer base. The e-business model, in sum, is dynamic.

Despite that, most literature on e-business model has taken a static perspective on business models, indirectly assuming them to remain stable over time (Gunzel & Wilker, 2009; Demil & Lecocq, 2010; Hacklin et al., 2018). In the real-world, organizations need to reinvent their business model frequently and align with fast-changing environments (Afuah and Tucci, 2003). To study how Flipkart aligned its business processes and supply chain activities with the vagaries of the market environment, this study invokes the tenets of three strategic management theories to explain the changing configurations of Flipkart's business models between 2007 and 2018: dynamic capability theory (Teece et al., 1997; Eisenhardt and Martin, 2000), contingency theory (Miles & Snow, 1978; Venkatraman, 1989) and strategic fit theory (Chorn, 1991).

Dynamic capability theory explains the success of an organization over time through its ability to change and adapt to the dynamic environment (Teece et al., 1997; Achtenhagen et al., 2013). The dynamic capability perspective suggests that firms need to adapt and renew their business models by sensing, seizing and transforming in order to maintain their competitive strength (Teece, 2007; Hacklin et al., 2018).

Contingency theory argues that a firm's performance is a function of the congruence between an organization structure, strategy and its environment (Miles & Snow, 1978; Venkatraman, 1989). The theory posits that there is no one best way of running firms, but environmental determinants (external circumstances) would push firms to produce specific organizational designs (Van de Ven, 2013). Therefore, a firm's performance would be determined by the degree to which it is able to match its resources and capabilities with the opportunities present in the external environment (Chorn, 1991). This matching constitutes the core of the strategic fit theory (Chorn, 1991). It warrants that the company either possesses or has access to the requisite resources and capabilities to capitalize on the opportunities available.

Guided by the tenets of these three theories, this study will review the growth and development of Flipkart, India's biggest e-commerce retailer.

RESEARCH METHODOLOGY

To understand the growth path of Flipkart, we employed a longitudinal case-study design. The research was carried out in two stages. The first stage was desk research. We went through the chronology of milestone events outlined, and all the top stories provided, on Flipkart's website (https://stories.flipkart.com/flipkart-timeline-milestones/), which contains extensive information about the company's growth history. These secondary data were helpful in identifying Flipkart's strategic initiatives since its inception, offering insights into the contemporaneous thinking of Flipkart at various junctures of its growth.

We then searched online for published documents and news articles relating to Flipkart to connect the company's milestone events to the larger context of India's socio-economic fabrics where its e-commerce market is firmly embedded. From these information, we attempted to make sense of the strategic actions taken by Flipkart and raised questions on the intentions behind those strategic initiatives.

The second stage was primary data collection. We conducted a series of semi-structured interviews with a member of the senior management team of Flipkart to seek clarifications to our questions. We triangulated the explanations provided with both the news articles and stories published on the Flipkart's website to identify the value drivers and to develop a process model to depict Flipkart's e-commerce growth path.

THE FLIPKART JOURNEY: AN OVERVIEW

Flipkart began as an online bookstore that promised to deliver anywhere in India. The sourcing of John Wood's book "*Leaving Microsoft to Change the World"*, Flipkart's first sale in late October 2007, underscores the company's customer-centric culture. Sachin Bansal and Binny Bansal, the two co-founders, searched some 50 bookstores in Bangalore for 2 days, including contacting some major book vendors in Delhi and Mumbai, for the book. While the book was eventually found, purchasing the book was another drama fit for a movie – Binny rode in the torrential rain across the waterlogged streets of Bangalore amid heavy traffic to Indiranagar, a medium-sized neighbourhood in east Bangalore, to buy the book only to realize that he had forgotten his wallet upon arrival. He had to return to borrow money before getting back to the bookstore to complete the purchase.

Exceedingly satisfied, Flipkart's first customer wrote the following testimonial that graced Flipkart's home page for months to come:

> *The best Indian online book store I have ever seen. Fast and free shipping, discounts and a large number of titles. I could not have expected more. You guys really rock. Good luck. (Excerpt from Venugopal, 2015)*

As the business grew, the co-founders no longer sourced books from bookstores personally. Nonetheless, the e-commerce retailer continued to run its operations from an apartment in Bangalore under a "Just-in-Time Procurement" model: no inventory - despatching pick-up boys to pick up books from vendors only when orders were received. The company used a manual order management process – orders, including quantity and supply source, were manually entered into Excel spreadsheets and printouts were handed to pickers-cum-packers to pick up and pack upon return.

While its procurement followed the lean principles, Flipkart's physical sourcing activities were not until it made its first hire of Ambur Iyyappa, in 2009. Iyyappa has a super memory. He could remember every step of the process to coordinate the pick-up and delivery staff to ensure all customer needs were fulfilled. Soon, his mobile phone number became Flipkart's *de facto* customer support hotline.

Iyyappa built efficiency into Flipkart's manual processes without a computerised system. He created an "on-the-go inventiveness" scheme to optimize the pick-up cum delivery staff's time by getting them to get updated printouts of work-orders through emails at cyber-cafes close to their locations after each pick-up or delivery. Iyyappa ran the entire process, including expedited deliveries, directly through his head, driving a manual, partly analog, order management system with machine precision.

> *"Iyyappa would know exactly which books were pending to be bought, which customers were waiting for delivery, etc. When a customer called, he would know exactly what was happening with his or her order without looking at the systems. He had also found an effective way of pasting all this order information into Gmail and*

using that as an ERP/Servicing search engine for orders!" (Statement by Binny Bansal, reported by Venugopal (2016))

When Iyyappa joined Flipkart, the ecommerce retailer was working with about 10-12 big publishers in Bangalore and shipping around 100 orders a day. That same year, Flipkart also expanded its operations by selling books from international publishers and commenced taking pre-order for books yet to be published. The business began to scale up, with orders reaching a thousand a day.

While Iyyappa's memory also scaled up in parallel, the co-founders realized that their business had grown to become deeply dependent on Iyyappa's tacit order management system. Drawing inspiration from Iyyappa's home-made "on-the-go inventiveness" schema, the two co-founders wrote Flipkart's first Product Requirements Document to mimic how Iyyappa had been coordinating with pick-up and delivery staff on a daily basis, accompanied by an order management and inventory management systems that also attempted to replicate Iyyappa's daily routine.

The automation of the order management process did not extend to solving customer problems in Flipkart. It remained in the hands of the even temperament and patient Iyyappa, who was given a free-hand to improvise solutions to solve the most pressing of problems for customers. He used his ingenuity, which, combined with his passion and positive attitudes, made handling escalated issues, seems so simple. Iyyappa's interest to make every customer happy unscored Flipkart's customer-centric focus since its founding.

In September 2009, Flipkart offices appeared in Delhi and Mumbai. Its success began to catch the attention of investors. Accel Partner invested USD1 million in Flipkart in 2009, followed by Tiger Global's investment of USD10 million in 2010.

To extend its reach to the population of India, especially those living in rural areas, the majority of which did not hold a bank account then, Flipkart pioneered the Cash-on-Delivery payment mode in 2010 to build trust and avail its online shopping services to all. In that same year, Flipkart also introduced a 30-day return policy for purchases made and acquired the social book recommendation portal weRead. The attractiveness of the e-commerce firm blossomed.

In 2010, Flipkart expanded its product range beyond books to include music, movies, games, electronics and mobile phones. The volume of incoming orders escalated. With nearly 2.5% of its revenue spent on payment to third-party logistics service partners, Flipkart decided to open a separate 3PL company to expedite their order delivery and meet skyrocketing customer demand. E-kart, Flipkart's Logistics arm, was launched. Commenced as a pilot, Flipkart logistics arm proved to be a viable business idea in three months. E-kart's performance outshined other courier services in India, where the preoccupation of logistics operations at the time was B2B, not B2C, services.

With E-kart handling about 80% of the company's e-commerce logistics, Flipkart acquired Chakpak and Mime360 to bring digital content to the Indian shoppers' fingertips and further expanded its shopping categories to include cameras, computers, laptops, large appliances, health and personal care products plus stationery.

As e-commerce in India began to flourish, consumers' apprehension of sharing debit or credit card details through online payment portals compounded by fear of buying fake products online grew. Consumers were hesitant to shop online. To boost sales and gain consumers' trust, Flipkart launched their card-on-delivery option in 2011 to allow customers to pay using their credit/debit card only after their order(s) was received. To bolster consumers' trust, Flipkart also launched a 30-day product replacement policy to array consumers' fear of receiving faulty products through online purchase. Faulty electronic gadgets, mobile phones in particular, could be returned for a replacement at no cost to consumers. This policy built trust in consumers toward brand products online, increasing Flipkart's sale by 40%. Flipkart's attractiveness grew further. Tiger Global invested another USD20 million into the company.

In line with the rising popularity of Mobile Apps, Flipkart launched its mobile shopping app in 2012. In that same year, Flipkart received PCI DSS Certification, which made online payment easier for its customers. To gain greater expertise of the electronic market, Flipkart acquired LetsBuy, an electronic online retailer, in 2012. The company also increased its category list and variety in fashion and lifestyle category: fashion, perfumes, watches, menswear, toys, posters and baby care. It also launched its electronics private label, DigiFlip, as well as Flyte MP3, dubbed the 'iTunes of India', for online music sales. The expansionary path of Flipkart drew an investment of USD150 million from Nasper, a broad-based multinational internet and media group considered as one of the largest technology investor in the world.

While its business and supply chain processes appeared to be on smooth running, Flipkart were losing sale from customers in immediate need of their purchased products. Further, young consumers, who comprised nearly 80% of online buyers, were demanding faster delivery and willing to bear the extra delivery charge, if it was not excessive. In response, Flipkart launched its "same day delivery" service in 2013. A nominal charge was levied but the service could also be provided free of charge, pending on the quantity and value of the purchased product and pincode used.

The unstoppable growth of Flipkart drew a private equity investment of USD200 million in 2013, giving it the financial means to expand. In 2014, Flipkart collaborated with Xiaomi, Motorola and Micromax to launch their new models exclusively on Flipkart website. The collaboration pushed Flipkart's sale to a new level and fortified the brand value of Xiaomi, Motorola and Micromax in the Indian market. Flipkart daily visits surged by 120%; Motorola mobile became the leading selling phone.

In the same year, Flipkart also acquired Myntra, an online fashion and lifestyle platform, to gain greater connectivity with local and international suppliers. The acquisition helped Flipkart attain a big supply base and extended its reach in the online fashion and lifestyle industry.

Apart from extending its product supply base, Flipkart also moved to consolidate its position as the e-commerce leader with the cheapest online sale in India. It initiated a Big Billion Day Sale in 2014, offering products with more than 90% discounts off the MRP (Max. retail price) in India across a range of products. The Big Billion Day Sale lifted the awareness of major brands among Indian buyers and roped in USD100 million in 10 hours of sale.

The momentum continued. In 2015, Flipkart promoted the use of its Mobile App by blocking the use of its website on mobile devices, creating easy access to its shopping portal while on the move. The move propelled Flipkart's sales further.

With its sales leaping to greater heights, Flipkart realized that it needed to strengthen its last-mile delivery logistics. The e-commerce retailer invested in MapMyIndia, a navigation device, to assist its last-mile delivery team to locate difficult-to-find addresses to meet timely deliveries. The company also partnered with Dabbawalla, a meal delivery team operating in Mumbai, and dPronto, a last-mile logistics start-up with a social mission, outsourcing a part of the last-mile deliveries in Mumbai and rural India to these two enterprises. The partnership not only expedited Flipkart's last-mile deliveries but also reduced the overall cost of the company's last-mile logistics.

To overcome problems of unavailability of customers during delivery, restricted entry of delivery persons into office complexes, gated communities and educational institutions, Flipkart also launched 20 'experience zones' across India to facilitate buying and self-pick-ups for consumers. Customers would be able to collect their shipments at their designated 'experience zone' at their convenience.

2015 also saw Flipkart introduced Flipkart Lite, a Mobile App that gives consumers the convenience of a native app but the experience equivalent to surfing on the web even when the device is offline. Not surprising, Flipkart became the first Indian App to reach 50 million users by 2016 with over 100 million registered customers. This is another milestone change in the journey of the e-commerce retailer as it moved on to acquire Jabong.com and PhonePe. The acquisition of Jabong.com, through its unit Myntra, further enlarged Flipkart’s range of offerings in the fashion and lifestyle market with a broad assortment of Indian and global brands. It also helped the e-commerce retailer to preserve its position as India’s No.1 e-commerce marketplace in the face of an onslaught by Amazon India.

The PhonePe acquisition, Flipkart’s third in the payments solution space, put the ecommerce retailer onto a Unified Payments Interface (UPI), an initiative of India’s National Payments Corporation with a potential of transforming the country’s entire payments ecosystem thus opening the possibility for mass adoption of online shopping in India.

By 2017, 10 years after its launch, Flipkart’s growth seemed unassailable. The e-commerce giant entered an exclusive exchange agreement with eBay “to jointly address the e-commerce market India” (eBay, 2017), as the following press release from eBay reveals:

> *In exchange for an equity stake in Flipkart, eBay has made a $500 million cash investment in and sold its eBay.in business to Flipkart. Effective immediately, Flipkart will own and operate eBay.in. Additionally, the companies are moving forward to jointly pursue cross-border trade opportunities to make eBay’s global inventory accessible to more India consumers, while eBay’s millions of active buyers globally will have access to more unique Indian inventory provided by Flipkart. (eBay, 2017)*

This fast-growing Indian start-up continues to capture the attention of big businesses. In 2018, Walmart bought 77% stake in Flipkart for USD16 billion, a move that the US retailer saw as its way to gain access to India’s fast-growing e-commerce market, which is expected to grow to USD200 billion within a decade. This was how the market perceives Flipkart, 10 years on.

DISCUSSION

From a nail-biting first sales to the relentless efforts the company expended to scope (and source) supplies and meet customer expectations, the story of Flipkart has highlighted the criticality of building supply chain capabilities to compete in the e-commerce space. Flipkart’s growth has been a result of a deliberated attempt to progressively expand its supply and customer base by building a multi-faceted supply chain. As Flipkart’s experience has demonstrated, this continuous extension was made possible by a selective adaptation to the changing conditions in the external environment - an adaptation that seeks to accomplish two key objectives. First, there was an obvious attempt on the part of Flipkart to continually align, and realign, the structure of its logistics processes to market opportunities. We refer to this realignment process as structural realignment. Second, there was an equally serious attempt to connect with the consumers at large, other than taking an out-of-the-way approach to meet customer expectations. We call this attempt expectation connectivity. Both these processes were tactically staged within the bounds of the company's resource capacity and accessibility to affordable technologies, a premise that matches the description of the theory of strategic fit.

The dynamic adaptation capability that drives these two processes is thus referred to as articulated adaptation. In other words, the adaptation was a calculated one. The company strategically selected small suppliers either with special know-how's (e.g., weRead in 2010 and LetBuy in 2012) or possessing innovative or high-demand lifestyle products (e.g., Motorola and Myntra in 2014) to give its website a distinctive niche as an e-commerce market of preference It also introduced innovative means (e.g., cash-on-delivery, digital wallet) that fit with the unique socio-economic and cultural setting of India to connect with prospective purchasers. All these initiatives were progressively and tactically launched in tune with its resource capacity, making the process a unique, path-dependent progression.

Articulated adaptation is, in our view, the growth engine of Flipkart. Because of its dynamic articulated adaptation capability, the company is able to pace its expansionary ambition to steadily increase its value through the staggering growth of its online traffic to attract
investors wanting a share of the burgeoning Indian e-commerce market. The recurrent external investments fuel further expansions. Figure 1 presents our interpretation of the way Flipkart had strategically orchestrated its circle of growth and development since its founding in 2007 to 2018.

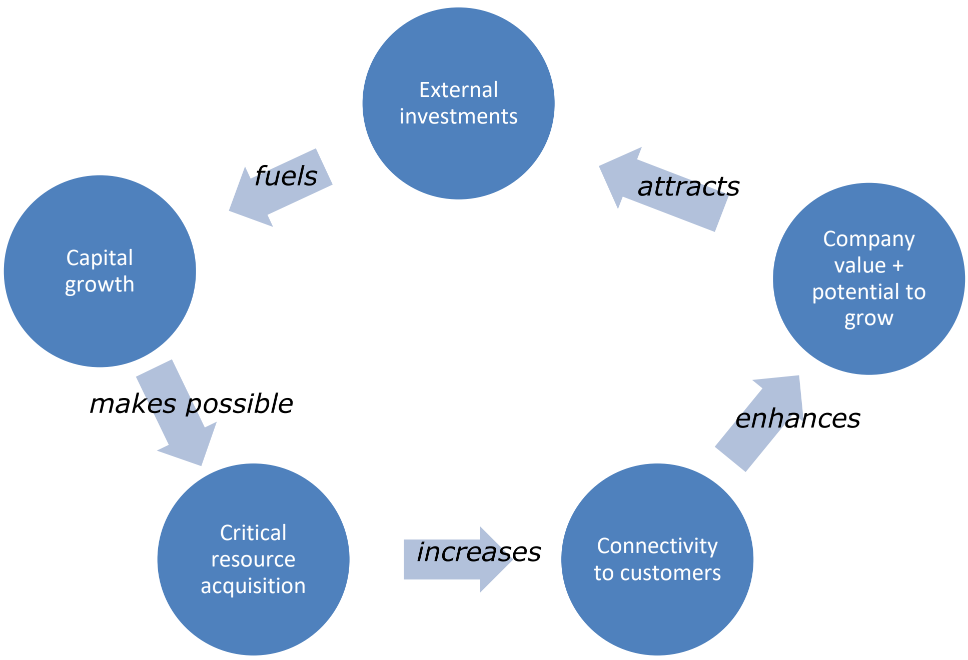

Figure 1: A Strategic Resource Building and Capital Generation Cycle

CONCLUSION, LIMITATIONS AND DIRECTIONS FOR FUTURE STUDIES

The success story of Flipkart, which grew from an initial investment of USD5,600 to become a multimillion-dollar online retailer within a period of 10 years, tells of how an e-commerce supply chain was established and grows. Flipkart's experience in recruiting targeted small suppliers with either special know-how or innovative, high-demand products to give its website a distinctive niche as an e-commerce market of preference and its introduction of innovative means to embed its operations within the unique socio-economic and cultural setting of India to connect with prospective purchasers validate

Mahadevan’s (2000) value-generating cycle of internet-based, e-commerce business model. The three dynamic logistics capabilities – articulated adaptation, structural realignment and expectation connectivity – shed empirical light on the operational details of the logistical stream critical to value generation in e-commerce businesses, which studies on business models (e.g., Mahadevan, 2000; Osterwalder et al., 2005; Zott et. al., 2011) have not illuminated.

Although collaboration and integration of supply chain entities have long been acknowledged as essential ingredients of firm performance and growth, little has been documented on how e-commerce companies collaborate with partners and competitors, integrating them to form competitive e-commerce supply chains. Examining the growth of Flipkart from the perspectives of dynamic capability theory, contingency theory and the concept of strategic fit, this study offers a theoretical explanation on how e-commerce supply chains evolve to form value configurations to propel them to achieve and sustain high performance.

Flipkart is a high-performing e-commerce company handling over 8 million shipments per month. Its meteoric growth trajectory within a span of 10 years holds many valuable lessons for budding e-commerce companies, both in and outside of India.

This research is based on the experience of a single firm, which is unique to the Indian socio-economic and cultural context. A multiple case study of the growth trajectory of other e-commerce firms in a range of socio-cultural settings is needed to validate and expand the theoretical constructs unearthed in this research.

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CAN FIRMS BE INNOVATIVE THROUGH ENGAGING WITH EXTERNAL PUBLIC SECTOR PARTNERS? A CASE STUDY OF AUSTRALIAN ADVANCED MANUFACTURING SMES

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Abstract

Purpose of this paper:

Several extensive reviews of innovation research by the Australian Government have emphasised the need to broaden our understanding of innovation. The relative cost of innovation is higher for SMEs than large firms, often due to their limited available resources. There is a paucity of research into the way advanced manufacturing SMEs effectively implement technological product and process innovation in collaboration with external partners. The aim of this research is to conceptually determine and empirically test a framework to effectively implement innovation within an Australian advanced manufacturing (AMSME) sector to improve competitiveness. This research enhances knowledge of the significance of resource transfers from public sector partners to the AMSMEs.

Design/methodology/approach:

This study employed case study as the research method. Five interviews were conducted amongst the advanced manufacturing SMEs who are the recepient of Australian Commonwealth grant to engage with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) for product-process innovation development and implementation. The dynamic capabilities view (DCV) was employed as a perspective for examining the combination and configurations of internal and external resources that enable a firm to build new capabilities which allow them to effectively implement innovation.

Findings: Results revealed that AMSMEs benefit from new-technology related capabilities including access to tacit and codified knowledge possessed by expert researchers and practitioners. Through CSIRO facilitated grants AMSMEs are connected to public sector experts with access to otherwise inaccessible testing and validation equipment. The new knowledge was found to contribute to process and product innovation benefits that can be expected to lead to market and financial benefits especially in the pre-production stages of concept and R&D.

Value: This study enhances understanding of the interrelationship between innovation and firm capabilities. The resource transfers provided by external partners clearly do enhance SMEs' abilities to effectively implement innovation and thus assist Australian manufacturing's vital shift of focus from heavy industry to high tech products based on sustainable and advanced processes.

Research limitations/implications: Future research, extending beyond external resources identified in this framework should allow comparative analysis between differing classes of external research providers (i.e. external market and commercial sources) and differing categories of SMEs (i.e. non-grant recipient).

Practical implications: Practical outcome benefits exist for policy and decision makers in (1) AMSMEs, (2) Government funding bodies, and (3) Grant facilitators (CSIRO SME Connect) and (4) Advisory Firms. The combinations and configurations of factors of innovation that the AMSME should commit to innovation have been explored and managers can make more informed decisions regarding resources they commit to the innovation process. AMSMEs can therefore, effectively implement innovation using the innovation framework.

Keywords: Australian manufacturing SMEs, Public sector partners, Product and process innovation, Technological innovation

INTRODUCTION

Innovation has been defined and discussed in various forms and perspectives with a clear consensus holding innovation as a priority for organisations to achieve competitiveness and high performance growth (Abidin et al., 2011). Firms must effectively implement innovation and continuously innovate to create new competitive advantages (Crossan and Apaydin, 2010). Developing innovation as a source of competitive advantage has become a strategic priority for small and medium sized enterprises (SMEs) (Brunswicker and Vanhaverbeke, 2015, McAdam et al., 2014, Dumay, 2014). Australian advanced manufacturing SMEs (AMSMEs) must carefully consider technological innovation in order to create social and economic value through sustained and incremental improvements to existing products (goods or services) in existing markets and to ensure a secure future with breakthroughs in major, disruptive products and production processes. It is through innovation that new-to-the-world, and subsequently new-to-the-firm, products and methods of production are discovered and applied. Exploring factors that facilitate the process by which SMEs can effectively implement innovation is therefore vital. The combination of internal and external resource factors of innovation and the relationship between them has a significant impact on innovation outcomes and ultimately the firm's competitiveness. Most SME managers face substantial resource constraints that heavily influences their decision making (Freel and Robson, 2016). SMEs can overcome new challenges by applying combinations of the internal and external resources available to the firm as capabilities that serve as innovation inputs (Roos and O'Connor, 2015). By successfully managing the inputs to innovation the AMSME can improve their innovation outputs and outcomes, survive and perhaps even flourish despite resource constraints (Sarasvathy and Venkataraman, 2011, Senyard et al., 2009). An example is where an AMSME uses a government grant to obtain direct interaction with the scientists or engineers with tacit knowledge or with access to equipment and routines required to unlock the potential of the new knowledge.

The aim of this research is to conceptually determine and empirically test a framework to effectively implement innovation within the AMSME sector to improve competitiveness. In order to achieve this, firstly an investigation into the internal and external factors of innovation was undertaken. Then, the research uncovered the extent that public sector partners, when added to the internal resources of the firm improve innovation outcomes. After this the investigation turned to the relationship between innovation (combination and configurations of factors) and competitiveness. The question to be explored is, "How can innovation be effectively implemented in Australian AMSMEs to improve competitiveness?"

We organise the paper as follows. Next section provides a review of literature and theoretical framework, enabling a lens to view both the firm and the phenomenon of innovation. The study will then reveal the research framework to investigate how firms can improve their competitiveness. The next section discusses the research methodology adapted in this study. The results of the analysis is provided and discussed with the outcomes proving timely and relevant, with much current, political and industry debate. The paper ends with a conclusion in the last section of the paper.

LITERATURE REVIEW

The nature of business competition in Australia has shifted over the past two decades, due largely to increasing complexity of the global business environment coupled with changes to customer preferences, government regulations, technology and competitors. This has reshaped the previously distinct manufacturing sector to the services sector (O'Connor et al., 2015, James et al., 2015). Pushed by prominent Australian academics aligned with industry the Australian Federal government announced advanced manufacturing (AM) as one of six sectors of strategic strength and competitive priority to Australia's secured future (Department of Industry, 2016). These advanced manufactures tend to be SMEs and also have the distinction of rarely being profiled or discussed in the media. The Federal Government estimates there are 2,500 globally-relevant and competitive AMSMEs that fall under the newly assigned AM sector classification from sub-sectors including: food and agribusiness, mining equipment and technology, engineering applications, precision instruments, cyber technologies, defence, aerospace and transport, medical devices, blood plasma therapies, and advanced materials and chemicals (Roberts, 2015). The pressing impetus to innovate for AMSMEs arises from technology and market changes, both locally and globally (Roos, 2015). It is through new knowledge, access to proven technology and effectively implemented innovation that AMSMEs can help build, grow and maintain a strong Australian manufacturing industry (Bennett, 2014).

It is now widely accepted in the literature that innovation is the combination of an inventive process and an implementation process (application, commercialisation, exploitation) to transform new knowledge into new economic or social value for defined stakeholders (Hindle, 2009, Hindle and Yencken, 2004). This can be displayed in a simple equation: *Innovation = Invention + Implementation.* Our study makes no pretence to further understanding of the inventive process. Instead, focus will be centred on the transformative, innovation implementation process. For the purposes of our study, innovation is therefore defined as a dual process encompassing: *"The creation of new products, processes, knowledge or services by using new or existing scientific or technological knowledge, which provide a degree of novelty either to the developer, the industrial sector, the nation or the world and succeed in the marketplace"* (Galanakis, 2006 p.1223). Our research has narrowed the focus of what is new, to include technological *type* innovations, in the *form* of either products (goods and services) and/or process (inclusive of new materials being used in the production process) (Camisón and Villar-López, 2014). "*Technological product and process innovation (TPP) has been implemented if it has been introduced on the market (product innovation) or used within a production process (process innovation)"* (Mortensen and Bloch, 2005 p.25). TPP account for nearly 50% of total innovation activities in the Australian manufacturing industry (Jayaram et al., 2013).

There is a shortage of research into the way firms effectively implement technological process innovation through combinations and configurations of resources, leading to new or substantially improved products. The actual impact of process innovation as a factor of innovation needs to be measured with regard to the aspects of speed, quality, flexibility and cost efficienc*y*. In the short run, investments in process innovations will likely require significant internal resources and result in financial losses (Gunday et al., 2011). This study will therefore focus on the lesser known impact of process innovation as a production-oriented activity and how improved efficiencies lead to new or improved products. Process innovations have an indirect effect on business performance through new or significantly improved products and/or services (Hervas-Oliver et al., 2014, Piening and Salge, 2015). This will enable the study of the interrelationship between product and process innovation to be advanced (Camisón and Villar-López, 2014). Gunday et al. (2011) also evaluated the in-firm innovation production process benefits and the resultant innovation performance and competitiveness of firms' measures through production, market and financial outcomes.

THEORETICAL BACKGROUND AND RESEARCH FRAMEWORK

In order to answer the research questions our study adopts the Dynamic Capabilities View (DCV) as a perspective for examining the combination and configurations of internal and external resources as innovation factors that enable a firm to build new capabilities which allow them to effectively implement innovation (Teece, 2012). The widely accepted view of Danneels (2016) is that first-order operational capabilities are defined as lower order current technology-related (functional, technological, technical and production) or current-market related (current-customers and markets) capabilities (Camisón and Villar-López, 2014). Operational capabilities use knowledge that has a clear, immediate use in current technologies and markets. This infers that they are specific to a particular technology or existing customer base. Simply, the firm is able to make a living by serving its current customers, in existing markets using their current technological processes and products. New-technology and new-market related capabilities are considered second-order capabilities and consistent with DCV as they enable a firm to build new operational capabilities, which allow them to use new technology and serve new markets. If a firm's current-technology and current-market related capabilities are insufficient to exploit the new knowledge then new-technology and new-market related capabilities must be exhibited. The quality of the first-order capabilities (e.g., knowledge about its customers and competitors and technological expertise) is then changed by the second-order, dynamic capabilities. After implementation (process innovation) or successful commercialisation of the innovation (product innovation) the firm must continue to evaluate new knowledge in order to innovate and thus the cycle of first and second-order capability assessment and enhancement repeats during the process of innovation evaluation. Significant to our research the process innovations have also been considered as second-order, dynamic capabilities in the literature (Piening and Salge, 2015).

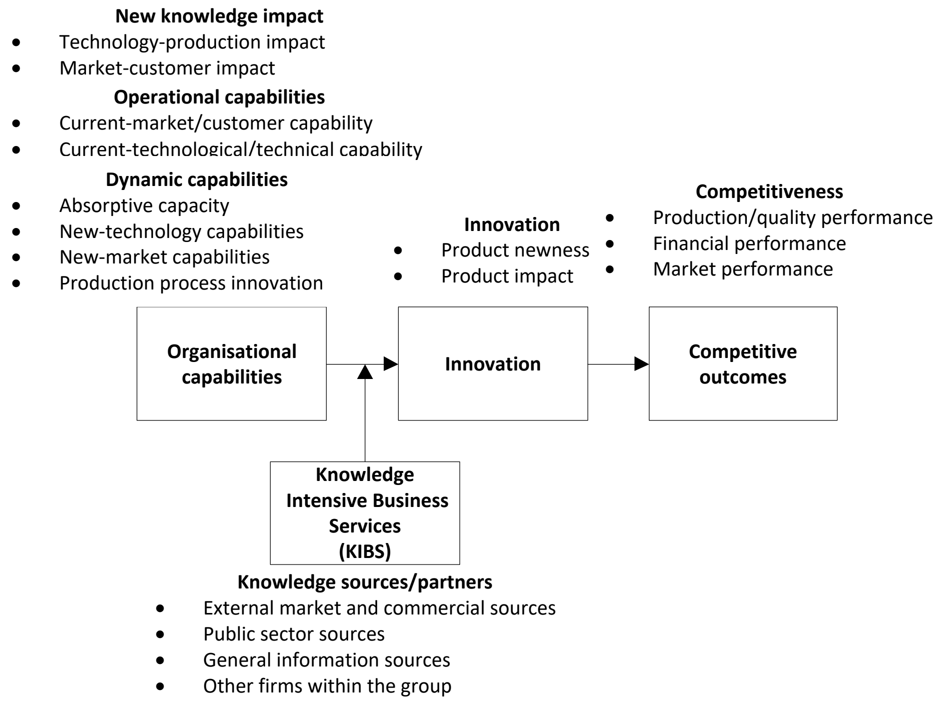

Figure 1: Conceptual framework of Innovation-competitiveness

The Open Innovation (OI) paradigm is viewed as an organisational innovation strategy to increase the competitive advantage of a firm (Natalicchio et al., 2017). It is through the critical dynamic capabilities, and in particular the absorptive capacity of SMEs, that linkages are made with external sources of new knowledge and resources. Although SMEs are often more flexible and focussed on specific products/services, few have shown the capacity to manage the innovation process by themselves particularly in knowledge-based and high-tech industrial markets (Grimaldi et al., 2013). Chestbrough (2002) considers the importance of accessing and exploiting external knowledge as an essential strategy to support OI. SMEs however, have been largely neglected in the OI literature (Brunswicker and Vanhaverbeke, 2015). The identification of different collaboration partners, and reasons for these collaborations, will enable better understanding of the external factors of innovation and thus will be important to this research project (Beckett & Chapman 2014; Bocken et al. 2014; Brunswicker & Vanhaverbeke 2015; Chatha, Butt & Tariq 2015). External stakeholders and sources for transfers of knowledge/technology and resources have been clustered by the Oslo Manual (2005) under external market and commercial sources, public sector sources and general information sources. Knowledge-intensive business service (KIBS) providers, such as public sector partners like CSIRO play a fundamental role in innovation and competitiveness in knowledge based economies and are now attracting a great deal of attention (Ciriaci et al., 2015).

RESEARCH DESIGN AND METHODOLOGY

Our study employed an interpretive, abductive approach to explore the innovation implementation processes through DCV. Because of the emergent nature of this topic, we opted for an exploratory multiple case study method. A qualitative case study methodology was appropriate because it supports study of complex phenomena within a specific context (Eisenhardt, 1989), in this case innovative AMSMEs. We examined the most recent information available about the company's strategy and the environment in which they operate. In addition, the first author conducted semi-structured interviews with key owners/managers to gain insight into the innovation implementation process within the company. The first author modified the tentative framework iteratively by comparing the case studies with theoretical foundations, the participant firms and grant facilitators. The second, third and fourth authors maintained an outside perspective during the iterative data collection.

Qualitative synthesists recommend that an in-depth synthesis of purposefully selected studies is more valuable than a superficial synthesis of a large number of studies. The logic and power of purposeful sampling lies in selecting cases that are information-rich and therefore can be studied in-depth (Suri, 2011). Key informants are required in order to identify and gain access to information-rich cases. In order to do this an initial meeting was held with the two Victorian based CSIRO grant facilitators as well as the director and manager of the programme. The purpose was to understand the grant selection process and to ascertain the importance of each sub-sector. In choosing the case studies that were used in the study, all defined AM sub-sectors were considered and the expert recommendation was made to focus on: (a) Food and Agribusiness (Food), (b) Medtech and Pharmaceutical (Medtech) and (c) Advanced materials (Materials). CSIRO's grant programme manager contacted the facilitators who covered each sub-sector, across both Melbourne and Sydney. The facilitators then provided a list of potential participant firms. The owner or senior manager was identified as the contact point due to their intimate knowledge of both the grant process and the company's innovation process. From an initial list of twenty participants, nine firms were contacted and five agreed to participate in our study. Table 1 reveals the firm and participant details from exploratory study.

A case study protocol was developed to guide the data collection process (Yin, 1989). In each SME, the principal researcher obtained informed consent and then interviewed one key executive who had been directly involved in innovation implementation. The enterprise as a single legal unit was selected and our study focussed on the particular innovation that the firm had received the grant for. The interviews lasted about one hour and were structured around the internal and external factors of innovation implementation and the changes and outcomes the innovation produced. All interviews were digitally audio recorded and later transcribed, verbatim by the principal researcher. In order to ensure validity the transcripts were then content analysed, using both Excel (manually) and then NVivo (computer-aided comparative). Data triangulation was also utilised. The transcripts were read and where required, amended by the participants. Case study interview transcripts were written and then member checked by CSIRO's facilitators, in consultation with participants. Thematic analysis (Braun and Clarke, 2006) was considered a suitable method for analysing our interview data for a number of reasons. From a practical viewpoint, it assisted in organising the data and allowed for case study description of the data set in rich detail. The themes within the dataset were identified and further analysis unearthed relevant sub-themes and items (Clarke, 2016). As the various capabilities emerged inductively from the field work, we again compared with the previous research, conceptually substantiating the capabilities and their interrelation with innovation implementation.

Table 1: Exploratory sample study details

(C)	Company (C#) description	Respondents' position, experience
C1	• Heavy duty radiators/4 market segments (Materials) • Company age 43 • Employees (FTE) 25	• Product Development Manager • 5.5 years in current role • Intimate product and strategic, market knowledge
C2	• Organic and recyclable building panels (Materials) • Company age 14 • Employees (FTE) 4	• Founder/owner • 14 years as founder/owner • Many years spent in steel industry
C3	• Global yeast ingredients business (Food) • Company age 14 • Employees (FTE) 6	• Global wine market director • 5+ years in current role • Advanced production and global market knowledge
C4	• Specialist chemical/polymer manufacturer (Materials) • Company age 8 • Employees (FTE) 11	• Operations Manager • 8 years in current role • Advanced chemical/production knowledge
C5	• Pharmaceutical research company (Medtech) • Company age 20 • Employees (FTE) 25	• Head of Drug Discovery • 9 years in current role • Advanced chemical and European market knowledge

RESULTS ANALYSIS AND DISCUSSION

The five case studies applied technological process innovation that lead to new or substantially improved products. All five cases manufactured a part or ingredient that fitted into a value chain and the inherent new knowledge in their innovation differed substantially across sub-sectors. The source of the new knowledge in four cases was externally discovered/ sourced, providing evidence of the importance to SMEs of OI in accessing and exploiting external knowledge (Chesbrough, 2015).

The overall pattern that emerges from these cases in relation to innovation is that all firms were generally challenging the industry status-quo. They engaged in a constant quest to find new ways to generate value for customers and gain a market advantage. They also worked closely with lead customers and key suppliers to create these innovations. In doing so they were seeking to secure and retain new business using approaches that other competitors had failed to recognise. The innovation trigger in three cases was scientific discovery, whilst in two cases regulatory changes provided the innovation impetus. The qualitative findings were consistent with our preliminary understanding of the innovation implementation process. In addition, the insights provided snapshots of the dynamic and operational capabilities (Zahra et al., 2006). These findings enabled us to link between kinds of innovations and impact on firm capabilities. In Table 2 we can see the impact of each innovation on both the technology-production and market-customer capabilities as either enhancing (conserve/entrench) or destroying (disrupt/render obsolete). This is reflective of whether the technology-market already exists and is being exploited by the firm or whether the technology-market is new to the firm.

Table 2: New knowledge impact on capabilities of AMSMES

Critical themes/ items		C1	C2	C3	C4	C5	Representative quotation
Production impact (enhancing (E), Destroying (D)	Production systems/ organization	E	D	E	E	E	C1. "We discovered that our own core baked process changes that solder alloy such that it actually puts a leaded layer, a led concentrated layer in there".
	Skills (labour, managerial, technical)	E	D	E	E	E	C1. "What we did with CSIRO was, we had evaluated a number of lead free, off the shelf lead free solders. We'd run a number of tests and we had set up a validation test here".
	Capital equipment	E	D	E	D	E	C2. "We are looking for another facility and looking for plant and equipment".
	Knowledge and experience base	E	D	E	E	E	C3. "It helped us to understand that we actually have to manufacture the yeast strain in a certain fashion".
Market~ customer impact (enhancing (E), Destroying (D)	Relationship with customer base	E	D	E	E	E	C2. "So with the nature of your customer base - this is almost an entirely new market".
	Channels of distribution and service	E	D	E	E	E	C1. "We do a lot of export directly to Caterpillar globally... Caterpillar production now runs out of our Thailand plant, we export out of there as well".
	Customer knowledge	E	D	E	E	E	C2. "Bad fires they had their in Melbourne in 2011 I think it was (customers required)... alternative building methods".

Based on (Danneels, 2016, Garcia and Calantone, 2002, Abernathy and Clarke, 1993) we have developed Figure 2. Figure 2 plots each of the 5 cases in either one of four quadrants, primarily based on the outcomes of Table 2. Due to the small sample size and qualitative nature of the research the exact X and Y axis coordinates are not considered. There are however, recommendations for the management of each kind of innovation but they are not included in this paper for brevity sake.

In support of the link between types of innovations and impact on capabilities, the incremental innovation implemented by Cases 1, 3 & 5 served to further conserve, entrench and build on both their current-market and their current-technology related capabilities (Table 3). The technology-production impact, was evident in Case 1: With an operating point at 230 degrees and a lead melting point at 189 degrees testing revealed structural changes to the alloy that meant the firm were able to meet the requirements with their current technology related capabilities. For Case 3 *"it helped us to understand that we actually have to manufacture the yeast strain in a certain fashion".* They were able to then draw on: *"Our key expertise… to do high quality dry yeast manufacturing".*

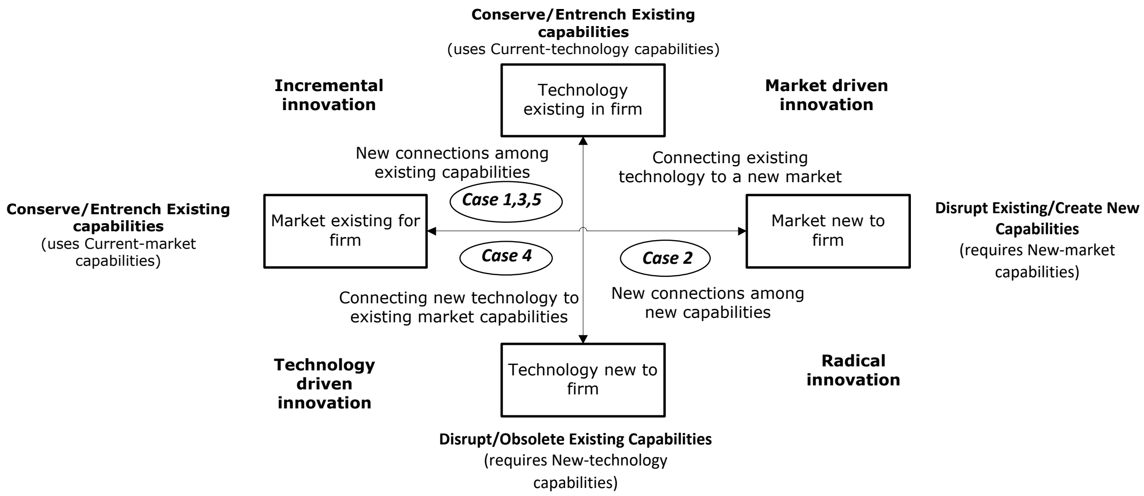

Figure 2: Link between kinds of innovations and impact on capabilities

Table 3: Operational capabilities of AMSMEs

Critical themes/ items		**C 1**	**C 2**	**C 3**	**C 4**	**C 5**	**Representative quotation**
Current-market capabilities	Knowledge about its customers and competitors.	✓	✓	✓	✓	✓	C1: "Because of this new innovation the competitors we have learned have all of a sudden gone".
	Distribution channels or sales force.	✓		✓	✓	✓	C3: 1. "… still sell it to distributors who then on-sell it for us globally and all around the world".
Current-technology capabilities	Production operations or facilities.	✓	✓	✓	✓	✓	C1: "The products are manufactured both in Thailand and in our plant (Melbourne)".
	Technological expertise.	✓		✓	✓	✓	C3: "But on top of that you've also got all of the technology and IP that is part of dry yeast manufacturing.
	Engineering skills and resources.	✓		✓	✓	✓	C1: "Now the metallurgy of that - we kind of know is possible from bonding two bits of copper together but we don't really have any clue about how to get it to happen".

In contrast Case 2 implemented a production process that was entirely new to the firm (Figure 2), the impact of which destroyed/replaced the current-technology related capabilities. This is also reflected (Table 4) in new-technology related capabilities (setting up new types of manufacturing facilities and operations): *"We are looking for another facility and looking for plant and equipment at the moment too".* The incremental innovations conserved/entrenched current capabilities and drew heavily on the current-market capabilities of Case 1, 3 & 5. The radical innovation type of Case 2 however resulted in a change in the *"… nature of (the) our customer base - this is almost an entirely new market".* Significantly and in support of the disruptive potential of the innovation, *"… the competitors have all of a sudden gone"*. The technology driven innovation implemented by Case 4 aligned with the extent of new-technology related capabilities and current-market related capabilities.

Table 4: Dynamic capabilities of AMSMEs

Critical themes/items		C1	C2	C3	C4	C5	Representative quotation
New-market related capabilities	Assessing the potential of new markets.		✓	✓		✓	C3: "It includes our distribution and our global pricing, which, markets we are going to go into, which geographies we are going to act in, and which ones we are not going to be a part of".
	Setting up new distribution channels.		✓		✓		C2: "Being an entirely new market has meant new distribution".
	Researching new competitors and new customers.		✓	✓	✓	✓	C2: "We need to make sure we produce a product that is fit for purpose for all markets".
New-technology related capabilities	Assessing the feasibility of new technologies.	✓		✓	✓	✓	C1: "What we did with CSIRO was, we had evaluated a number of lead free, off the shelf lead free solders. We'd run a number of tests and we had set up a validation test here".
	Recruiting engineers in technical areas it is not familiar with.	✓			✓		C1: "Actually we don't have the metallurgy capabilities to understand this problem and do something about it".
	Identifying promising new technologies.	✓	✓	✓	✓	✓	C3: "So that gave us valuable insight into what the pros and cons were. And that we should be getting hold of this technology as fast as possible".
	Implementing new types of production processes.			✓	✓	✓	C3: "It helped us to understand that we actually have to manufacture the yeast strain in a certain fashion To enable it to maximize the actual property that we are talking about".

Table 4 shows that regardless of the kind of innovation implemented all firms demonstrated dynamic capabilities. This is consistent with an OI strategy where firms must search for new knowledge outside of their own internal confinement (Natalicchio et al., 2017). Case 2 however had previously been operating in the steel industry and was now working with *"a recycled product and also an organic product"* that was *"almost an entirely new market". "We are building the first of these units right now, literally we started yesterday"* (Case 1). Our *"… next step is to get validation and once we are through validation we will go through the commercialisation process (with CSIRO)"* (Case 2). *"…We had a vested interest and they obviously had a vested interest to get it out there commercially into the wineries' industry"* (Case 3). In support of Chestbrough's (2002) open innovation paradigm all cases considered the importance of accessing and exploiting external knowledge as an essential strategy to support innovation implementation.

KNOWLEDGE INTENSIVE BUSINESS SERVICES (KIBS)

The external resources that all SMEs lacked were technology & process technologies and the human capital required to apply critical scientific skills. The point in which the CSIRO (KIBS) intervened ranged from support for self-diagnosis to implementation of solutions. In particular it was through CSIRO facilitated grants that AMSMEs connected to experts with access to otherwise inaccessible testing and validation equipment and experts (Table 5). This was a significant factor in the SMEs building enhanced capabilities.

Table 5: Knowledge intensive business services

Critical themes/ items		C1	C2	C3	C4	C5	Representative quotation
Public sector sources	Universities	✓	✓				C2: With the University of Wollongong. We had a collaboration grant where they obviously had the equipment and structural knowledge on building materials. And they've built a proto-type for us.
	CSIRO	✓	✓	✓	✓	✓	C1: These guys [CSIRO metallurgists]… They were just really top notch metallurgists
Other firms within the group		✓		✓	✓		C1: We also know through service branches of the business, both through the group and also through our own doings and general knowledge of the market place, you know, who really has the biggest market share.

Table 6 shows the new knowledge was found to contribute to production process innovation benefits including: increasing output quality in manufacturing processes, techniques, machinery and software (*“improved our quality metrics”* Case 1; *"... met the standard or went above and beyond the standard"* Case 2; and *"... maximize the actual property”* Case 3). Interestingly Case 2 was also able to decrease variable cost components in manufacturing processes, techniques, machinery and software. *"We are not importing product anymore because we don't need it. We are doing it differently which ultimately does the construction cheaper".*

Table 6: Production process innovation benefits

Critical themes/items		C1	C2	C3	C4	C5	Representative quotation
Process innovation (dynamic capability)	Decreasing variable cost and/ or increasing delivery speed in delivery related logistics processes		✓				C2: "The other thing that we are doing different too is we are not auto planning… saves heat to cure it”…
	Increasing output quality in manufacturing processes, techniques, machinery & software	✓	✓	✓	✓	✓	C1: "Yeah I mean we've probably improved our quality metrics".
	Decreasing variable cost components in manufacturing processes, techniques, machinery and software		✓				C2: "We are not importing product anymore because we don't need it. We are doing it differently which ultimately does the construction cheaper".

Table 7 shows the production performance of the firms was therefore improved through production conformance quality (Cases 1-5) and production cost (Case 2). This can be expected to lead to market and financial benefits (Table 7) especially in the pre-production stages of concept and R&D. This is consistent with the findings of Gunday et al., (2011).

Table 7: Competitive outcomes

Critical themes/items		C1	C2	C3	C4	C5	Representative quotation
Production performance	Production (volume) flexibility	✓	✓				C1: …highest volume for customers like Kenworth and Caterpillar… Low volume for the current industry, high volume for us.
	Production cost		✓				C2: "We are not auto planing it so we don't need to put the heat onto it to get it to cure".
	Conformance quality	✓	✓	✓		✓	C3: So there measure will be if the property shows itself through in a significant quantity
Financial and Market performance	Total sales	✓					C1: …turning over in terms of sales per year or pretty close to it. 75% of the annual [turnover].
	Market share	✓		✓			C3: So it just has that level of buy as I said very much the market pull and it will give us an increasing customer base for sure.
	Customer satisfaction	✓		✓			C1: …what we have done is protected our sales and are able to grow with our key customers
	Export revenue*	✓					C1: We do a lot more export directly out of here to Caterpillar globally

CONCLUSION, IMPLICATIONS AND LIMITATIONS

This study provides new insight into the way AMSMEs implement innovation and the impact that new knowledge has on capabilities. This research proposes an innovation reference model / framework on Australian advanced manufacturing, SMEs and industries of strategic importance. Research output identifies the significant internal and external factors of innovation, for which there is currently no principal framework in Australia. This enhances our understanding of the innovation implementation process and the interplay between internal and external factors of innovation. Theoretically and practically the study enriches understanding of the interrelationship between process and product innovation as called for by Camisón and Villar-López (2014). The resource transfers provided by external partners clearly do improve SMEs’ abilities to effectively implement innovation and thus assist Australian manufacturing’s vital shift of focus from heavy industry to high tech products based on sustainable and advanced processes. The findings of this study can be generalised to other knowledge based economies.

Practical outcome benefits exist for policy and decision makers in (1) AMSMEs, (2) government funding bodies, and (3) grant facilitators (CSIRO SME Connect) and (4) advisory firms. The combinations and configurations of factors of innovation that the AMSME should commit to innovation have been explored and managers can make more informed decisions regarding resources they commit to the innovation process. AMSMEs can therefore; effectively implement innovation using the innovation framework and KIBS can mentor them with an empirically tested framework. KIBS, such as facilitators of public sector research-industry collaboration programs and AMSMEs increase their understanding of how to improve process and product innovation output through identification and collaboration with external public sector partners as sources of new knowledge. Understanding the impact of innovation on a firm's capabilities will allow AMSMEs and practitioners to make an assessment regarding the attractiveness of the new knowledge at the firm level. This will allow firms and practitioners to concentrate on the activities that are likely to lead to radical, disruptive innovation as well as to successfully implement the innovation that they have discovered. For KIBS, such as CSIRO who act as gatekeepers of new knowledge, this framework can help them to determine AMSMEs who are in the best position to implement and exploit inventions that they have access to.

Further research should focus on a much larger sample size of AMSMEs and include both grant and non-grant recipient SMEs who have accessed more external knowledge/partners and have actually undertaken commercialisation. The findings of this study can then reveal an innovation evaluation framework that can also be tested quantitatively. Further study is needed to link the importance of absorptive capacity (Ferreras-Méndez et al., 2015) to each kind of innovation. Further research also needs to consider a wider range of KIBS and the particular point of intervention, the knowledge/resource gaps that they fill and the benefits to the firm. Whether the knowledge flows are inbound (outside-in), outbound (inside-out) or coupled and the specific variation exhibited also requires more investigation (Pisano, 2017).

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A CONCEPTUAL FRAMEWORK OF ENVIRONMENTAL SUSTAINABILITY IN THE OIL AND GAS SUPPLY CHAINS: NATURAL RESOURCE BASED VIEW (NRBV) AND INSTITUTIONAL THEORY APPROACHES.

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Abstract

Purpose: The aim of this paper is to conceptualise a structural model of environmental sustainability for the O&G SC. Following the recommendation of Carters and Rodgers (2008) that a conceptual framework should be underpinned by strong theoretical foundation, we combined the relevant elements of the Institutional theory (Dimmagio and Powell 1983) with the Natural Resource Based View (NRBV) of Hart (1995) to depict the roles of regulatory pressures in driving supply chain innovations and environmental capabilities towards competitiveness of O&G firms. This research proposes structural model and relevant hypothesis to delineate the causal relationships among constructs.

Design/methodology/approach: This research adopts a theory building approach (Meredith 1983) to develop a conceptual framework of environmental sustainability for the O&G SC. The proposed model is based on a structured literature review which synthesised the extant into four clusters (coercive pressures, resources, strategic environmental capabilities and competitive advantage) that are considered relevant to the objectives of the study within the two theoretical lenses (Institutional theory and NRBV). These clusters were developed into various constructs that made up our model, based on hypothesis developed from the extant literature. Finally, the managerial implications, value and limitations of the study were highlighted.

Findings: In line with Liang et al. (2007), we found that regulatory pressure is a critical factor in the O&G firm's adoption of environmental practices, hence we depict this as the antecedent of resources and environmental capabilities in our proposed model. We also found that environmental capabilities can enhance the competitiveness of O&G firms. Based on the above, an overarching model of environmental sustainability of the O&G supply chain was developed.

Value: In the first instance, this paper has contributed to theory building process in the field of GSCM/SSCM by developing a new theoretical model for the O&G SC. Unlike previous models on environmental sustainability in the O&G industry, our study utilised relevant components of existing theories propose a new model of environmental sustainability in the O&G SC. Besides, our model depiction of clean technology as one of the strategic environmental capabilities needed by O&G firms is very novel in the O&G industry considering the global drive towards clean energy and renewables.

Research limitations/implications Although the model is purely conceptual at this stage, its development have also contributed to theory-based research in the field of supply chain management.

Practical Contribution On empirical verification, this work can furnish the supply chain managers with validated measurement scales to evaluate the strengths and weakness in

their supply chain innovation and the impacts on environmental capabilities and competitive advantage. It can also assist policy makers in the O&G industry to evaluate the impacts of sustainability policies on firms' acquisition of strategic resources and capabilities.

1. INTRODUCTION

The O&G industry is reputed as a highly 'pollutive' industry with destructive impacts on the natural environment. Indeed, various incidents and accidents that occurred across its supply chains have caused devastating effects on the environment. Such example is seen in the Piper Alpha oil spills which resulted into 167 deaths and huge financial costs. Consequently, the O&G industry is a critical industry subject to stringent national and international environmental regulations (Ahmad et al. 2017). However, whether these regulations enhance innovations to develop environmental capabilities that are needed for the competitive advantage of O&G firms still remains unclear. Whereas concerted efforts are being channelled into energy transitioning from fossils to renewables, it is believed that O&G will still play a crucial role in the global energy mix in the next decades (Ahmad et al. 2017).

Therefore, *"…in view of human dependence on non-renewable energy, which leads to the oil industry's continued existence, any effort to reduce the negative impacts of such a destructive industry, however minimal, should not be undermined"* (George et al. 2016:197). Based on the above, this study aims to propose a green oil and gas supply chain management (GOGSCM) framework, based on the relevant elements of the institutional theory (coercive government regulatory pressures) and NRBV (specific resources, strategic environmental capabilities and competitive advantage) to depict how O&G firms can enhance their competitiveness through their adoption of environmental management practices. The remaining part of the paper is structured into various sections which include theoretical basis, methodology, model development, hypothesis development and conclusion.

2. THE THEORECTICAL FONDATION

2.1. Overview of the O&G supply chain

Typically, an O&G industry supply chain is made up of three segments namely, the upstream, the midstream and the downstream sectors. While the upstream is concerned with exploration and production of crude oil and natural gas, the downstream covers the refining, distribution, transportation and marketing of the final O&G products to retail outlets and final consumers. The midstream, which is the link between the upstream and downstream activities has no production activities, rather it is comprised of the logistics activities and facilities that move the crude and natural gas produced at the upstream to the refineries.

Due to the nature of the O&G industry, the entire supply chain is prone to high risk of environmental degradation. Surprisingly, little attention has been paid to sustainability issues in the O&G supply chain despite its importance to the global energy consumption. For example, while sustainability issues have dominated the fields of operations management and SCM since the late 90s and early 2000, the first sustainability research specific to O&G SC was conducted in 2007 (Lakhal et al. 2007). As at 2017, Ahmad et al. (2017) found that only ten articles were specific to sustainable/green supply chain management in the O&G industry. Our literature search covering the period between 2001 and 2018 also found twenty-two articles that are relevant to sustainability of O&G SC. Although some of these studies have proposed frameworks of environmental sustainability in the O&G SC, their frameworks are not often based on established theories such as the NRBV and Institutional theory. This has therefore constituted an area of interest to this study.

2.2. The Institutional Theory: Regulatory Pressures Perspective

Institutional theory is based on the notion that structural and behavioural changes in organisations are more driven by the need to acquire institutional legitimacy than competition and desire for efficiency (Liang et al. 2007). Therefore, it is a theory that delineates how specific external pressures drive organisations' strategic choices. Specifically, DiMaggio and Powell (1983) portend that three institutional isomorphism namely the mimetic, normative and coercive pressures influence firms' strategic choices. Mimetic pressures arise from uncertainties which result into firms' adoption of behaviours of other institutions like successful competitors to earn legitimacy. On the other hand, normative pressures occur as a result of the needs for firms to internalise societal norms, usually defined by institutions such as professional bodies. Finally, coercive pressures emanates from powerful organisations in a firm's environment, with a capacity to either sanction or reward actions taken by firms (DiMaggio and Powell 1983; Esfahbodi et al. 2017). Among others, such pressures can emanate from government institutions through environmental regulations.

Government regulatory pressure is a special form of coercive pressures because it is based on government institutions' power to force certain requirements on firms (Braganza and Franken 2007). Therefore, non-compliance with the imposed requirements can lead to serious sanction against firms. For example, TJX, a retail multinational was convicted to pay several million US dollars, for failing to comply with the US data security law. For this reason, coercive regulatory pressure is adjudged to have greater impacts on firms' strategic choices than other forms of institutional isomorphism. Indeed, the literature on institutional theory In SCM suggests that government regulations play a crucial role in organisation's adoption of environmental management practices. Also, in the O&G industry, Ford et al. (2014) found that regulatory pressures have impacts on environmental practices. In view of the foregoing, government regulatory pressure is considered by us as a critical driver of environmental sustainability in the O&G industry.

2.3. The Natural Resource-Based View (NRBV) of the Firm

Hart (1995) theorized the NRBV as a way of integrating the natural environment into the Resource-Based View theory (RBV). Basically, the traditional RBV portends that the competitive advantage of firms is dependent on their ability to acquire firm-level resources and capabilities that are difficult to replicate by the competitors. However, Hart (1995) contends that the future competitive advantage of firms will transcend beyond mere acquisition of internal resources and capabilities but dependent on their ability to utilise resources to develop strategic environmental capabilities. Specifically, NRBV posits that organisations' sustained competitive advantage is dependent on their ability to utilise their tacit, causally ambiguous and socially complex resources to develop three types of proactive environmental strategies namely pollution prevention, product stewardship and sustainable development.

A review of NRBV adoption in research after fifteen years revealed that the strategic capabilities of sustainable development has re-emerged into two categories namely clean technology and Base of the pyramid capabilities (Hart and Dowell 2011). In the field of SCM, NRBV is a popular theoretical lens adopted to facilitate the incorporation of the green and sustainable concepts. Also, NRBV has been confirmed as a relevant theory in the context of sustainability of the O&G industry (Hastings 1999). Therefore, we also considered the theory as a relevant foundation for our model development.

3. METHODOLOGY

This research adopts a theory building approach (Meredith 1993) to develop a model of environmental sustainability for O&G SC. Following the procedures in Carter and Rogers (2008), we commenced our research through a rigorous review of literature on O&G SC, NRBV and institutional theory. We focused mainly on synthesising findings and identifying themes in relation to the state of current research on NRBV and Institutional theory in the context of O&G SC. Basically, the literature review was conducted using structured keywords (such as sustainability, supply chain, green, oil and gas, petroleum, NRBV, Institutional theory) on four electronic databases namely EBSCO, Emerald, ScienceDirect and google scholar. The articles found were examined for relevance using two criteria namely: (a) selection of only articles that study O&G SSCM and O&G GSCM (2) selection of articles that study NRBV, institutional theory in the context of SCM.

The relevant articles were synthesised into four relevant clusters from the two underlining theories (NRBV and institutional theory) as depicted in Figure 1. Based on these clusters, relevant constructs were developed in line with the objective of this study. From the extant literature, causal relationships were established among constructs through hypotheses. Finally, a structural model was developed and its managerial implications were discussed.

4. THEORECTICAL MODEL DEVELOPMENT

Based on the synthesis of the literature, our model is based on four research clusters presented in Figure 1.

Figure 9. Research cluster for model development.

Our adoption of government pressures as the only element of institutional theory in the first cluster is based on the position of the literature that government regulations have critical impacts on firms' adoption of sustainability practices. Besides, both national and international regulations are very crucial in the O&G industry because of the climate change and global warming issues. However, there is a dearth of research on the impacts of these regulations on O&G firms' environmental strategies and competitive advantage.

In conceptualising the 'resources' cluster, we followed the principles of NRBV which posits that firm can only derive competitive advantage from resources that are tacit, socially complex and causally ambiguous (Hart 1995; Hart and Dowell 2011). Since intangible resources are more difficult to replicate by competitors and same have been found to enhance organisations' green competitiveness, we follow the model of Kwak et al. (2018) by adopting '*supply chain innovation'* as the construct of our 'resources' cluster. This variable constitutes an area of interest because the position of the extant literature on the impacts of innovation on firms' performance has remained inconclusive. Hence, there is a need for further research in this area.

Our model follows the pattern of previous research on environmental sustainability in O&G industry (Hastings 1999) to retain the original NRBV variables of pollution prevention, product stewardship and sustainable development as our strategic environmental capabilities (Hart 1995). However, considering the difficulty of operationalising sustainable development in business research and its reclassification into *Clean Technology and Base of Pyramid (*Hart and Dowell 2011), our model adopts clean technology as the third variable under strategic environmental capabilities cluster. This is because clean technology is considered as one of most topical issues in the O&G industry because of the drives towards renewables and electric cars.

To delineate our cluster on competitive advantage, we follow the position of Porter (1985) that firm's competitive advantage are rooted in costs and differentiation. However, since the O&G products are highly homogeneous (Ahmad 2017), we argue that product differentiation might not lead to competitive advantage for O&G firms. Therefore, considering the negative environmental impacts of the O&G industry, we argue further that ability of firms to minimise negative impacts of operations and products on environment can be a source of competitive advantage in the O&G industry. Based on the above, our model conceptualises economic competitiveness and environmental competitiveness as the relevant constructs of our 'competitive advantage' cluster.

5. CONSTRUCTS

From the foregoing, our model identifies seven constructs namely *coercive pressures-government regulations*, *supply chain innovation* (as the antecedents), strategic environmental capabilities of *pollution prevention, product stewardship and clean technology* (as the intervention strategies), *environmental competitiveness and economic competitiveness* (as the outcomes). In this study, these constructs are defined as presented in Table 1.

Constructs	Definition	Reference
Coercive Pressures	Regulatory pressures exerted on firms by governments and their agencies to ensure compliance with environmental standards.	DiMaggio and Powell 1983; Esfahbodi et al. 2017
Supply Chain Innovation	Any incremental or radical change within the SC network, SC technology or SC processes (or combination of all) that can influence environmental practices of firms.	Arlbjørn et al. 2011
Pollution Prevention Capabilities	Capacity to develop Process innovation for reducing emissions, effluents and waste	Hart 1995; Hart and Dowell 2011
Product Stewardship Capabilities	Ability to develop measures for reducing the environmental impacts of products on the society throughout their life-cycle	Hart 1995; Hart and Dowell 2011
Clean Technology Capabilities	Ability to adapt to disruptive change in the industry by adopting technology than can cause changes or diversification in processes and products.	Hart and Dowell 2011
Environmental Competitiveness	Reputational benefits derived from effectively managing environmental impacts of activities more than the competition	Hart 1995
Economic Competitiveness	Economic benefits arising from taking proactive environmental measures ahead of competition	Porter 1985; Hart 1995; Hart and Dowell 2011

Table 2. Definitions of constructs.

6. HYPOTHESIS DEVELOPMENT

6.1. Coercive Pressures and Supply Chain Innovation

The beginning of the current millennium witnessed increased government regulations targeted at making companies to implement Environmental Health and Safety (EHS) practices, including cleaner production. Unlike the earlier 'command and control' approach to regulations, convincing arguments in support of flexible regulations with capacity to enhance innovations motivated governments in the developed nations to enact laws that fosters organisations' capacity to develop innovations (Zhu et al. 2016). Such example is seen in Germany where government regulations has enhanced firms' innovation to reduce emissions, avoid hazardous substances and increase product recyclability. In the context of SCM, Zhu et al. (2016) observes that IT products retailers in Europe successfully leveraged on innovations developed by their Taiwan manufacturers to comply with EU environmental regulations. Also in the O&G industry, Ford, Steen and Verreynne (2014) found that environmental regulations enhances innovations in the Australian O&G industry. Based on the foregoing, we hypothesize as follows:

H1: Coercive pressures have direct and positive impacts on supply chain innovation in the O&G industry

6.2. Coercive Pressures and Strategic Environmental Capabilities

Usually, firms generate pollution and other environmental footprints in their operations. Traditionally, costs associated with these environmental impacts are generally treated as externalities by firms (Demeritt 2009). However, through the imposition of regulations, companies are increasingly been held accountable for the costs of negative environmental impacts of their activities. Consequently, many firms are developing strategic capabilities for environmental management practices (Zhu et al. 2016). For instance, the 'take back' law in Germany which holds companies responsible for life cycle management of products have also compelled firms to implement product management and pollution prevention techniques through cleaner production and more efficient house cleaning (Hart 1995). Also, in the O&G industry, Sharma (2001) found that government regulations are positively related to the adoption of environmental strategies. Therefore, we hypothesize as follows:

H2a: Coercive pressures have positive impacts on pollution prevention capabilities of O&G firms.

H2b: Coercive pressures have positive impacts on product stewardship capabilities of O&G firms.

H2a: Coercive pressures have positive impacts on clean technology capabilities of O&G firms.

6.3. Supply Chain Innovation and Strategic Environmental Capabilities

Generally, innovation enables firms to develop the necessary capabilities needed for improving their traditional inefficient business processes and product. To maximise this, many firms are leveraging on innovations generated through their supply chain networks (Arbjorn et al. 2011). This is because many firms lack the sufficient knowledge to effectively manage and respond to environmental issues from their product life cycles (Hart 1995). Hence, they collaborate with stakeholders for innovations. According to Ahmad et al. (2016), O&G firms develop product stewardship capabilities through innovation generated alongside suppliers and logistics partners. On this note, we hypothesise further as follows:

H3a: Supply chain innovations have positive impacts on the pollution prevention capabilities of O&G firms.

H3b: Supply chain innovations have positive impacts on the product stewardship capabilities of O&G firms.

H3c: Supply chain innovations have positive impactss on the clean technology capabilities of O&G firms.

6.4. Strategic Environmental Capabilities and Competitive Advantages

The extant literature remains inconclusive on the nexus between proactive strategic environmental practices and competitive advantage (Aragón-Correa and Rubio-Lopez 2007). While some empirical studies established neutral and negative findings on the nexus between the two variables, some others have yielded positive results. Arguably, proactive environmental practices can result into competitive advantage in terms of cost reductions and efficiency gained through eco-design, pollution prevention, cleaner production, recycling and reuse of outputs (Hart 1995). For instance, Texas Instruments Company is able to save $8 million annually through its product stewardship capabilities. Also In addition to economic benefits, Hastings (1999) found that an improved environmental reputation (eco-reputation) can confer competitive advantage on O&G firms. Based on the foregoing, we therefore hypothesize that:

H4a: Pollution prevention capabilities have positive impacts on the environmental competitiveness of O&G firms.

H4b: Pollution prevention capabilities have positive impacts on the economic competitiveness of O&G firms.

H5a: Product stewardship capabilities have positive impacts on the environmental competitiveness of O&G firms.

H5b: Product stewardship capabilities have positive impacts on the economic competitiveness of O&G firms.

H6a: Clean technology capabilities have positive impacts on the environmental competitiveness of O&G firms.

H6b: Clean technology capabilities have positive impacts on the economic competitiveness of O&G firms.

6.5. Environmental Competitiveness and Economic Competitiveness

According to Ismai et al. (2006), organisations that are perceived as environmental friendly are able to experience higher patronage from consumers. Thus, higher environmental reputation has a positive relationship with revenues accruable to firms. In practice, companies that are involved in environmental issues are found to be exposed to cash flow distortion (Klassen and McLaughlin 1996). Such occurrences also affect the competitiveness of their value in the stock market. For example, the share price of BP dropped sharply by over 50% upon the Deepwater Horizon oil spills in 2010 (Fodor and Stowe 2015). In contrast, firms with higher level of eco-reputation are able to generate competitive advantage in terms of cost reduction (Klassen and McLaughlin 1996). Stemming from the above, we hypothesise that:

H7: Environmental competitiveness has positive impacts on the economic competitiveness of O&G firms.

Having established the causal relationships among the constructs of our model, the structural model of environmental sustainability of O&G SC is presented in Figure 2.

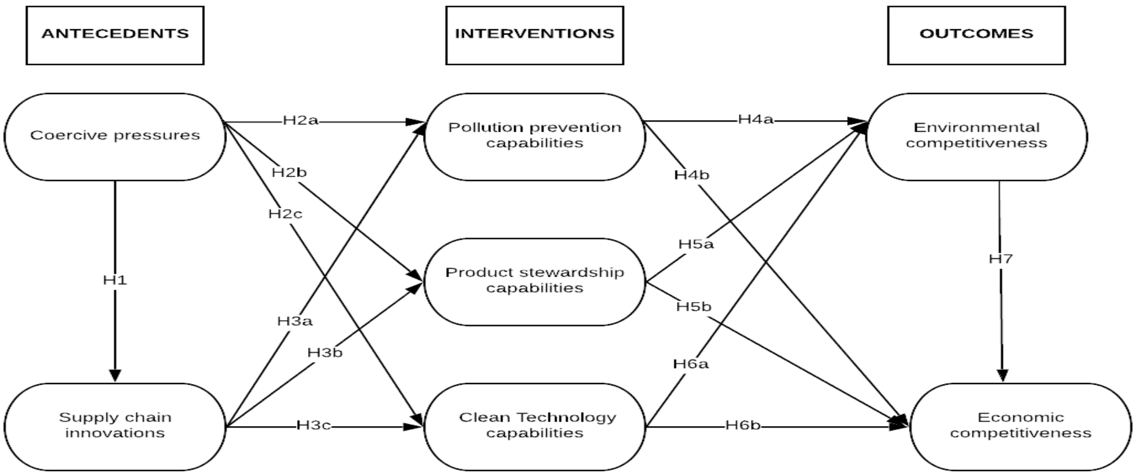

Figure 10. Proposed structural model of environmental sustainability for O&G SC

7. CONCLUSION

The purpose of this paper is to propose a structural model of environmental sustainability for the O&G SC. Following the recommendations of Caters and Rodgers (2008) that conceptual model development should be underpinned by sound theories, we have logically conceptualised institutional theory as the drivers of the NRBV to establish the causal relationships among various constructs identified from both theories. Among others, our model is different from previous models on sustainability in the O&G SC because it is based strictly on existing theories. Besides, the concept of supply chain innovation as antecedents of environmental capabilities in the context of O&G SC sustainability has not been explored in previous studies on O&G SC. Similarly, our adoption of clean technology as a strategic environmental capability in the O&G industry is novel because there is a dearth of research on this construct in the context of O&G SC. In terms of practical implications, our proposed model can help the operations manager in the O&G

industry to foster innovations in their SC towards compliance with extant regulations and minimization of environmental impacts of operations and products. Also, in view of the global efforts to shift attention to clean energy, our model, when empirically tested can assist O&G managers to build capabilities for the development and adoption of clean technology which can aid the production of clean energy. This will not only results into environmental competitiveness, it will also enhance the level of economic competitiveness of O&G firms. Notwithstanding the above, the limitation of this study include the fact that the proposed model has not been empirically validated in the O&G industry. Our future research will address this through a measurement model adapted from previous studies. Further research can also explore the roles of mimetic and normative isomorphism as drivers of strategic environmental capabilities in O&G SC.

Future research can develop measurement items for the constructs from the extant literature. Also, a large questionnaire survey can be administered with the top management officers of the O&G industries to test the hypotheses proposed in this research.

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A SUPPLY CHAIN VIEW OF ADDITIVE MANUFACTURING BUSINESS MODELS

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ABSTRACT
Purpose - To provide a scientific analysis of growth prospects in Additive Manufacturing (AM), in particular to propose a model for market size estimation taking uncertainty into consideration and a model of key processes and stakeholders in an AM supply chain.

Methodology - This research is based on a quantitative analysis of publicly available market growth estimates and an extensive review of literature on existing supply chain business models (e.g. Deloitte, 2019; Durach *et al.,* 2017; Rogers *et al.,* 2018). The proposed model was pre-tested, using opinions and insights from three business managers.

Findings - Although the AM market is growing rapidly, our estimates indicate that hype currently greatly exceeds reality. Further, traditional manufacturing through established supply chains will maintain its dominant role for the foreseeable future. Assessment from three business managers working with AM products reveals that our proposed model is potentially useful when mapping out the AM supply chain landscape.

Value - A sequential view of key aspects of the AM supply chain building upon previous literature and experts' insights is proposed for the first time.

Practical implications: First, the market analysis method provides a basis for estimating AM market growth potential, which is an essential decision-making tool for practitioners. Second, the AM Value Chain model provides a basis for the analysis of key market players and opportunities for value creation, especially in certain section-specific applications.

Keywords: supply chain, 3D printing, additive manufacturing, business models

INTRODUCTION

Additive Manufacturing (AM) and its current and future impact on supply chains is currently enjoying extensive media coverage as well as governmental support, however, current adoption rates are not developing as rapidly as expected. According to the forecasts of consultancies and market research organisations, the widespread AM adoption, along with high market volumes that, as we approach the end of the estimation periods, seem rather over optimistic (McKinsey & Co., 2017). Despite appearances to the contrary, when one looks at industry data, AM currently represents a very small percentage of global manufacturing, i.e. 0.06%, with traditional (i.e. conventional) manufacturing making up the rest (Wohler's Associates, 2016). According to a global survey of 900 companies by

EY (2016), 38% of participants stated intentions to incorporate AM into their production processes. However, for the foreseeable future it is unlikely to completely replace traditional methods. It is instead expected to either be used as an additional production technology for otherwise uneconomical or 'impossible to manufacture' products, or be part of a hybrid technology.

Adoption of AM technologies will impact the supply chains of businesses across a variety of industries, therefore, a deeper understanding of market developments and opportunities for value creation are valuable for practitioners that are either currently adopting AM or plan to do so in future. This paper aims to look beyond the hype surrounding AM by analysing the existing market growth forecasts and moreover calculating revised and more reliable estimations of global market size and growth expectations. Furthermore, we provide a basis for estimating the business impact of AM in terms of supply chain management activities. To do so, we propose a model for the AM value chain, based partially on the model developed by the German 'Mechanical Engineering Industry Association' (VDMA e.V.).

BACKGROUND

Additive manufacturing is broadly defined as the collective terms for technologies that enable 3D printing of physical objects (Conner, *et al.*, 2014). As the technology developed, business applications grew, meaning that AM progressed beyond its rapid prototyping origins and is now increasingly being used for production items, with some sectors such as aerospace and healthcare leading the way (Campbell, *et al.*, 2012; Özceylan, *et al.*, 2018). Following the advent of cloud computing-based technologies, mobile data and the corresponding digitalization of supply chains, AM is now becoming a viable business option (McKinsey & Co., 2017; Stratasys, 2017). While coverage of the technical aspects of AM for applications such as engineering (Frazier, 2014; Villamil, *et al.*, 2018), healthcare and medical devices (Gibson and Srinath, 2015) is relatively plentiful, the business perspective is lacking in. This is particularly the case in key aspects such as the impact of AM on business models, supply chains and traditional manufacturers' degree of 'fit' for AM (Özceylan, *et al.*, 2018; Rogers, *et al.*, 2018). Also, research that focuses on key partners such as service providers and networks are scarce. Academic publications covering these areas of AM are a more recent trend, as most were published from 2014 onwards (Durach, *et al.*, 2017; Öberg, *et al.*, 2018; Sasson and Chandler Johnson, 2016). Therefore, there is an imperative to improve upon the coverage of the AM market from a more holistic perspective, and more specifically to better understand its implications on firms' value chains and supply chains.

I. Supply chain perspective

Porter (1992) proposed that a firm's activities can be viewed as a value chain of primary activities, such as operations and supporting activities such as procurement. As AM has the potential of making processes such as design or distribution more collaborative, questions regarding how these processes will be conducted in the future arise (Villamil, *et al.*, 2018). For example, collaboration is required between suppliers of AM raw materials and equipment manufacturers, as materials must be compatible with machines and production techniques (Oettmeier and Hofmann, 2016). Research on supply chain collaboration suggests "social resistors" impose barriers to creating competitive advantages through collaborative processes, e.g. users and manufacturers (Swanson, *et al.*, 2017). Therefore, rethinking processes to encapsulate the whole supply chain is required to make organisations fit for AM (Frazier, 2014).

The current view from academia predicts considerable – and even transformative – changes to supply chains. However, the consensus appears to be that AM will not replace traditional methods but instead used to enhance traditional manufacturing (Durach, *et al.*, 2017; Sasson and Chandler Johnson, 2016). In brief, issues with AM are related to material technology (allowing a unit to be produced from different materials at once), production speed and quality, legal issues (intellectual property, liability and warranties, and pricing of printers materials and scanners (Gausemeier, *et al.*, 2017). Entering the market for such a technology requires dynamic and responsive supply chains for a sustained competitive advantage but to date few manufacturers have a clear AM strategy or use cases (EY, 2016). This paper addresses the aforementioned research gaps by proposing a synthesis of market growth expectations and an AM Value Chain Model derived from qualitative and quantitative research.

II. Market analysis

In line with the approach taken by Berekoven, *et al.* (2006), whereby they found reliable and representative output data can be collected from external public sources provided the samples are large enough, this research draws on freely publicly available secondary sources used as a basis for a quantitative analysis of the growth in AM market. In particular, we rely on reports prepared by management consultancies, AM businesses and adopters, as well as market research organisations. These reports are included to ensure sufficient coverage of differing perspectives in calculating objective market estimates.

To ensure a robust estimation of AM market size and growth can be calculated, simplifying assumptions need to be applied. The year 2017 is set as the "present" owing to the time-lag of published data. Although past data on market volumes differs, it is assumed here that they are equal to the average of publicly reported estimates. Owing to inconsistent and inseparable data all AM-revenues are treated equally, meaning there is no separation made between B2C and B2B customers, as well as between revenues from sale of equipment, technical consulting or other services. For future growth rates, two extreme growth scenarios starting in 2016 are included in the calculations to frame forecasts, namely, the optimistic scenario with a growth rate of 34% and the rather pessimistic scenario with a growth rate of only 10%.

Estimates for growth rates are obtained via a two-step calculation. The compound annual growth rate (CAGR) for the past four years is calculated using equation [1.1] (Anson, *et al.*, 2011). The same goes for forecasted market volumes from 2018 to 2022.

$$CAGR_{(t_0;t_n)} = \sqrt[t_n - t_0]{\frac{Market\ Size_{t_n}}{Market\ Size_{t_0}}} - 1 \qquad [1.1]$$

Uncertainty is included in these estimates by using two different growth scenarios in the derivation of our (conservative) estimates. In this way, future estimates display a corridor of possible outcomes, whereby our estimates will always be below public estimates or the average of all estimates. Aggregated estimates are obtained by averaging annual data according to equations [1.2] to [1.4].

$$\emptyset\ Public\ Estimate = \frac{\sum Public\ Estimates}{N_{Public\ Estimates}} \qquad [1.2]$$

$$\emptyset\ Our\ Estimate = \frac{Growth_{High} + Growth_{Low} + \emptyset\ Public\ Estimates}{3} \qquad [1.3]$$

$$\emptyset\ All\ Est. = \frac{\sum Public\ Estimates + \emptyset\ Our\ Estimate + Growth_{High} + Growth_{Low}}{N_{Public\ Estimates} + 3} \qquad [1.4]$$

This generic and initial model yields robust estimates of market size and growth. The rationale for this approach is that this research seeks to capture diverse public opinions, and at the same time include the possibility of sharply declining market growth into the final estimate. Using this methodology, the past CAGR from 2013 – 2017 calculated from sample data and own growth scenarios (as mentioned above) amounted to 27% p.a., mostly due to strong growth in 2013 and 2014. From then on, growth declined to 24 % in 2016 and 2017. The data suggests a slight increase that leads to a sustainable growth rate of 26 % from 2018 – 2022. Absolute market volumes in 2017 lie between 7.1 and 8.6 $Billion. We thus arrive at a conservative estimate of 8.0 $Billion in 2017, which is expected to rise to 25.3 $Billion by 2022. Owing to the speculative nature of the figures, no likelihood is applied to any of these scenarios.

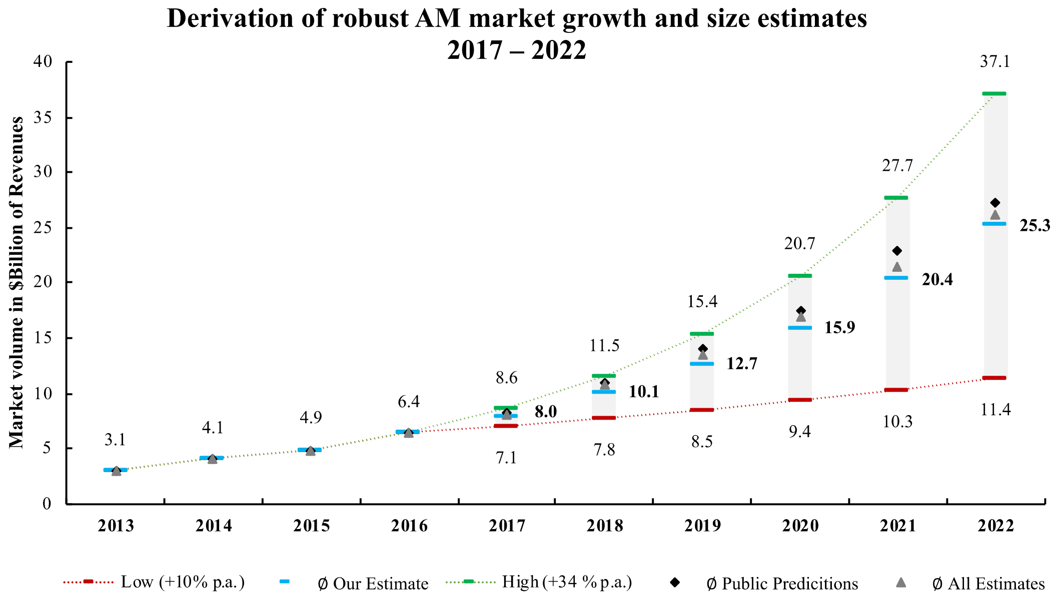

FIGURE 1: *Derivation of robust AM market growth and size estimates (2017 – 2022) (own calculations, based on data from (3DPrintingIndustry, 2017; 3DPrintingIndustry, 2018; ATKearney, 2015; MarketsandMarkets, 2016; MarketsandMarkets, 2014; oerlikon, 2017; Orbis Research, 2017; RolandBerger, 2016; RolandBerger, 2017; UPS, 2016; Wohler's Associates, 2016))*

To date the market has been driven by growth of big players such as 3DSystems and Stratasys, both based in the US. In particular, the development of more cost efficient solutions drove past growth rates (UPS, 2016). As both grew much less than the rest of the market from 2015 to 2017, they are partially responsible for the declining market growth rates experienced (3D Systems, 2018; Stratasys, 2017). In 2019, however, 3D printing's growth phase is predicted to return with significant increase in sales by large public companies including 3D printers, materials and services (Deloitte, 2019). Future market growth should come from adoption of AM quality improvements, increased production speed and material diversity (Sculpteo, 2018). Despite benefits that include waste reduction, increased complexity of product geometry and high degrees of customizability, widespread adoption has not yet happened. The challenges hindering adoption include insufficient production speed, precision and material diversity, as well as increased energy demand and product dimensionality i.e. objects that are too large for a given printer (Villamil, *et al.*, 2018). Also, if an otherwise modular production unit that is now printed requires repair, the whole unit has to be replaced – instead of just the broken part. Lastly, switching costs and necessary investments to adopt AM on a large scale are still too high for many companies and manufacturing process standardisation and certification are still developing (Frazier, 2014). Future growth rates are highly dependent on whether these issues are tackled or not. Nevertheless, 19% of participants of a global survey by Sculpteo express confidence in the market, as they expect to increase their spending on AM by more than 100% during 2018. Another 20% expect to increase AM spending between 51–100%, mainly for accelerated product development (Sculpteo, 2018).

Although the different estimates in Figure 1 are clustered tightly, suggesting broad agreement, scenarios on the upper and lower bounds are still possible. The central tendency remains highly positive, but due to the hype surrounding the market estimates require cautious examination. The main guide and the undisputed AM-reports market leader, the annual 'Wohler's Report' is highly anticipated by market observers. Apart from the considerable depth of analysis in the reports, the central hypothesis for long-term market growth could be questioned. While technically correct, it would take 15 years of annual market growth of 34% in our 'high'-scenario – and 46 years if growth slows down to 10% p.a.

What this analysis clearly indicates is that AM is here to stay and in time, depending on the nature of the industry, is likely to be an integral part of a manufacturing organisation's supply chain strategy. Therefore, identifying the sources of value creation within the AM market, as well as understanding the corresponding supply chain implications will provide useful insights for manufacturing companies when evaluating if and when to use AM.

III. Additive manufacturing value chain model

In this section, we present value creating activities and linkages between AM businesses. On that ground, we analyse and integrate stakeholder groups to form the AM Value Chain Model. The stakeholder groups are illustrated in Figure 2.

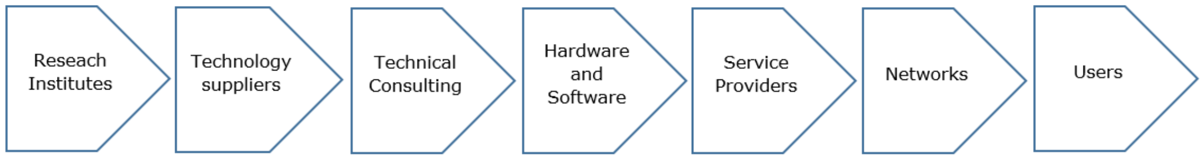

FIGURE 2: AM Value Chain Model (own illustration, based on (ABN Amro, 2017; BCG, 2017; EY, 2016; New and Payne, 1995; Porter, 1992; Rogers, *et al.,*2016; RolandBerger, 2013; VDMA 2018a))

The proposed model, in combination with the results of the market analysis, allows a deeper understanding of interrelations within the market. As AM enjoyed increased management attention in recent years, businesses consider how and if AM could be implemented. Given the availability of necessary resources, traditional manufacturers can enter the AM market by means of acquisition (e.g. General Electric), the establishment of networks or collaborations and development of own solutions (e.g. HP) and specialisation in selected aspects of value creation such as processing software (e.g. Siemens) (Rogers, *et al.*, 2018). Furthermore, businesses already utilizing AM technology may also share spare printing capacities on a contract basis via online marketplaces, (e.g. Jellypipe AG, 2018) and/or in business networks.

AM will substantially shorten traditional supply chains and allow businesses to skip several, often costly, time and energy consuming steps in a manufacturing process and thus free up working capital along the supply chain (Verhoef, *et al*., 2018). Two factors increasing supply chain complexity in traditional manufacturing – regionalisation and customisation – are expected to be addressed by AM.

In addition, AM adoption has the potential to 'de-globalise' mass production, as it enables production close to a target market. Depending on the industry, AM may make offshoring to benefit from lower labour rates obsolete (Gibson, *et al.*, 2015; Hannibal and Knight, 2018). Warehousing costs are reduced owing to just-in-time production, part consolidation reduces complexity, and part delivery is accelerated (Conner, *et al.,* 2014). Time-to-market, as well as response time to demand shifts is reduced because digital "inventories" of product designs allow for quick adjustments (Stratasys, 2017). Further, although print time generally depends on the complexity of the objects, the quality of print job and the materials being used, printers are getting twice faster than they used to be (Deloitte, 2019). Also, major issues of unknown proportions are intellectual property rights in the context of customer co-creation and the digitalisation of products (Leupold and Glossner, 2016). An aspect not to be neglected is that for supply chain collaboration; platforms facilitating an exchange between collaborators need to be established beforehand. This brings forth an array of issues related to 'social resistors' in organisations (Swanson, *et al.,* 2017). As the Union of German academies (Union der deutschen Akademien der Wissenschaften) asserts, there are many issues across various fields of research and law that need to be addressed prior to AM being considered an economic and sustainable production technology (Gausemeier, *et al.,* 2017).

CONCLUSIONS, IMPLICATIONS AND A FUTURE RESEARCH AGENDA

This research aims to determine the business impact of AM by looking beyond the hype surrounding the market and taking an objective view based on two aspects: key market growth metrics and the supply chain. We present a generic estimation model for market growth metrics that takes into account publicly available estimates and our own growth scenarios. The analysis highlighted the wide variability of existing forecasts and proposes a method of calculating aggregated growth estimates. Furthermore, in discussing the probability of a large-scale AM adoption in mass manufacturing, this paper concludes that AM is currently not advanced enough to be a viable alternative to large-scale traditional manufacturing. There are markets and parts that justify switching to AM but each case requires individual economic assessment of costs and benefits, and there will always be parts that are best manufactured conventionally. This view is widely supported by academic literature and existing business cases. Being able to assess the business case for AM is vital for organisations across a range of industries, as savings can be made. Sectors such as aerospace and healthcare are already showing increasing rates of production level AM, as well as for spare parts and tooling. Businesses in these and other high tech industries expect the technology to play an increasing role in the future, hence the formation of industry networks.

The specific contribution of this paper is twofold. Firstly, the AM market analysis calculations provide a basis for estimating AM market growth potential and hence are a decision making tool for practitioners when assessing current and future developments of the AM market. Secondly, the proposed AM Value Chain Model, provides the basis for mapping out the key market players and opportunities for value creation. As estimated growth rates show, the AM market is not yet stable or indeed saturated. Further research is needed to better understand the role and positioning of AM market-participants across the supply chain, as the line between technology supplier, service provider and consultant can be fluid. Analysing the practical implications on supply chains through use case business model transformation of AM-adopters in a global or regional context is also an important next step, to test the practical applicability of the model in this dynamic and disruptive market.

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INTERORGANISATIONAL DYNAMIC CAPABILITIES IN SUPPLY CHAINS – A CONCEPTUAL FRAMEWORK

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ABSTRACT

In recent years logistics scholars have stressed the need for interorganisational collaborative development as a means to sustain the competitiveness of a supply chain. Existing literature is fragmented and there is a need for further categorisation and systematisation on how to create, extend and modify resources in a supply chain. Dynamic capabilities theory constitutes a promising ground for such a development. The purpose of this paper is to present a systematic literature review on existing interorganisational dynamic capabilities and propose a conceptual framework of these at different hierarchical levels.

KEYWORDS: Dynamic capabilities, supply chain, network, learning

Due to space limitations, some references have been removed throughout this work-in-progress paper version.

INTRODUCTION

In recent years logistics scholars have stressed the need for interorganisational collaborative development as a means to sustain competitiveness, not the least from a supply chain perspective. Grounded in theories such as the resource based view of the firm (RBV) and the relational view (RV), dynamic capabilities has increasingly been acknowledged as a promising theoretical lens for such development efforts. Dynamic capabilities, typically defined as "the capacity of an organization to purposefully create, extend, or modify its resource base" (Helfat et al. 2007, p. 4), has in a logistics and SCM context been further conceptualised into "dynamic supply chain capabilities" (e.g. Defee & Fugate, 2010; Beske, 2012). So far however, there is limited research on dynamic capabilities beyond the intraorganisational firm perspective. In fact, even the overall linkage between dynamic capabilities theory and logistics/SCM research is still thin (Beske, 2012). A sign of this is the lack of consistency regarding key terms. Forkmann et al. (2016) argues that "existing literature on supply chain management uses a variety of terms to describe organizational capabilities, but these definitions are often inconsistent with the understanding of capabilities in the management literature" (Forkmann et al., 2016, p. 186).

The increased interest in interorganisational development is not only seen in a logistics context, but also in management literature in general. Indeed, long term success of companies and competitiveness is increasingly explained by valuable external resources accessed via networks or other types of collaborative relationships. For instance, from a knowledge-perspective, it has been argued that corporate innovation is increasingly explained by interorganisational relationships; marketing researchers stresses that networks of firms offer benefits beyond those of single companies, and service researchers claim that service innovation increasingly is brought to the market not by single firms, but by a network of independent firms. In essence, a common trait for the literature on interorganisational collaboration and development is the notion that interorganisational dynamic capabilities is fast becoming fundamental for long term sustainable competitive advantage. Thus, improved knowledge and structure regarding interorganisational dynamic capabilities (DCs) could be an important prerequisite for understanding how to successfully manage collaborative efforts in the supply chain.

Despite extant literature stating the relevance of interorganisational DCs, existing research is still fragmented and ill-structured, with lack of empirical data (Schepis et al., 2017). Overall, existing literature is not clear about the scope regarding interorganisational DCs and for whom competitive advantage is created (i.e. the individual firm or a network of firms, or a combination of these). To strengthen future analysis and understanding of interorganisational DCs, there is a need for clarification of different hierarchal levels of dynamic capabilities and a categorisation of the capabilities at these levels.

The purpose of this paper is to present a systematic literature review on existing interorganisational dynamic capabilities and propose a conceptual framework of these at different hierarchical levels.

As a means to strengthen logistics and SCM research on interorganisational dynamic capabilities, this study goes beyond the research scope of logistics and SCM and investigates interorganisational DCs in a broader context, including general strategic management as well as industrial marketing research. More specifically, the paper sets out to (1) conduct a systematic literature review in which interorganisational dynamic capabilities are categorized and described, and (2) conceptually construct a framework of dynamic capabilities at different hierarchical levels, ranging from those controlled by a network of independent firms to those controlled by a single firm.

METHODOLOGY

The research approach for the paper was initiated by an initial screening of 20 articles in the area of general strategic management, industrial marketing and logistics/SCM that were occupied with interorganisational development of resource bases, see Figure 1. A first draft to a conceptual framework of interorganisational DCs at 4 different hierarchical levels was elaborated. As an umbrella term "interorganisational dynamic capabilities" was established as a means to stress its underlying theoretical anchoring in dynamic capabilities theory (e.g. Helfat et al., 2007) and its attention to the creation, extension and modification of resources and capabilities *across* company borders and an extended resource base. In relation to the literature reviewed, this term typically covers commonly used terms such as capabilities of "strategic nets" (Möller & Svahn, 2003; Schepis et al., 2017) and "dynamic supply chain capabilities" (Defee & Fugate, 2010; Beske, 2012).

Based on the initial article screening and the tentative conceptual framework, a search string was thereafter constructed to cover existing literature regarding interorganisational DCs. A systematic literature review approach was followed, which rendered 36 articles that were included in the review results. The review results were several, but are in this paper limited to a thematic presentation of (1) antecedents to interorganisational DCs and (2) classes of interorganisational DCs. The result from the review was thereafter reflected against the developed conceptual framework as a means to further develop and characterise the different levels included in the framework.

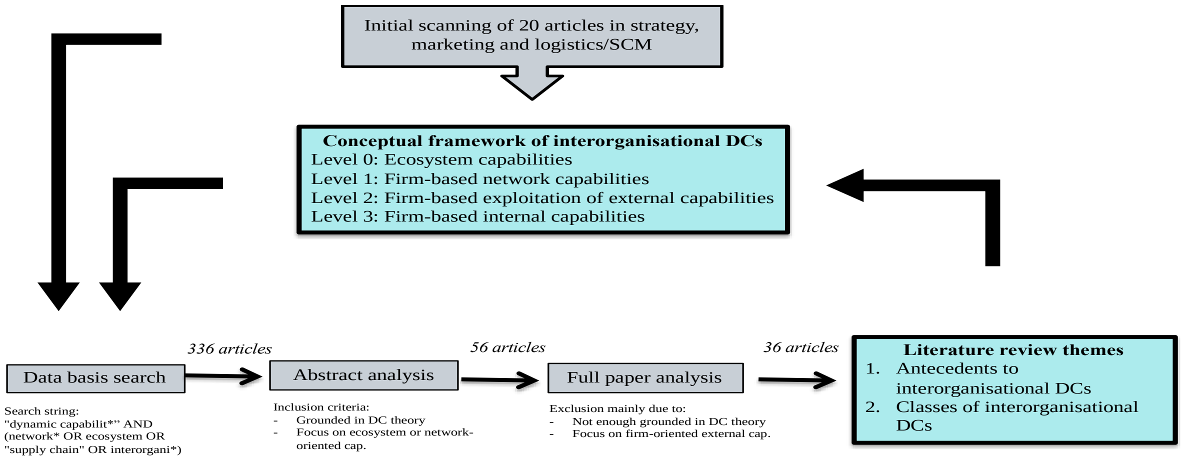

Figure 1: Overview of the research approach

ANTECEDENTS OF INTERORGANISATIONAL DCs

A number of antecedents to interorganizational DCs are suggested in the reviewed literature. Below some of the major ones are presented:

Strategic Orientation: An appropriate strategic orientation towards the network and its purpose can be a key enabler to dynamic capabilities, and highlights the strategic intentions of a company entering a network and is based on individual goals, values and vision (Beske, 2012). In a network, each company needs to clearly communicate its specific orientation as it can affect the entire network (Beske, 2012). A variety of different types of strategic orientations occurs in literature. For instance, a "Supply Chain Orientation" can enable implementation of dynamic capabilities within a supply chain (Defee and Fugate, 2010).

Learning and knowledge transfer: Whereas literature emphasize learning as well as knowledge transfer to be a crucial dynamic capability (e.g. in the context of absorptive capacity), research also underline learning and knowledge transfer as an important antecedent for the creation of dynamic capabilities (Beske, 2012). In a dynamic environment it is important that companies have the ability to learn and codify new knowledge in order to achieve long-term competitiveness. A network can create both formal and informal links between members in order to share knowledge in terms of experiences and routines. Crucial for such sharing is technology-related tools and their applications, but also harmony between technology and its exploitation among people.

Heterogeneity: Heterogenous members provide a diverse range of resources that can create rare constellations of resources within a network (Beske, 2012; Cabenelas et al., 2013), which in turn can enable members to create unique dynamic capabilities. Heterogeneity in a network is also a key factor for formulation of new knowledge and the knowledge exchange is often larger among members from different sectors.

Trust: To engage in an alliance or network, trust is essential in order for members to be open about their strategy and operations. Trust is developed through continuous collaboration among members and requires a large amount of time and resources to grow (e.g. Beske, 2012). Trust is often reflected in expectations in terms of past experience, leadership and intentions. Also, knowledge sharing depends highly on trust as a high level of trust typically results in a higher degree of knowledge sharing among members (Beske, 2012).

DYNAMIC CAPABILITIES AT DIFFERENT HIERARCHICAL LEVELS – A CONCEPTUAL FRAMEWORK

Below a conceptual framework of dynamic capabilities at different hierarchical levels are developed. The different levels are elaborated based on (1) the control of the capability,

(2) receiver of benefits (originated from the capability at hand), and (3) the existence of interorganisational resource involvement, see Table 1.

	Network or firm level control	Receiver of benefits	Involvement of external resources
Level 0: Ecosystem capabilities	Network level	Network	Yes
Level 1: Firm-based network capabilities	Firm level	Network	Yes
Level 2: Firm-based exploitation of external capabilities	Firm level	Individual firm	Yes
Level 3: Firm-based internal capabilities	Firm level	Individual firm	No

Table 1: A framework of interorganisational dynamic capabilities

Level 0: Ecosystem capabilities

Network capabilities are controlled by a network of independent companies, beyond the scope and control of an individual firm (hence the terminology of "level 0"). In contrast to the other capability levels elaborated below, ecosystem capabilities should be placed above the company level. They are hence naturally considered to be "external resources" from a company perspective, as well as "self-organizing" (Butler & Soontiens, 2015). The companies in the network are all, but to a varying degree, benefiting from these capabilities.

Ecosystem capabilities typically exist in an environment that in a marketing context has been labelled strategic business nets (e.g. Möller & Svahn, 2003; Butler & Soontiens, 2015; Schepis et al., 2017). Schepis et al. (2017) understand a net "to be a distinct sub-network formed by actors and bounded by their cooperation around a particular goal" (Schepis et al., 2017, p. 2). A strategic business net is intentionally developed and maintained for explicit purposes (Möller & Svahn, 2003; Butler & Soontiens, 2015; Schepis et al., 2017), with a defined role or task against its environment (e.g. Cabenelas et al., 2013)[1].

The notion that ecosystem capabilities only occurs in a business net environment with explicitly defined objective is in line with common definitions of DCs, as these are stressed to be conscious and aligned with specific purposes (e.g. Helfat et al., 2007).

Level 0 capabilities can best be described as routines that are accepted and supported by the member companies, i.e. they are not controlled by a single company. Some examples of ecosystem capabilities provided by the literature review are:

Governance routines: Butler & Soontiens (2015) argued that "While networks have a proven ability to offer firms collective benefits well beyond those of single operations, they require the development of specific organizational capabilities" (Butler & Soontiens, 2015, p. 478). In a similar vein, Cabanelas et al. (2013) emphasise that successful governance of a network is of major importance. Such a governance typically includes clear division of roles among network members, including decision-making procedures and multidisciplinary teams in the network to foster commitment, and understanding.

In contrast to a general network, and based on the understanding of a strategic net, we consider ecosystem capabilities to be operating in a closed system, with defined boundaries as well as members (Schepis et al., 2017). This in turn implies that rules and routines regarding the entering and exit of network members becomes part of the

[1] A parallel can be drawn to logistics research literature, and the difference between a supply chain on the one hand, and supply chain management on the other.

governance routine (this could also be managed by individual companies, see below). In fact, design of how multiple network members should interact is a key management question (Butler & Soontiens, 2015), and appropriate governance routines could here facilitate long term orchestration and development.

Monitoring routines: Another fundamental capability at the ecosystem capability level is the ability to clearly demonstrate the effective performance of the network and its use for the network participants (Cabenelas et al., 2013). Of particular importance is to provide an understanding for the benefits such as financial returns for the different participating firms. Thus, a crucial network capability includes an effective monitoring of the network's performance.

Standardisation routines: Standardisation enables efficient knowledge and experience sharing among network members. "Interaction norms" and "governance mechanisms" facilitate ongoing exchange among the network members (Schepis et al., 2017).

Level 1: Firm-based network capabilities

Firm-based network capabilities are here understood as capabilities managed by one of the network member companies, but which benefits the network as a whole. As for the ecosystem capabilities, the firm-based network capabilities are relying on a combination of resources that go beyond company borders.

We acknowledge, in line with a rich existing research body, that individual firms could play a crucial leadership role for the development and transformation of the entire network of actors. In fact, as often highlighted in logistics and SCM research, an (often) powerful channel captain could shape the performance of the supply chain (or network) as a whole. In a marketing context, such a role take part in hub-driven nets (Schepis et al., 2017), managed by a "hub firm" (Giudici et al., 2018) in which the management responsibility is concentrated to a lead actor. In recent years this role has been emphasised. For instance, in a digitalisation context, Helfat & Raubitschek (2018) argues that for leaders of digital platform-based ecosystems, it is necessary to possess innovation capabilities, environmental scanning and sensing capabilities and integrative capabilities. A crucial task related to these capabilities is the shaping, and future performance, of the platform. Some examples of firm-based network capabilities:

Boundary management: Forkmann et al. (2016) elaborate the dynamic capability of how to manage the boundary of the network with the objective to manage relationships in the network. More specifically, they explore the relationship initiating capability, developing capability as well as terminating capability, that together emphasise the need for managing network membership over time.

Visioning: A major challenge for the network and hence an important network-oriented capability, is to create legitimacy for the overall network goals, and encourage individual network members to contribute to the network, by aligning specific company goals with the broader, overall goals of the network (Schepis et al., 2017), hence a "vision proximity" is crucial (Cabenelas et al., 2013). For this, a visionary leadership is required.

Orchestration: Strongly related to visioning and the alignment of overall goals among the network members, a key observation in literature is the need for a purposeful coordination of resources and capabilities among members of the network over time. For instance, Pitelis & Teece (2018) extends internationalisation theory with an orchestration theory, claiming that there is a need for multinational enterprises to orchestrate "a global process of value and wealth creation and capture" (p. 524) in a network of actors. Adner (2017) develops the ecosystem concept and argues that the "ecosystem elements" of activities, actors, positions and links must be orchestrated.

This orchestrating is typically conducted by a powerful, channel captain or similar, actor, but also other less powerful players could have this role. For instance, Giudici et al. (2018) investigates the role of a venture association and its orchestrating capabilities in a network. Their orchestrating efforts are geared towards a more supportive role towards the network members, rather than managing as such.

Co-evolving: Except for orchestration of existing capabilities, there is also a need for an ability among network members to co-evolve. In a supply chain context, Defee & Fugate considers co-evolving to be a dynamic supply chain capability defined as "a DSCC held, individually, by two or more supply chain members that facilitates the joint development of new capabilities between supply chain-oriented firms that aspire to compete on the basis of superior supply chain capabilities" (Defee & Fugate, 2010, pp. 190)

Knowledge management and learning: Another fundamental firm-based dynamic capability is knowledge management and learning which benefits not only the focal firm, but also other members of the network. For instance, existing literature on absorptive capacity often overlooks the fact that collaboration and social integration is of major importance for the absorption of external knowledge. Thus, absorptive capacity is not only an issue for a focal firm perspective, but also for the network. By means of increased collaboration, as well as desorptive capacities, successful absorptive capacities can be ensured. Knowledge is also increasingly understood to not be possible to be acquired and maintained internally, but in collaborative networks. For instance, in a supply chain context, Defee & Fugate (2010) points out that knowledge accessing is a crucial dynamic supply chain capability, defined as "a dynamic capability held by two or more parties that fosters an understanding of the current knowledge resources possessed by each party" (p. 188).

Level 2: Firm-based exploitation of external resources

A network and its resources could also – and should be – exploited by individual network members for their own interests and gains, for instance creation of firm competitive advantage. Such capabilities have increasingly been highlighted in literature as necessary complement to internal capabilities, see e.g. the relational view. For instance, external knowledge acquisition is an essential ingredient in most companies of today, which is often manifested in research regarding absorptive capacity or sensing capabilities, in which external resources often plays a crucial role.

Level 3: Internal capabilities

Last, but not least, internal dynamic capabilities, constitute an important source for development and adjustment towards environmental changes. Within the rich dynamic capabilities theory, several seminal typologies of such internal dynamic capabilities have been developed, the framework of sensing, seizing and transforming capabilities.

DISCUSSION

Dynamic capabilities exist in parallel at different levels ranging from individual companies to wider networks. To identify the relevant levels, and categories of dynamic capabilities at the different levels, constitutes an important foundation for future research in dynamic capabilities theory in general, but it also serves as a platform for future logistics research. The conceptual framework elaborated in this research is a first attempt towards such understanding and knowledge building.

In logistics and SCM research the traditional unit of analysis has been the dyadic relationship or supply chain, although the existence of a network of suppliers and customers since long has been acknowledged. The need for moving beyond the single supply chain has in recent years been accelerated by the era of digitalization, in which larger networks of companies and their interdependencies become even more crucial to understand. For instance, the emergence of digital platforms (Helfat & Raubitschek, 2018) operated by e.g. Amazon and Alibaba has got increased attention in logistics and SCM research recent years. Another example is the implementation of Internet of Things (IoT). IoT typically renders advantages related to traceability and visibility in the supply chain that helps to overview and predict flow of goods and information beyond the company borders, thus expanding the potential network of collaboration partners. So far, however, little is known about the relationship between the occurrence and utilization of IoT devices in networks of companies on the one hand, and collaborative development on the other (such as interorganisational dynamic capabilities as is targeted in this paper).

Except for drivers related to digitalization, another example of the need for analysis beyond the single supply chain is the emergence of closed loop supply chains, in which members of the traditional forward supply chain are linked with new members in the reverse supply chain. Together, they constitute a network of companies that needs to continuously update their current logistics operations.

For practitioners, the research provides an important step towards an understanding for how to improve collaborative efforts in a supply chain. In addition, it provides a comprehensive understanding for some of the major building blocks regarding interorganisational dynamic capabilities. Ultimately, it also improves understanding for why a company should join, stay or possibly leave a network.

The research findings from this paper open up for several interesting learnings and future research themes. First, this paper has taken a comprehensive scope in its search for relevant literature mainly covering the three research disciplines of strategic management theory, industrial marketing and logistics/SCM. A general learning from this research is the limited referencing between above all industrial marketing on the one hand, and logistics/SCM on the other. Both these research disciplines tend to originate from the same strategic management sources but fails to link their current research to each other. In order to avoid "reinventing the wheel again", future research in both these research disciplines could benefit from aligning their research efforts.

Second, in order to limit the scope of the presented literature review, only papers explicitly discussing DCs have been included. Issues regarding joint collaborative development in a supply chain can however be elaborated from alternative viewpoints. Future research should therefore include additional theoretical lenses.

Third, current research, including this paper, has been geared towards the role of the leading, most powerful members in the network, typically the channel captain position, or the "hub firm" (Giudici et al., 2018). Future research should target the less powerful members of the network and their role, benefits and incentives for being part of the network (Schepis et al., 2017). As pointed out by Adner (2017) the role of the *leader* (of an ecosystem) as well as the role of a *follower* must be understood.

Fourth, another related future research topic is the existence of complementary dynamic capabilities at other network members, which further enhance network performance and benefits for the network as a whole. For instance, an absorptive capacity in which a network member exploit external knowledge may be enhanced by the existence of desorptive capabilities at the knowledge providing company. Research remains unclear regarding how this match between different dynamic capabilities among different network members could interact and support each other.

Fifth, the review reveals that classes of interorganisational DCs should be considered to in their context, in particular the characteristics of a value system/network is here emphasised. Möller and Svahn (2003) conceptualise different value systems ranging from stable, existing networks with well-known members and operations to emergent, future-oriented networks based on more radical innovations. According to the authors, different types of DCs are required for the different networks. Whereas operations-oriented capabilities such as demand forecasting and cross-firm information systems are needed in the former network type, network visioning and network orchestration capabilities are needed in the latter. In addition, the role of learning and knowledge becomes different in the different types of networks. Future research has continued the work provided by Möller & Svahn (2003) but still this issue needs more research attention, in particular in a logistics and supply chain context.

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COMPREHENSIVE PLANNING OF A SUSTAINABLE HYDROGEN ECONOMY CONSIDERING BUSINESS, SOCIAL, ENVIRONMENTAL IMPACTS: RENEWABLE HYDROGEN SUPPLY CHAIN IN JEJU ISLAND, KOREA

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Purpose of this paper:

For the successful realization of the hydrogen economy, this study performs comprehensive design and analysis of the hydrogen supply infrastructure from economic and sustainability perspectives.

Design/methodology/approach:

We develop a new optimization-based approach for the strategic design and analysis of a renewable hydrogen supply system. For the system, we include the whole process stages from using a wind-powered and methane-reforming hydrogen production, storage and transportation, and fuel station as a final demand. We then develop a network optimization model for the proposed hydrogen supply system using a mixed-integer linear programming technique.

Findings:

Through the case study of Jeju Island, Korea, we illustrated the capability of the proposed model by identifying the optimal hydrogen supply network (e.g, type, quantity and location of facilities) and operational strategy (e.g., temporal flows of electricity and hydrogen between different regions). As a result, we analyzed economic (e.g., major cost drivers) and environmental performances (CO_2 reduction and land occupation) of the proposed supply network.

Value:

The proposed optimization-based methods are a very first comprehensive and practical tool for designing a renewable hydrogen supply chain by dealing with various issues arising during planning, design, and operation stages. And the findings from case study provide are useful and easily applied to other application by providing a decision-making guidance to stakeholders for planning hydrogen supply system.

Practical implications:

To illustrate the capability of the proposed approach, we present a real case study pertaining to the design of the wind-based hydrogen supply (WBHS) system for the road transportation sector of Jeju Island, Korea.

Keywords

Two-stage stochastic, wind power, planning, hydrogen supply, optimization

1. Introduction

Hydrogen is one of the most attractive alternatives to the current carbon-based energy system, since it can be produced from diverse resources and used as a carbon-free energy source from the end-user perspective [1]. Not only is hydrogen an environmentally clean energy resource, it is also an energy carrier that can convert energy from primary energy sources to different end-user energy forms. A large number of studies in the literature have dealt with problems regarding the design and analysis of hydrogen supply systems and related infrastructure [2,3]. When it is produced from renewable energy sources (RES) such as wind energy, the merits of hydrogen can be further enhanced. Even though RES have many advantages, it has intermittent nature [4]. Due to intermittent nature of the RES, energy supply system using renewable energy source leads to oversized equipment and unnecessary operation. Many researchers have attempted to investigate the feasibility of renewable hydrogen systems and to analyze the economics with regard to installation and operation of renewable hydrogen supply infrastructure [5,6]. The design of hydrogen supply systems using wind energy is highly complex owing to the presence of a number of alternative options (e.g., different locations, timing, types) and parameter uncertainty (e.g., wind speed and wind direction). While many approaches and models have been developed, no study comprehensively addresses all the problems that may arise in a renewable hydrogen supply system with the intermittent nature.

Therefore, the purpose of this study is to develop a new optimization model with two-stage stochastic linear programming for the wind-based hydrogen supply system, which be capable of addressing all design issues (from the type of wind turbine, layout of a wind farm and the number of wind turbine to supply chain problems) as well as operational strategies.

Nomenclature

(a) Sets	
i	the set of facilities
j	the set of regions
k	the set of wind farm layouts
l	the set of transportation modes
p	the set of probabilities
(b) Subsets	
$i \in I^{ET}$	electrolysis facility
$i \in I^{S}$	Storage facility
$i \in I^{WT}$	wind turbine
$l \in L^{H}$	hydrogen transportation
(c) Parameters	
GA_j	available area in region $j \in J^O$, km²
$D^T{}_{jt}$	Demand in region j during each time period t, ton/day
R_{iptjk}	output power from a wind turbine $i \in I^{WT}$ in region $j \in J$ with layout $k \in K$ under probability $p \in P$ having wind farm layout $k \in K$, MWh/d
θ_{tp}	probability of wind power during each time period t under probability $p \in P$
η_i	energy conversion efficiency of electrolysis $i \in I^{ET}$, %
M_t	the number of days in each period time t
$\delta^P{}_i$	minimum capacity of production facilities i ton/day

ε^{p}_{i}	maximum capacity of production facilities i ton/day
(d) Continuous variables	
DE_{jt}	amount of hydrogen delivered to the final demand in region j during each time period t ton/day
P_{ijt}	amount of hydrogen produced from production facilities i in region j during each time period t
$Q_{jj'tl}$	flow rate of hydrogen between regions j and j' during each time period t by transportation modes l
S_{ijt}	amount of hydrogen stored in $i \in I^{S}$ in region j during each time period t, ton/d
FCC	facility capital cost, $
FOC	facility operating cost, $/year
HTC	hydrogen transportation capital cost, $
ETC	electricity transmission capital cost, $
TAC	total annual cost, $/year
$ETOC$	electricity transmission operating cost, $/year
$HTOC$	hydrogen transportation operating cost, $/year
(e) Integer variables	
$NP_{i^{wp}jk}$	number of wind turbine $i \in I^{WT}$ in region j having wind farm layout $k \in K$

2. Problem statement

2.1. Wind-based hydrogen supply system

To generate and design the comprehensive the WBHS system, we consider overall activities from electricity generation and transmission to hydrogen production, storage, and transportation. Figure 1 shows the schematic structure of the WBHS system, which consists of two main divisions: wind to power generation and hydrogen supply chain.

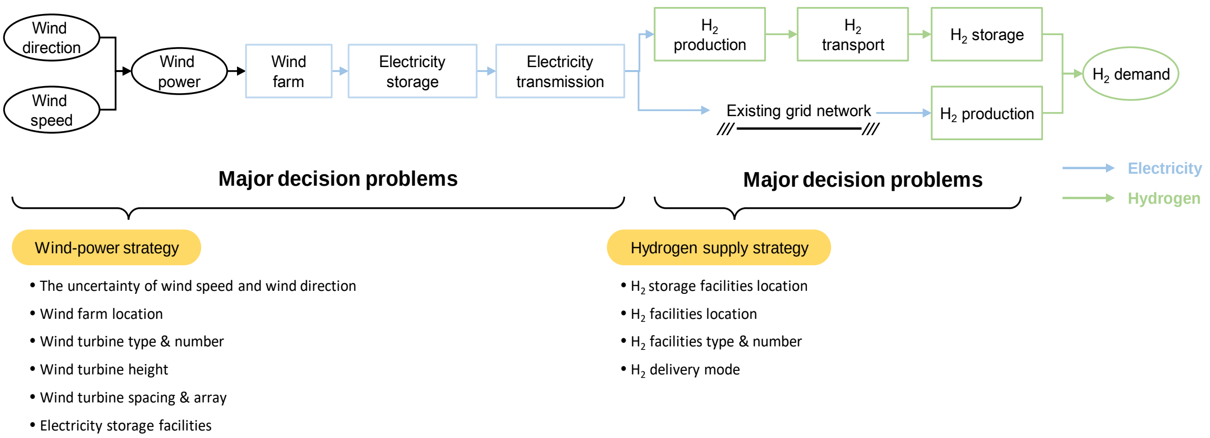


Figure 1. Superstructure of the WPHS system and corresponding decision problems.

The power generation from wind energy includes two different important variables (i.e. wind direction and wind speed). Wind turbine power output is proportional to the cube of the wind speed. The power output is plotted against direction rather than wind speed. In this study, we consider both the wind direction and wind speed to calculate wind turbine output. These wind turbines have different wind turbines sizes and layout structures. Then, the generated electricity is sent to the storage facilities to store. Note that storage technology has the important role in RES-based energy supply system, since it can buffer the intermittent of RES. The stored electricity is transmitted to hydrogen production facilities to convert to hydrogen. In the hydrogen supply chain, we consider typical hydrogen supply activities such as hydrogen production, transportation, storage. To produce hydrogen, we consider only a single facility, called a water electrolysis plant with different capacities. The facility converts electricity into hydrogen. Depending on time period, hydrogen storage facilities store the hydrogen produced by the water electrolysis plants and distribute the stored hydrogen to fueling stations in adjacent regions.

3. Optimization model

To achieve the goal of this study, we develop a new optimization model which is extended based upon the previous works. The optimization model is proposed using a mixed-integer linear programming (MILP) technique with two-stage stochastic programming and implemented in GAMS environment with CPLEX Solver. The formulation of a two-stage SP model is as follows:

$$\underset{x}{Min}\ f^1(x) + E_\theta\{Q(x,\theta)\} \qquad (1)$$

$$x \in \mathbf{R}^{n1}, \theta \in \mathbf{R}^{n2}$$

$$Q(x,\theta) = \underset{y}{Min}\ f^2(x,y,\theta)$$

$$s.t. h(x,y,\theta) = 0; \ \ g(x,y,\theta) \le 0$$

$$y \in \mathbf{R}^{n3}$$

Where x is the vector of first-stage decisions which are made prior to the uncertainty realization; y is the vector of second-stage decisions which are made after the realized of uncertain parameters θ which is described by a continuous probability distribution function or a finite number of discrete scenarios through sampling approximations; $h(x,y,\theta)$ and $g(x,y,\theta)$ are the vectors of equality and in equality constraints, respectively; and the objective function contains the first-stage cost $f^1(x)$ and the expectation of the minimum second-stage cost $Q(x,\theta)$ over all realizations.

3.1 Constraints

Figure 2 represents the structure of the optimization model for the design of the wind-based hydrogen supply system. Flows of wind power and hydrogen are represented as arrows and the technologies are presented denoted as nodes in the network. The main assumptions and other constraints used in this study are mainly adopted our previous work.

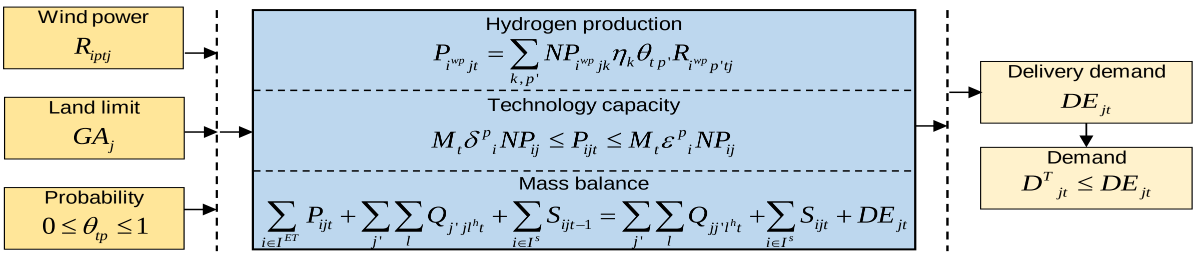


Figure 2. The structure the optimization model.

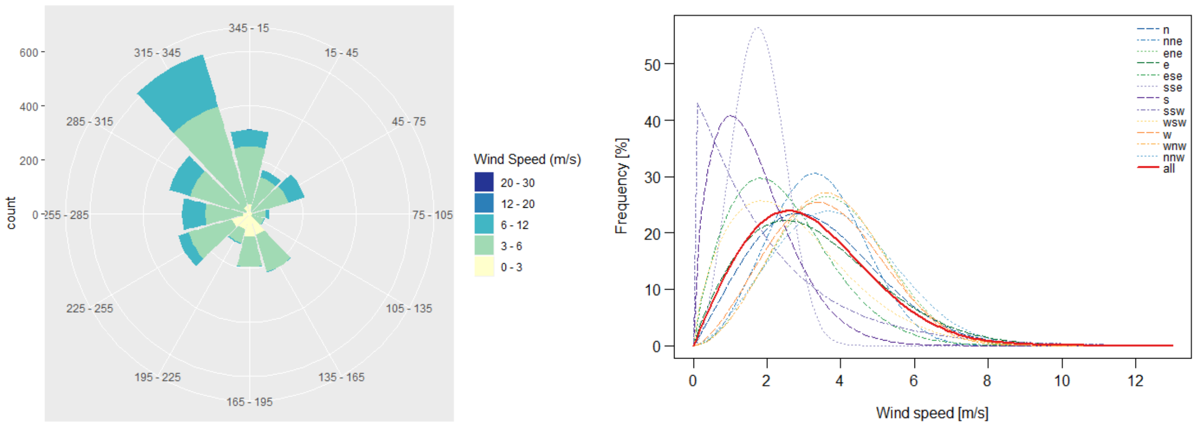
3.2 Objectives function

In this study, the objective of the proposed model is to minimize the total annual cost of the WBPS system. The TAC (total annual cost) is consists of FCC (facility capital cost), HTC (hydrogen transportation capital cost), ETC (electricity transmission capital cost), FOC (facility operating cost), HTOC (hydrogen transportation operating cost) and ETOC (electricity transmission operating cost):

$$TAC = \frac{FCC + HTC + ETC}{CCF} + FOC + HTOC + ETOC \quad (2)$$

4. Case study: the renewable hydrogen supply chain at Jeju Island

We apply the proposed approach to the design problem of the WPHS system at Jeju Island, Korea. Jeju Island as the largest island is the southernmost part of Korea. Jeju Island is one of the Korean provinces with the highest RES potential, in particular, wind power; 60% of the wind potential in Korea is concentrated at Jeju Island[7].



(a) (b)

Figure 3. Characteristics of the wind data in west of Jeju Island: (a) wind rose; (b) Weibull distribution.

As shown in Figure 3, the wind data in west of Jeju Island is processed with wind rose and Weibull distribution, which is a widely used probability distribution for wind speed modelling [8]. For each of the 12 direction sectors, the Weibull distribution can be used to derive 12 sector-wise Weibull distributions. From this distribution, n calculate the probability of wind speed and wind direction.

In this study, the cost of the hydrogen technologies, including production, storage, and dispense, are estimated based on the results of economic analyses in the literature as shown in Table 1 [9].

Table 1. Technical and economic parameters of the hydrogen facilities

	Electrolysis			Storage	
				Small	Large
Capacity (ton/d)	1	5	15	5	15
Capital cost ($10^6$$)	14.7	25.4	49.2	13.3	25.8
Operating cost ($/ton)	27	27	27	15	15

In this study, we consider one mode of hydrogen transportation, a tank truck. The technical parameters used for the capital and operating costs are summarized in Table 2[10].

Table 2. Capital and operating costs of a tanker truck

Capacity (ton/trip)	4
Average speed (km/h)	55
Mode availability (h/day)	18

Load/ unload time (h/trip)	2
Driver wage ($/h)	23
Fuel price ($/kg of H_2)	3.4
Maintenance expenses ($/km)	0.1
General expenses ($/day)	8.2
Fuel economy (km/kg of H_2)	80.5
Capital cost ($10^6$$)	0.5

The delivery distances for the twelve regions at Jeju Island are measured as the real road distance (center to center) as shown in Table 3.

Table 3. Delivery distance within and between regions.

	R1	R2	R3	R4	R5	R6
R1	2	40	73	69	36	17
R2	40	2	33	38	42	43
R3	73	33	2	26	57	76
R4	69	38	26	2	33	59
R5	36	42	57	33	2	27
R6	17	43	76	59	27	2

5. Results and discussion

5.1 Optimal network of the WPHS system

Figure 4 summarizes the optimal configuration of the WBHS system with flows of hydrogen and electricity. Region 1 has a significant number of wind turbines because of its high wind speed. Due to the limited land size and land cost, the rest of the required electricity are generated from the wind farms established in other regions. Although region 12 has the second highest wind speed, the number of the wind farms is not relatively large compared to other regions owing to high electricity transmission cost to regions 3 and 4.

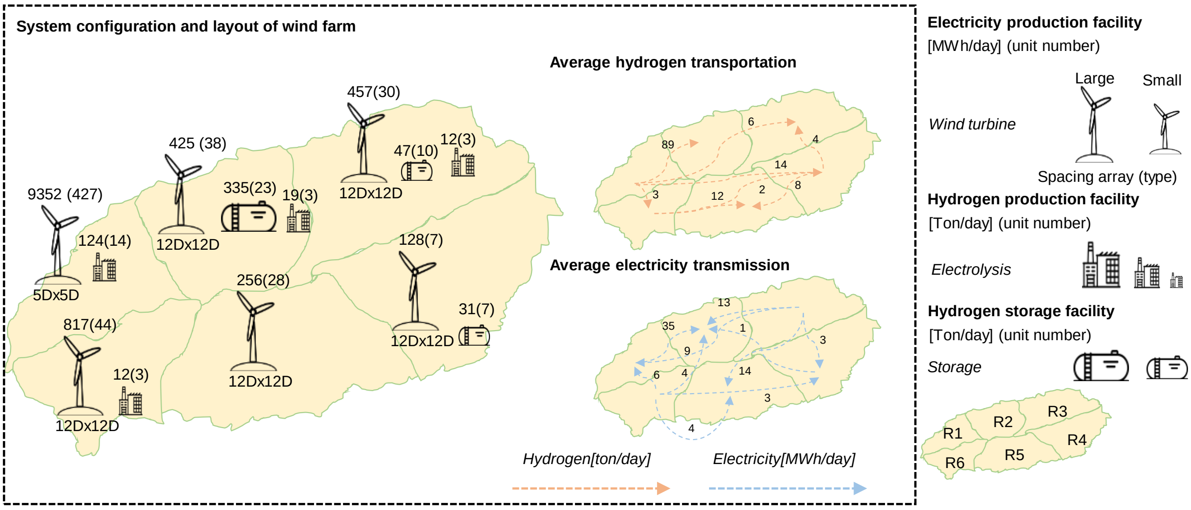


Figure 4. Optimal configuration of the WBHS system, and electricity and hydrogen flows.

Figure 5 shows the monthly changes in the produced, demanded and stored amounts of hydrogen. This figure represents the optimal operational strategies for handling hydrogen to determine the rates of hydrogen production and storage to deal with the intermittent of wind energy in each month. Due to the high wind speed in November- April, hydrogen production in November-April is higher than other period. The abundance of hydrogen production against the demand in this period is stored in the storage facility to balance production with demand at later. In particular, 372 tons of hydrogen is supplied by the hydrogen storage system in March. The effect of hydrogen storage is also observed in

WBHS systems. Therefore, establishing a storage system to balance hydrogen supply and demand is clearly a more economically suitable strategy than a production-oriented strategy.

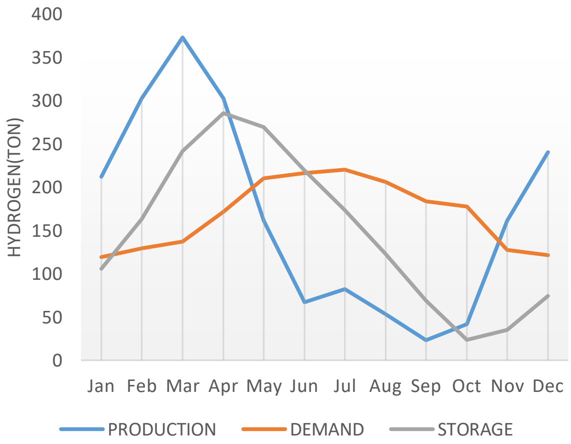


Figure 5. Amounts of hydrogen demanded, produced, and stored in different time periods by the WBHS system.

The costs required to design and operate the WBHS system are summarized in Table 3. The capital cost of the electrolysis is the main cost component: 44.7% of the total network cost. The calculated levelized cost of hydrogen is 11.5$/kg of hydrogen. The cost of hydrogen in WBHS system is very expensive than the cost of previous work [11]. Note that the total cost is the network cost, which includes all the required infrastructure such as electricity network. Moreover, the huge capacity of hydrogen storage system is needed to deal with the intermittent of wind energy.

Table 3. Cost breakdown of the total cost of the WBHS system ($/year)

Capital cost	
Wind turbine	8.2.E+06
Electrolysis	1.0.E+07
Storage facilities	2.2.E+06
Hydrogen transportation	4.2.E+05
Electricity transportation	7.4.E+05
Land purchase	8.0.E+05
Operating cost	
Wind turbine	3.8.E+05
Electrolysis	4.5.E+04
Storage facilities	5.6.E+03
Hydrogen transportation	2.6.E+04
Total network cost	2.3.E+07
Levelized cost ($/kg of H_2)	11.5

6. Conclusions

In this study, a new design and analysis framework of the WBHS system under the uncertainty of wind speed and wind direction was presented. The proposed model using an MILP was developed to determine the optimal design and operation conditions of WBHS system, which minimizes the total annual cost subject to various constraints. Furthermore, we considered two types of energy storage system, which are electricity storage system called battery and hydrogen storage system. In this study, the hydrogen storage system is selected to minimize the total annual cost in Jeju Island. The land limitation in region with high wind potential caused the erecting of additional wind turbines, even if in regions with low wind potential. While the proposed approach is undoubtedly useful, further research based on our results may proceed to address the practical barriers against the establishment of the WBHS system.

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THE EFFECT OF SUPPLY CHAIN COOPERATION ON THE STRATEGY OF SMES IN HUNGARY

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Abstract
Purpose
This study aims to examine how Supply Chain Management (SCM) affect the creation and modification of the strategy of Hungarian Small and Medium Enterprises (SMEs).

Design/methodology/approach
After a detailed literature review, we set up our hypothesis: SMEs don't pay enough attention to their strategies. This is increasingly true of dealing with important factors such as 1.) Supply Chain cooperation or 2.) Digitalisation. For data collection,we conducted a question-based survey. The questions were directed towards the conformity of the companies' "Strategy", their (external) "Supply Chain" and their readiness on "Digitalisation". In total, 273 valid responses were collected from Hungarian SMEs, with focus on the highly industrialised North-Western region of the country. The survey was answered by executives of companies of the production-, commerce- and service sectors. The methodology applied for analysis of the data acquired was empirical analysis (SPSS). In the current paper we highlight how far the cooperation with other SC members will influence the creation/modification of the strategy of these companies.

Findings
Results of the study showed that nearly 50% of Hungarian SMEs have not changed their company strategy in the past three years. (Rearranging their organizational structure has been their lowest priority). However, SMEs that modify their company strategy more frequently (every year or every other year), usually use the pull system rather than the push system. It is true for both, the Supplier's and the Customer's side. They also use up-to-date management tools e.g. VMI or postponement more frequently.

Value
This research shows a backlog of supply chain practices' implementation in Hungarian SMEs. Strategic decision makers should be aware of the challenges SMEs are facing when cooperating vertically or horizontally with other SC member companies. International research benchmarks show that an appropriate strategy change has high impact on the company's performance.

Research limitations/implications
We are aware of the limitations of our research. For example, we didn't distinguish between SMEs acting in the FMCG sector vs. industrial goods sector. The unique structure of the

SME sector in Hungary makes benchmarking results also uncertain. As a next step we would also need to fine-tune the given chain's dominance influencing factor.

Practical Contribution
Findings of this study can be used by strategic-level management in SMEs to better understand what tools their company could use in SCM operation, and whether they need to reiterate their strategy to fit the market's needs in the age of globalisation and time based economy.

INTRODUCTION

In all countries economic growth is strongly supported by SMEs as the backbone of the economy. Few examples of SME contribution are 1) job opportunities 2) being able to act as suppliers of goods and services for large companies and organizations. SMEs in the 'non-financial business economy' in Hungary account for slightly more than half of total value added. It has been observed that SMEs have been the main players in Hungarian economic activities, as they account for more than 99.8% of all companies and employ 69.7% of the Hungarian workforce (SBA Fact Sheet, 2016).

Majority of the SMEs still have simple systems and procedures. They run the business more flexibly, have immediate feedback, short decision-making chain, better understanding of, and quicker response to customer needs compared to larger companies (Singh et al., 2008). SMEs are competing one another from all over the world due to globalization and liberalization which levelled up in the area of world economy. This situation puts SMEs under intense pressure to stay up to date and innovative. Digitalization is one form of globalization that affects almost every aspect of human activities today. This affects not only companies' strategy, but also their communication patterns, work styles, transportation systems, and even the manufacturing processes including Supply Chain Management (SCM) (Schwab, 2015; The Economist, 2012).

Since the biggest proportion of the companies in Hungary are SMEs, the majority of active workforce in Hungary is also employed by them. Additionally due to their significant contribution to the government economy it is important to ensure that SMEs can manage their businesses efficiently. This can be achieved by adopting company strategies matching the current globalization changes in the business environment, and by implementing digitalization in their business processes.

This study will try to examine how SCM affect the strategy creation and modification of Hungarian Small and Medium Enterprises (SMEs), through a review of a questionnaire conducted with Supply Chain (SC) members in SME organizations. In the next section we review relevant literature on our subject and develop our hypotheses on the relation of digitalization, changes in organization strategy and SCM.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Hypothesis is a starting point for further analysis in any research. Several previous researches related to strategies in organizations helped in the development of our hypothesis. In this literature review, we will speak about 4 different hypothesis. Those are organization strategies that relate to globalization, digitalization, supply chain/logistic and push/pull strategy in supply chain system.

Changes in Organization Strategy towards Globalization

Strategy is defined as the adoption of a company towards competitiveness in its environment. Some strategies are more successful in relation to organizational performance than others (Hambrick, 1980). This study focuses on how SMEs change their business strategy in a competitive market in relation to globalization and SCM.

Globalization is a term that is currently on the trend towards a world economy integrated with all dimensions, namely economics, technology, politics and culture (Wagner, 2005). On the other hand, globalization is a growing interdependency in terms of economic growth which includes several actors, namely consumers, producers, suppliers and governments worldwide. Relevance of market boundaries between domestic and international sectors is reduced if their business develops overseas (Gary, 2000). Several researches have shown the effects of globalization in some companies and identified the attributes which it supported in a complex environment. The real issue these companies are facing is how to balance between global integration and local responsiveness (Yongjiang, 2003). Most of SMEs worldwide still have a local mind-set.

Changes in environmental factors greatly affect companies, so there is a strong urge for the organizations to implement changes in their strategy. Strategy development and implementation is the key to SME's success the world of globalization (Porter, 1980). The company’s strategy reflects the short and long term challenges and opportunities within the actual business environment.

For a small scale company the positive effect of changing the strategy is the improvement of their global competitiveness. This happens due to improvements in their product quality and reduction of delivery lead time (Singh, et al., 2010). However, SMEs are facing several challenges related to globalization which also impact their organization’s strategy changes. The areas concerned are more emphasized towards the need for improved management skills, managing their global logistics, dealing with cultural and language differences, increased cost, increased need for regularisation, etc. (Prater and Ghosh, 2005). Several SMEs find that these factors make their organization more stagnant unless they change their strategy. This leads to the following hypothesis:

H1 SMEs don’t pay enough attention to their strategies

In this part, we were focusing on SMEs that have not changed their strategy in 3 or more years or actually they don’t have any strategy at all. To prove that they don’t pay attention to their strategy, we have collected their input about the last time they changed their organization strategy.

Will Digitalization Appear in Your Strategy?

The effects of technology development are characterized by shortened product life cycle, changed market forces and consumer behaviour that make the companies face new challenges on the global competitive landscape (Livari, 2015). The advancement of Internet and Information Technologies impact every aspect in the organization, many business organizations including SMEs started to implement digitalization in their strategy as a tool to improve their market and operational efficiency (Li, et al., 2009).

The positive impacts of the internal organization's digitalization lead to increased efficiency including improved business processes, attaining better accuracy and quality, and consistency by eliminating manual steps. Real time data can be accessed by using digitalization integrating structured and also unstructured data, providing better views on organizational data, and integrating data from other sources (Parviainen, et al., 2017).

This research examines how SMEs include digitalization in their strategy. Some SMEs have a difficult time undertaking digital transformation. Organisations face struggles such as transformation on lower levels which is not accompanied by the top management level, or higher costs of implementing new internal processes reflecting in the product value. Based on these facts, another hypotheses for digitalization is:

H2 SMEs usually do not include digitalization into their strategy

Digitalization is nowadays a strategic priority, it is crucial to set up large scale of initiatives in any organization, society and industry. However, we had an assumption that SMEs still not prioritize it to be inputted in their strategy, rather than other aspects. To measure it, we are asking whether they already include this digitalization in their strategy currently.

Will Supply Chain Appear in Your Strategy?

Global competition is currently rising, therefore it is required for companies to always innovate the process of managing their suppliers. Nurturing good partnerships with suppliers is able to make the company more secure. SMEs are more vulnerable to environmental changes due to limited resources, technology and lower bargaining power which make them less likely to develop compared to big enterprises (Kumar, et al., 2014). In this case, supplier relationship management (SRM) plays definitely a major role in SCM.

Productivity increment that occurs in manufacturing organizations is caused by the implementation of lean production which eliminates unproductive practices within the organization. Former ineffectiveness could have been caused by several aspects, such as poor supplier performance, not sufficiently specified customer demand, and uncertain business environment. Integration carried out by internal organizations with other parties (suppliers and customers or distributors) is referred to as SCM. SMEs have a significant impact on SCM where they can play a role as suppliers, distributors, producers and customers (Singh, et al., 2008).

Based on case studies that occurred in Indian's SMEs, it was shown that several issues can occur due to insufficient management of on supply chain e. g. absence of good indigenous supplier, fluctuating customer demand, necessity to invest in finished goods inventory. However, studies show that SMEs focusing more on internal business and profit maximization, working with limited finance and technological capabilities do not improve their SCM process sufficiently (Thakkar, et al., 2012). Consequently our third hypotheses below:

H3 SMEs generally don't build specific Supply Chain Function into their strategy

It is a fact that SMEs are playing significant role in the country's economy, usually in manufacturing industry, SMEs play the role of a supplier, a vendor or a distributor. They are basically part of big enterprises' supply chain system. However, we had an opinion that they do not consider supply chain when building their strategy. To prove our hypothesis we were asking whether they include supply chain in their strategy or not.

Will Pull System Used by SMEs that Frequently Modify Strategy?

Increased productivity and efficiency are carried out continuously by manufacturing companies with the implementation of new strategies, business processes and IT solutions.

Best practices also allow companies to achieve on-demand manufacturing through the implementation of pull production strategy (Zayati, et al., 2012). Many organizations also race for optimizing their operational costs. The Pull system that focuses more on demand as a drive is able to impact the organization by decreasing their inventory cost, reduce variability faced by manufacturers due to lead time reduction and manage their resource more efficiently (Singh and Ratha, 2016). SMEs that regularly change their organization strategy usually used pull system in their SCM strategy that adequately in line with market changes. Another hypotheses related to SCM is:

H4 SMEs that frequently modify their strategy implemented are more likely to use the pull system in SCM

A general difficulty in management is e. g. the determination of inventory, what to order and when. The type of inventory control system will depend on fluctuation of demand. The pull system can help organizations to have enough inventory, not more not less that required, to meet customer's demand. We assume that SMEs that frequently modify their strategy usually use the pull system in SCM to make sure that their organization can avoid any loss in terms of inventory cost. Based on this, we will do cross tab to see the relationship between the frequency of strategy changes and SCM strategy of suppliers.

RESEARCH METHOD

In order to identify the effects of SCM on SME strategy, this research will conduct an inferential statistical analysis. The sample in this study embraces micro, small, medium companies and large corporations in Hungary. These belong to the industrial fields of production (42,2%), commerce and trade (28%), and services (29,8%). The European Commission defines micro companies as those with 9 or less employees, small companies those with between 10 and 49 employees, whereas companies with between 50 and 249 employees are designated as medium-sized enterprises, furthermore the ones with more than 250 employees shall be called big enterprises (Eurostat: Structural Business Statistics).

Following this definition, a question-based survey was conducted. As SCM is of central importance in the process of corporate strategy change, being the function where corporate strategy change is initiated, therefore the questionnaires are able to capture valuable insider opinions, which can explain how digitalization or globalization affects SMEs. The questions were directed onto the conformity of the companies' "Strategy", their (external) "Supply Chain" and their readiness on "Digitalization". The questionnaire was conducted with strategic leaders of these companies. A cover letter explained the details of the survey, contact information and also instructions for completion of the survey. Respondents were also informed that all information provided would be treated in the strictest confidence and that only aggregated findings would be reported. A selection of 274 companies were interviewed by the students of the Széchenyi István University throughout 4 months in 2018. Those valid responses were collected from Hungarian SMEs, with focus on the highly industrialised North-Western region of the country. The collected data is sufficient to be able to do further analysis and make some conclusions.

Descriptive statistics are used to examine the division by company size. From the total number of companies, we have 30% micro-, 39% small enterprises, 22% medium size and 9% big corporations. The questions aimed to reveal the strengths of the corporate strategy by naming the functions in the organizational chart, as well as the interpretation of the supply chain by defining the time of strategy changes. The analysis of the data acquired was done by empirical analysis (SPSS). We are aware of the limitations of our research. For example, we did not distinguish between SMEs acting in the FMCG sector vs. industrial goods sector. The unique structure (the overrepresentation of micro-enterprises) of the SME sector in Hungary makes benchmarking results also uncertain.

RESULT AND DISCUSSION

Most of the questionnaire involved multiple choice questions. Additionally we asked that respondents to rate their agreement with statements on a 5 point Likert scale (1 = rather not, 5 = yes): "How do you rate your company's strategy-consciousness?" Figure I shows responses, differentiating between the groups of company's size. Considering the high number of respondents, the cross table divided respondents in too many groups, which was not quite suitable for the analysis of the correlation. We decided to set up two categories for the companies, we labelled the first group with employees who marked 1, 2 or 3 on the Likert scale "rather not conscious" group, and the second group indicating 4 or 5 as "rather conscious" of strategy. Based on the amount of responses received for the individual evaluations within the scale, we could detect significance (p =0.013).

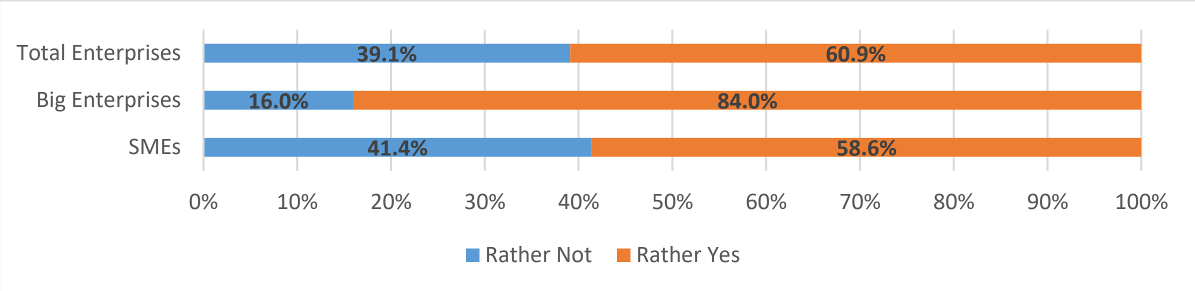

Figure I. Companies' Strategy Consciousness towards Company's Size
(Source: own development)

Based on Figure I, it can be seen that SMEs' rate of strategy consciousness was 58,6%. However, the result was not significantly different compared to the SMEs that were not conscious with their strategy (41,4%). We can summarize that the result did not support H1, nevertheless most of the SMEs were still not rule out strategy for their business. **Therefore, we can accept our first hypothesis: SMEs do not pay enough attention to their organization strategy.**

In terms of digitalization, respondents were asked whether they include digitalization in their strategy or not: "Does the organizational chart include Industry 4.0 or digitalization functions?". The results are shown in Figure II. The response profile suggested that SMEs do not include industry 4.0 or digitalization in their company strategy (77,4%). On the other hand, it can be seen that big enterprises are more likely to consider industry 4.0 or digitalization into their strategy (64,0%). The result was found quite significant (p=0.000007). **This finding supports our second hypothesis that states digitalization is not included in the organization strategy.**

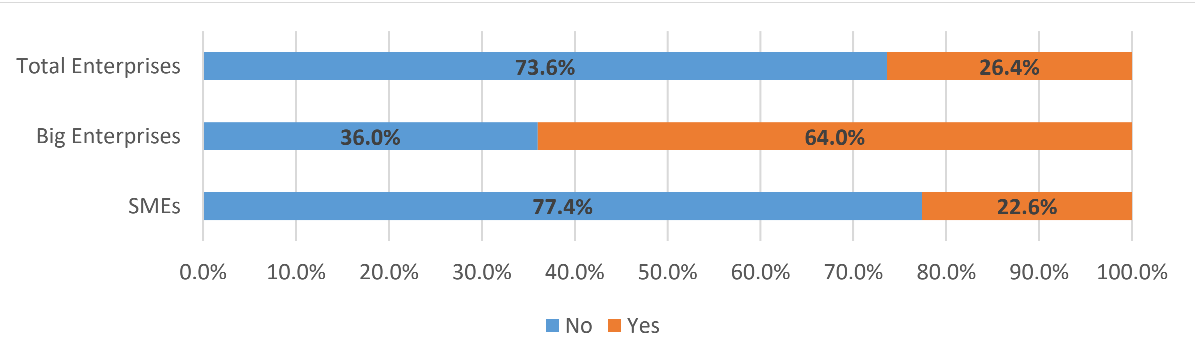

Figure II. Strategy of Industry 4.0 or digitalization towards Company's Size
(Source: own development)

According to our third hypothesis, we have asked whether SMEs build specific Supply Chain Function in their organization strategy or not. The related question was "Does your strategy include logistics and/or supply chain chapter or sub-chapter?" Based on Figure III, it is visible that 55.6% of SMEs do not have these chapters/sub-chapters in their strategy. On the other hand, we can also see that 72% of big enterprises have considered supply chain/logistics to be part of their strategy. The larger size of the company, the more aware on Supply Chain Function to be included in their organization strategy. At this point, we can summarize (p=0.008) that **our third hypothesis is relevant: SMEs generally don't build specific Supply Chain Function in their strategy.**

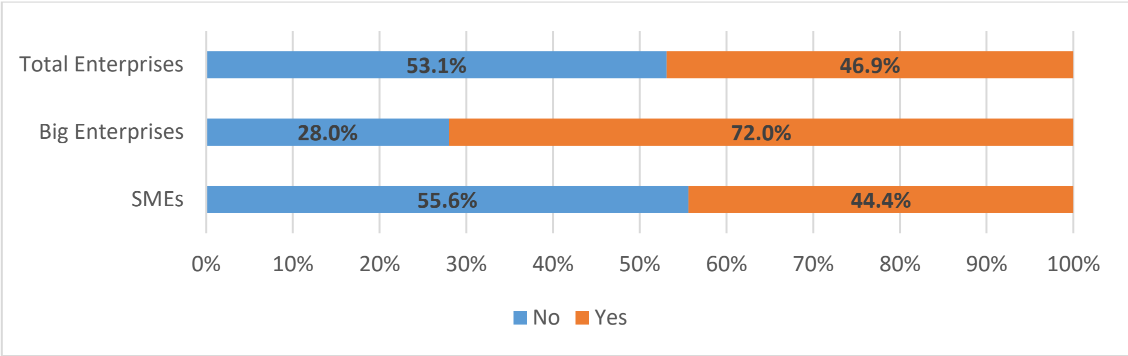

Figure III. Strategy of Supply Chain/Logistics towards Company's Size
(Source: own development)

Since the normal variance was not adequate during the analysis about those SMEs that frequently change their strategy assume pull system in SCM, we presented the results using the Kruskal-Wallis test. This non-parametric statistical procedure is based on a hypothesis test to assess whether some samples can be derived from the same distribution (Spurrier, J.D., 2003). The significant Kruskal-Wallis test shows that at least one sample has a stochastic dominance over another sample (i.e. if one of the two groups is randomly excluded, the chance of which group is 50-50% is significantly different) is removed.

In this case the nominal variables will be the answers to the question "When was the last time the company's strategy changed substantially?" The answers are denoted "lately" (1, 2 years ago, or using rolling strategic plan), and "long time ago" (3 or more years ago). The ratio variable will be the numerical value given for the question: "Approximately how many percent of the suppliers deliver according to pull system or push system?" Examining both versions, we considered the normal distribution of these data, as variance analysis works only with normal distribution. In this case, we cannot talk about normal distribution because the mean is smaller than the median, so the distribution is asymmetric on the right. The skewness (-0.294) furthermore the kurtiosis (-1.251) confirms it in Figure IV.

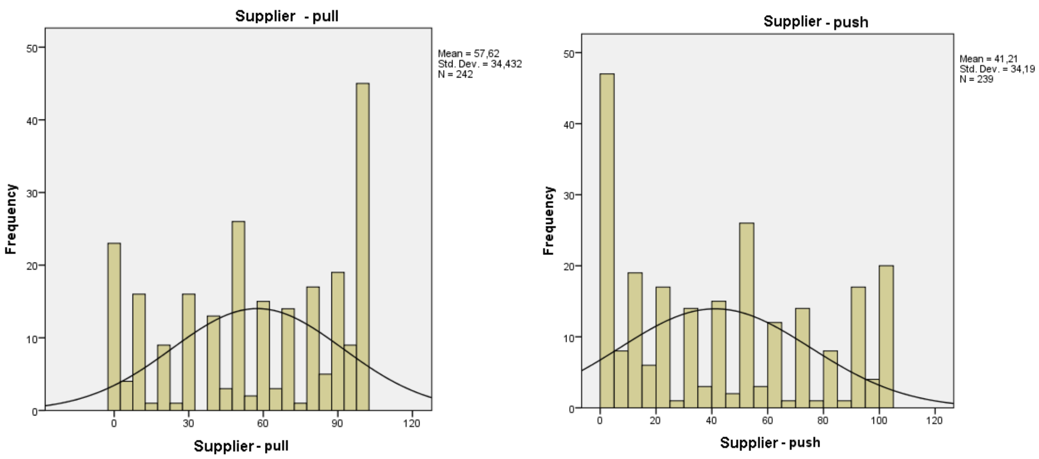

Figure IV. Distribution of supplier strategy
(Source: SPSS)

According to the Kruskal-Wallis correlation study, none of these are significant. In this case, **we rejected our fourth hypothesis. Those SMEs that often change their strategy are not necessarily operating with pull system in SCM.**

CONCLUSION

Benchmarking the SMEs Company's strategy reveals an interesting paradox towards SC and digitalization implementation. The survey findings reveal that SMEs in Hungary still do not pay enough attention to their company strategy compared to larger business, especially SC and the digitalization function. This finding has been well supported by a previous study by Fawcett, et al. (2009) stated that SMEs are not actively pursuing SCM as a strategic weapon. However, this current result still does not change their competitive advantage in the market, showing that SMEs are still part of the big SCM loop, whether they are in the role of supplier, distributor or retailer.

Our study offers three contributions: First, this study is among the few to research the relation between a company's strategy, its SC and digitalization functions. Importantly, we investigate a setting with more detail of pull or push strategy in its SC system. Several findings above should become a benchmark for decision makers. They should be aware of the challenges SMEs are facing when cooperating vertically or horizontally with other SC member companies. International research benchmarks show that an appropriate strategy change has high impact on each company's performance. Secondly, practical implications can be used by strategic-level management in SMEs to better understand what tools their company could use in SCM operation, and whether they need to reiterate their strategy to fit market needs in the age of globalisation and time based economy. Thirdly, this research contributes to the enhancement of study related to SMEs business management in Hungary.

When interpreting this study's findings, its limitations should also be considered. We didn't distinguish between SMEs acting in the FMCG sector vs. industrial goods sector. The unique structure of the SME sector in Hungary makes benchmarking results also uncertain. It will lead to future research that the research will need to fine-tune the given chain's dominance influencing factor.

Another idea of future research is the enhancement of research methodology by including refined methodology. Triangulation could also bring additional considerations in future research. It is a powerful technique that facilitates validation of data through cross verification from two or more sources. To elaborate insights and experiences we could use qualitative method of case study or small group discussions with practitioners working in enterprises. This way we could make sure that quantitative result from this study is also being verified by practitioners.

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Session 2: Applications of ICT in Supply Chains

THE ROLE OF ORGANIZATIONAL META-KNOWLEDGE FOR CYBER-PHYSICAL SOCIAL SYSTEMS IN INDUSTRY 4.0

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Purpose
One of the central ideas of Industry 4.0 is to increase flexibility. This involves collaboration of artificial decision-makers (intelligent agents) and human workers in cyber-physical social systems (CPSS). Information systems supporting those work processes must become cyber production management systems to provide knowledge for socio-digital coordination.
Knowledge includes capabilities for accomplishing tasks and an overview of the process and organization structure (knowing who knows what). The latter is known as organizational meta-knowledge which is crucial for coordinating distributed work involving multiple parties with different capabilities. We identify the necessity of meta-knowledge in CPSS from an interdisciplinary perspective of business informatics and organizational psychology. This paper reviews research on work process planning according to where meta-knowledge is generated or needed to facilitate developing new assistance technologies for CPSS.

Design/methodology/approach
Conventional production achieves process performance through division of labor by specialization. Manufacturing lines coordinate teams of specialized workers in repetitive processes. However, Industry 4.0 introduces flexibility to increase efficiency (throughput maximization, cost and effort minimization) and reliability (robustness against failure). From an organizational psychology perspective, specialized teams only work efficiently if they have common meta-knowledge. Flexibility changes the required meta-knowledge as roles become re-assigned and task-related knowledge becomes re-located. Thus, it is crucial to provide teams with up-to-date meta-knowledge about process and role organization.

Findings
Three major planning and scheduling procedures affect knowledge. Given a workforce, qualification management(1) provides workers with the capabilities to perform required tasks. It includes hiring staff, buying machinery, training employees, or providing assisting technology to guide workers through unfamiliar tasks. In CPSS, capabilities should also include knowledge about how to interact in teams including artificial agents.
Knowledge requirements result from shift planning(2) which assembles teams that cover a set of roles with the required team members' capabilities. Since cooperation requires meta-knowledge about capabilities of others to ensure process efficiency/reliability, shift planning in CPSS must account for and provide that meta-knowledge.
The resulting team compositions constrain the optimal scheduling of jobs(3) to teams of workers with given capabilities. In CPSS, meta-knowledge must be provided to human and artificial decision-makers and updated in the case of role changes and re-scheduling of tasks to maintain robustness against failures.

Value
The human perspective in socio-digital teams is currently underrated in optimization, planning, simulation, and information systems design. We point out where to extend

research and technology based on psychological findings to develop insights and tools for knowledge management in CPSS for researchers and practitioners.

Practical Contribution

Assistance systems providing task-related knowledge must be extended with team coordination functionalities including meta-knowledge. Human-agent-interactions with those systems must be evaluated in experiments, simulations, and field tests

INTRODUCTION

One of the central ideas of Industry 4.0 is to increase flexibility and robustness in interconnected manufacturing and logistics processes through adaptation [1]. By means of distributed process control (e.g., cyber-physical and multiagent systems) [2] as well as smart assistance technologies (e.g., augmented reality) [3], new opportunities arise for reacting to system changes. These changes can be caused by internal or external dynamics like non-availability of workers and machines or changes in demand and supply. For example, material flows can be re-routed and manufacturing processes re-scheduled dynamically by means of negotiation, local decision-making, and self-organization [4]. This allows for fast adaptation of work processes involving both artificial decision-makers (i.e., intelligent agents) and human workers using a common information system infrastructure to keep track of tasks, roles, and processes in a dynamic organization.

However, adaptivity in manufacturing requires extensive effort for coordinating distributed and partly autonomous processes. Involving both artificial agents and human workers, these are not only cyber-physical, but *cyber-physical social systems* (CPSS) [5]. Information systems supporting those work processes must account for that fact. They must become *cyber production management systems* [6] which provide all parties involved with the required knowledge for successful coordination and adaptation.

In logistics and manufacturing, knowledge refers to the required capabilities for accomplishing a task as well as to a certain overview of the overall process and organization structure that task is located in. The latter is known as *organizational meta-knowledge* which is crucial for coordinating distributed work involving multiple parties with different capabilities [7]. This paper focuses on the role of meta-knowledge in CPSS from the interdisciplinary perspective of business informatics and organizational psychology. From that perspective, both the technical side of autonomous production systems and the cognitive side of teams as knowledge processing entities are combined to contribute to the design of information system infrastructures for Industry 4.0.

In particular, this paper identifies the necessity to support organizational meta-knowledge with information systems in dynamic CPSS. This leads to the research question of how to design such knowledge management information systems in a distributed decision-making environment. The paper reviews research on work process planning according to where meta-knowledge is generated or needed to facilitate developing new assistance technologies for CPSS. To that end, it identifies three major planning and scheduling procedures which affect knowledge in Industry 4.0, discusses existing work in that context, and points out challenges for developing future information systems for CPSS.

Consequently, the remainder of this paper focuses on the analysis phase in the process of design-oriented research in business informatics [8]. The following section introduces an example application in Industry 4.0. It provides an analysis of the requirements of that example with respect to knowledge management for human and artificial decision-makers from an interdisciplinary point of view. From that perspective, the section points out the role of meta-knowledge for successful coordination in cyber-physical social systems. It reviews work in qualification management, shift planning, and job scheduling to identify challenges for knowledge management in CPSS. The subsequent and final section then summarizes those findings and points out their implications for developing information systems for CPSS in Industry and Logistics 4.0.

KNOWLEDGE MANAGEMENT IN INDUSTRY 4.0

Industry and Logistics 4.0 approaches are characterized by adding autonomy and self-organization to manufacturing processes in order to increase their flexibility and robustness. To that end, such approaches utilize technology like the Internet of Things, multiagent systems, and augmented or even virtual reality to create cyber-physical systems in which physical components are enhanced by decision-making capabilities.

For example, at the time the term *Industry 4.0* was coined [1], Ganji et al. presented a flexible manufacturing approach for automotive tail-lights that uses those technologies [9]. In their case study, artificial agents represent both individual products as well as assembly stations. To add flexibility to the manufacturing process, the product agents are free to decide which final product variant their represented physical object should become, depending on the current demand for each variant. They can even react to demand changes during the assembly process and change their decisions. Additionally, the system gains robustness by allowing for dynamic reallocation of assembly orders to an alternative station if one or more stations become unavailable. Consequently, the described example demonstrates how autonomous logistics control can transform a conventional *production line* into a flexible *assembly network* as depicted in Fig. 1.

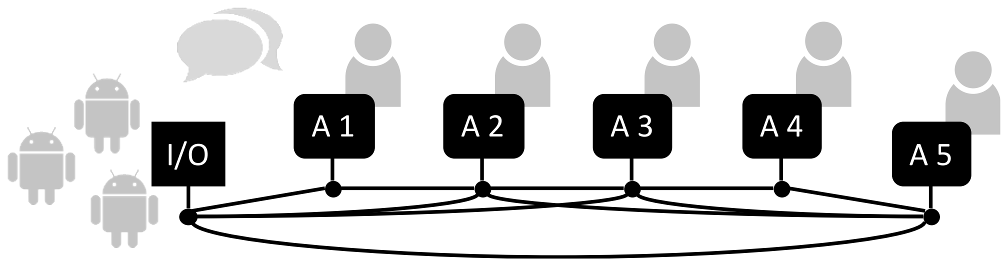

Figure 1. Example assembly network consisting of an input/output, five assembly stations, as well as connections between them

Nevertheless, Fig. 1 also shows that the described example process is not fully automated. Instead, human workers perform the actual assembly which is the case in most real-world logistics and manufacturing scenarios. These workers have to cope with the increased flexibility, making the overall manufacturing process less intuitive and foreseeable. If a station becomes unavailable or product demands change, a worker will be faced with changing assembly orders. Additionally, they might have to step in for and support their colleagues to ensure the overall system’s capability of processing these orders. To that end, coordination between human workers and artificial agents is necessary, making the cyber-physical system in fact a *cyber-physical social system* [5].

The requirement for coordination and flexibility has drastic impacts on organizational roles and knowledge management in CPSS. Workers need to have the required capabilities to process different tasks and possibly switch between them on. Moreover, they need to coordinate and form hybrid teams comprising both human co-workers as well as artificial entities. From this perspective, workers play an active role in controlling manufacturing and logistics processes which is one of the core ideas of Industry 4.0: Instead of being governed in their work by automation, humans should be enabled by technology to gain better control of their work processes. This, however, necessitates an understanding of human teamwork as well as its challenges in order to facilitate designing such technology. Thus, we adopt an interdisciplinary point of view including *organizational psychology* and *business informatics* in the following sections to analyze knowledge management, its challenges, and related concepts for CPSS in logistics.

Organizational Roles and Meta-Knowledge in Cyber-Physical Social Systems
In Industry 4.0, flexibility is introduced into manufacturing and logistics to increase efficiency (throughput maximization, cost and effort minimization) and reliability (robustness against failure). From an organizational psychology point of view, these performance factors are directly affected by role and knowledge structures within teams of workers as they have major impact on their ability to successfully coordinate their activities. As Timm et al. point out [10], *knowledge* refers to the required capabilities as well as to the availability of information to conduct specific tasks. Such knowledge can either be shared among team members (generalists) or it can be divided between them (specialists). This distribution or division of knowledge in teams affects a team's task-processing efficiency, coordination, potential information overload, and its resilience against disturbances [11]. While *specialist* (divided) knowledge can enhance the efficiency by division of labor, *generalist* (shared) knowledge increases a team's ability to cope with disturbances by means of redundant capabilities.

In the aforementioned logistics example application, knowledge and labor is largely divided between the workers as they perform specialized tasks at the different assembly stations. Nonetheless, some tasks can be substituted with others to compensate for non-available stations by slightly changing product configurations. Thus, workers can step in for each other as they also possess a certain amount of overlapping capabilities; i.e., shared knowledge. This shows that knowledge is closely related to the *organizational roles* of different workers [12]: Their assigned roles define their tasks within the organization which, in turn, result in specific knowledge requirements. Vice versa, a worker's actually available knowledge can restrict them to certain roles or enable them to switch between roles for increased organizational adaptivity.

However, specialized teams can only work efficiently if these teams have *common meta-knowledge* about the organizational structure and the distribution of task-related knowledge. Workers can only assist and step in for each other if they know their co-workers' tasks and roles in the process; i.e., with whom to coordinate in what manner. Such a *transactive memory* provides a shared context for the performance of divided tasks [13]. It contains knowledge about the location of expertise (*knowing who knows what*) which facilitates coordination and further specialization [14]. Moreover, a transactive memory increases both a team's performance in dynamic environments (which is crucial for adaptive and flexible CPSS) and its ability to include new members [15].

In fact, the preceding considerations hold for both human and artificial team members. In the application example, the agents representing products and assembly stations must know with whom to coordinate the products' routes through the manufacturing network in order to maintain a correct assembly sequence as well as to avoid congestions, material shortages, and idle times. In conventional production, Fordian manufacturing lines serve as a physical device for coordinating teams of highly specialized workers in repetitive processes; i.e., they embody meta-knowledge about tasks and their sequences in their physical configurations. However, if external demand changes or a station becomes unavailable in CPSS, schedules must be adapted which potentially leads to changing roles of workers at other stations (i.e., alternative tasks must be performed in compensation). This also changes the required meta-knowledge of workers as roles become re-assigned and task-related knowledge becomes re-located. Thus, it is crucial to provide teams with up-to-date knowledge about the current process and role organization. To that end, the following section presents existing work and challenges for knowledge management in CPSS from a business informatics perspective.

Managing Knowledge in Industry 4.0: Objectives and Challenges
With respect to the preceding discussion, existing work can be grouped by three major planning and scheduling procedures which affect work processes as depicted in Fig. 2. Given a particular workforce, *qualification management* has the task of providing workers with the capabilities to perform required tasks. These requirements result from regular

shift planning activities which take the composition of workers' capabilities as input for forming teams with specific role assignments for each member. In turn, team compositions constrain the *scheduling of jobs* for manufacturing and logistics: efficient and reliable processes require teams of workers with specific capabilities.

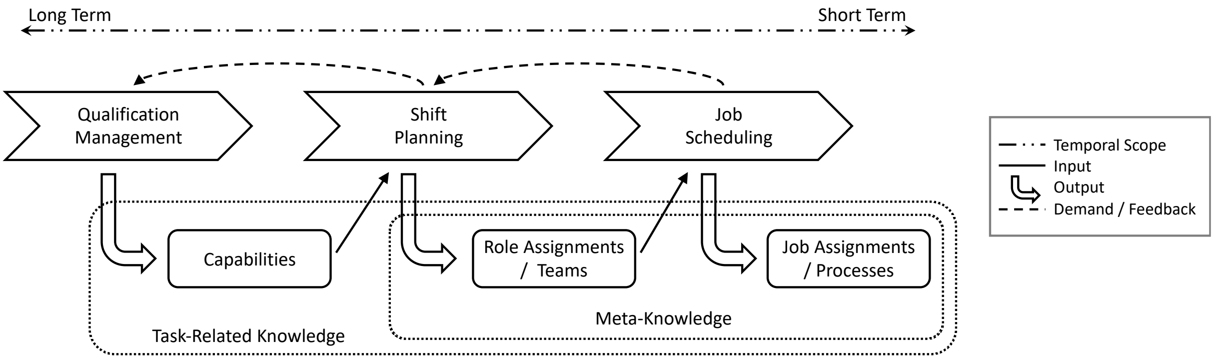

Figure 2. Planning and scheduling processes which affect knowledge management in Industry and Logistics 4.0

Qualification Management and Capabilities. To conduct any work in manufacturing and logistics, it is necessary to have the right composition of staff with the required capabilities. Qualification management provides personnel with task-related knowledge of *how to do things*. This can be achieved by hiring specialized staff and buying new machinery, by training existing employees, or by providing them with assisting technology. In Industry 4.0 and CPSS, the latter is discussed. In particular, augmented reality (AR) systems have been proposed to support workers in dynamically changing environments and guide them through unfamiliar tasks [3]. As Quandt et al. show [16], these tasks can range from process modeling and product development, over production processes and navigation, to quality control and maintenance [17-19].

However, in CPSS, qualification management refers to the capabilities of both artificial agents and human workers. In the example, product agents must be capable of navigating and coordinating their actions with the station agents. If demands change or a station becomes unavailable, they must re-schedule their processes through communication [20]. The challenge for information systems to assist human workers is to share information not only between personnel but also with artificial agents and vice versa. Otherwise, processes can become incomprehensible which endangers their reliability.

Shift Planning and Role Assignments. Since work processes consist of different tasks, workers form teams in which these tasks are connected to specific roles. Each role is defined by a set of tasks a person filling that role is supposed to perform [12]. The problem of assigning roles to the available workforce is known as the *nurse scheduling problem* in which teams must be assembled that cover a set of required roles with the team members' capabilities [21]. For instance, a team with five different assembly roles as well as station and product agents are required in the example. In CPSS, roles and team formation have been primarily researched for structuring multiagent systems. These techniques draw inspiration from human organizations, ranging from rigid *hierarchies* and more flexible *holarchies* to dynamically established *teams* for particular tasks [22-23]. Selecting an appropriate organizational structure is crucial for effective and efficient multiagent coordination, particularly in dynamic environments [24].

Nonetheless, as pointed out above, cooperating in a team with distributed roles requires meta-knowledge about the capabilities of other team members to ensure process efficiency and reliability. Multiagent researchers have identified this need and developed methods for agents to reason about the capabilities of their counterparts and to integrate them into an organizational structure for the tasks at hand [25-26]. Still, this meta-knowledge has to be shared with others, especially in hybrid teams of humans and artificial agents. Therefore, a challenge for information systems in CPSS is to provide not only task-related knowledge but also meta-knowledge for successful teamwork.

Job Scheduling and Job Assignments. Given established teams, actual jobs and tasks must be scheduled and assigned to team members to be performed at specific time instances. Finding the best sequence of jobs to be assigned to workers or machines is known as the *job-shop-scheduling problem* [27]. While there are numerous algorithms for job-shop-scheduling in operations research [27], the inherent distribution and dynamics of CPSS necessitates solutions based on communication which allow for distributed decision-making and re-scheduling of tasks in case of changing conditions. In fact, distributed planning and process monitoring is one of the classic research areas in artificial intelligence and multiagent systems [28]. In this context, negotiation-based task assignment, combinatorial auctions, and self-organization techniques have been successfully applied to decentralized manufacturing control and logistics [4].

Nevertheless, distributed work process planning and control, again, requires meta-knowledge about roles and capabilities. As Timm et al. demonstrate [10], specialized teams with meta-knowledge perform better in distributed job-shop scenarios than generalized ones. Hence, the required meta-knowledge must be provided to the team and updated in the case of role changes and re-scheduling of tasks to maintain robustness against failures. When human and artificial decision-makers work together, both need access to this knowledge. From an information systems perspective, the challenge amounts to where meta-knowledge should be stored and how it can be updated.

CONCLUSIONS AND IMPLICATIONS

This paper has identified the role of organizational meta-knowledge in cyber-physical social systems for flexible production and logistics in Industry 4.0. It has adopted an interdisciplinary perspective of business informatics and organizational psychology to analyze knowledge management requirements for successfully coordinating distributed activities. Using an Industry 4.0 example, the paper has shown where task-related knowledge and meta-knowledge is required and provided in qualification management, shift planning, as well as job scheduling. In that context, the challenges for knowledge management are to explicate task-related knowledge and process information in hybrid teams of human workers and artificial agents (*who is capable of which task?*), to achieve the same for organizational meta-knowledge (*who is responsible for which task?*), and to provide this knowledge where it is required when it is needed (*who is currently available for which task?*). To the latter end, a dedicated infrastructure is necessary which facilitates sharing both task-related and meta-knowledge between human workers and artificial agents in Industry 4.0.

The technologies to provide task-related knowledge in practical applications are readily available in the form of knowledge brokers [29], the Electronic Product Code Information Services (EPCIS) in the Internet of Things [30] or the Directory Facilitator in multiagent systems [31]. Nevertheless, the human perspective in socio-digital teams is underrated in optimization, planning, simulation, and information systems design. Current approaches to Industry 4.0 mainly focus either on complete automation or on assistance systems for providing task-related knowledge to human workers. These latter systems should additionally be extended with team coordination functionalities to include organizational meta-knowledge. As this paper has shown, meta-knowledge is crucial for successful coordination between specialist workers and agents. Therefore, interactions of humans with such systems must be evaluated in experiments as well as field tests. Only if human workers can gain control over their constantly adapting work processes, they will be able to cope with ever increasing flexibility and change. This is the central challenge for information systems design in Industry 4.0 on its way toward human-centric cyber production management systems.

ACKNOWLEDGMENTS
This work has been conducted within the interdisciplinary project AdaptPRO: Adaptive Process and Role design in Organisations (TI 548/-1). It is funded by the German Research Foundation (DFG) within the Priority Program "Intentional Forgetting in Organisations" (SPP 1921).

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ELECTROMOBILITY AND DIGITALIZATION: DO AUTOMOTIVE SUPPLY NETWORKS ADAPT IN REVOLUTIONARY OR EVOLUTIONARY PATTERNS?

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ABSTRACT

Purpose of this paper:
Two major trends, electric mobility and digitalization, are going to transform the automotive industry. Car manufacturers and suppliers alike are under increasing pressure to adapt to these trends. This paper shows how German car manufacturers and their suppliers assess electric mobility and digitalization in terms of supply network adaptability. It is discussed if these trends follow evolutionary or revolutionary patterns.

Design/methodology/approach:
Adaptation can be seen as a process of evolution – in natural ecosystems as well as in supply networks. Evolutionary Economics and Punctuated Equilibrium are combined into a theory framework to analyze the adaptation processes of German automotive supply networks. Data has been collected in four in-depth interviews with managers of German car manufacturers and tier-1 automotive suppliers, respectively.

Findings:
Both car manufacturers and automotive suppliers see electric mobility as a trend that is still in an equilibrium and can be dealt with slower, gradual modes of adaptation. However, some experts have the opinion that this will only work until a tipping point is reached. In contrast, the impact of digitalization on automotive supply networks is much less clear. While some experts see a distinct revolutionary impact on the supply networks which requires an abrupt adaptation to new scenarios, others follow a more conservative view assuming a longer time allowance for supply networks to adapt gradually. The data suggests that the former have a focus on the connected car/autonomous driving, while the latter are following a more general approach that also includes "smartphone-on-wheels" concepts. Irrespective of the impact on a company's products, digitalization changes the way a company works internally and collaborates with both its supply network and its customers. Both car manufacturers and tier-1 suppliers agree that the supply networks enjoy long phases of relative stability. Trends requiring a rapid, fundamental adaptation are rare. This suggests that the theory framework that combines Punctuated Equilibrium and Evolutionary Economics is a promising toolset for analyzing the adaptation of supply networks.

Value:
This paper presents empirical insight from the automotive industry on how car manufacturers and tier-1 suppliers prepare to cope with the trends of electric mobility and digitalization. To the best of our knowledge, this paper is the first attempt to combine Punctuated Equilibrium and Evolutionary Economics into a conceptual model for the adaptation of supply networks as a response to fundamental changes.

Research limitations/implications:
It needs more empirical data, from case studies for instance, to develop a more detailed conceptual model of how supply networks adapt to long-term, fundamental changes.

INTRODUCTION

Germany is one of the largest car manufacturers in the world – and the automotive industry is of high macroeconomic importance to the country: It is responsible for about half the German trade surplus (DESTATIS, 2017a), is the country's strongest exporter with a share of 18% (DESTATIS, 2017b), and employs close to 830,000 people (DESTATIS, 2017c). In its 2016 annual report, the Association of the German Automotive Industry (VDA) names two major trends – electric mobility and digitalization – that are transforming the industry and pushing it into a "*new networked world of mobility*" (VDA, 2016). A recent market survey sees a strong growth of electric powertrain solutions bringing suppliers for the conventional powertrain under increasing pressure against a general background of growing volatility in the automotive market (Berret *et al.*, 2016). To cope with these structural changes, automotive manufacturers have to develop new supply chain concepts (Klug, 2013; Klötzer and Pflaum, 2017).

According to Lee (2004) successful supply chains have three main features: *adaptability* (coping with long-term structural shifts in the market), *agility* (adapting to disturbances and short-term demand fluctuations), and *alignment* (getting all involved partners to be committed to a joint supply chain target system). As both electric mobility and digitalization could lead to structural changes in the market, the adaptability of automotive supply chains is in great demand.

Adaptation can be seen as a process of evolution – in natural ecosystems as well as in supply chains. Hence, frameworks using concepts of the theory of evolution could be useful to better understand mechanisms of adaptation in supply chains, e.g. Evolutionary Economics (Nelson and Winter, 1982) and Punctuated Equilibrium (Eldredge and Gould, 1972), both proposed for this purpose by Ketchen and Hult (2007). In this paper, we will combine these concepts into a theory framework to analyze how German OEMs and tier-1 suppliers cope with electric mobility and digitalization.

The rest of the paper is organized as follows: The literature review focuses on (1) outlining mechanisms of adaption in supply chains and (2) describing the challenges of electric mobility and digitalization from a supply chain perspective. Then, a theory framework is established than combines Punctuated Equilibrium and Evolutionary Economics. The results from four in-depth interviews, which have been conducted with managers of two OEMs and two tier-one suppliers, are presented. The paper ends with drawing conclusions from these interviews and outlining directions for further research in this area.

LITERATURE REVIEW

Adaptation is the process to facilitate survival under changing environmental conditions (Chakravarthy, 1982). In the supply chain context, the term adaptation is not used consistently (Eckstein *et al.*, 2015). Chan and Chan (2010) define adaptation as a mechanism to cope with supply chain uncertainties. Chan (2003) suggests that adaptability is a special form of flexibility that allows a supply chain "*to respond to diversity or change*", without making any restrictions on the type of change. Stefanelli et al. (2015) define adaptability as the ability to follow a specific target without losing the ability to pursue other targets at the same time, e.g. by being able to compete on both price and availability of goods at the same time (Christopher and Towill, 2002). In this paper, we follow Lee's (2004) definition, which clearly distinguishes between short-term flexibility (agility) to cope with, for instance, demand volatility or supply shortages and long-term flexibility (adaptability), i.e. adjusting a "*supply chain's design to meet structural shifts in markets; modify supply network to strategies, products, and technologies*". Adaptability has a strategic focus (Hülsmann *et al.*, 2008) and requires sensing fundamental changes in the market environment as well as being able to adjust the supply chain’s configuration accordingly (Eckstein *et al.*, 2015). If necessary, past best-practice processes and legacy structures must be abandoned (Ketchen and Hult, 2007) in order to regain competitive advantage (Tuominen *et al.*, 2004; Dubey *et al.*, 2018).

The extant literature has collected many factors that have an impact on the adaptability of a supply network, such as supply chain visibility (Dubey *et al.*, 2018), information systems that support the identification of fundamental changes in the market environment (Ketchen and Hult, 2007), establishing supply chain portfolios instead of single supply chains (Seifert and Langenberg, 2011), the ability to evaluate the needs of ultimate consumers rather than direct customers (Lee, 2004), common standards in the supply network that support smooth interaction (Reeves and Deimler, 2011), flexible product designs (Lee, 2004), innovativeness (Eckstein *et al.*, 2015), and a “built-in”, structural flexibility in the supply network (Christopher and Holweg, 2011).

Chakravarthy (1982) distinguishes three states of adaptation: (1) ignoring the changing environment, (2) reacting to the changes in environment, and (3) anticipating the changes. In the latter state, scenario building and monitoring the supply network’s environment for critical shifts are fundamental for adaptation. When a shift is detected and a scenario becomes relevant, adaptation can be prepared and subsequently implemented to again reach a stable operation of the supply network (Stefanelli *et al.*, 2015). Marin-Garcia et al. (2018) have suggested a scale for supply chain adaptability that uses eight variables: (1) accommodation to changes in demand volume, (2) accommodation to changes in production mix, (3) assessing production technology life-cycles, (4) use of leading-edge technology in manufacturing plants, (5) monitoring of global economies for potential new markets, (6) considering the needs of both immediate and ultimate customers, (7) monitoring of global economies for new suppliers, and (8) understanding the suppliers’ distribution process.

The trend to electric cars is changing the supply chains of automotive manufacturers: Even though electric cars might share body and chassis modules with cars driven by combustion engines, the powertrain (engine, gearbox, differential, and drive shaft) is quite different (Günther *et al.*, 2015). Some of a car’s most sophisticated mechanical systems are replaced by much simpler ones (e.g. the combustion engine by an electric motor) or even become completely obsolete (the gearbox, for instance). On the contrary, electric cars have much more electronic components. The battery system is a supply chain challenge because it requires metals like lithium or cobalt, which are in limited supply (Olivetti *et al.*, 2017). Also, mining these metals imposes huge risks on the environment (Steinweg, 2011) while their criticality for the battery supply chain brings sociopolitical as well as geopolitical risks. According to Bill Russo of Automobility, a Shanghai-based consulting firm, the pure size of the Chinese market and the Chinese government’s strong support for electric mobility on both the supply side and the demand side have the potential to “*suck the world’s [electric-vehicle] supply chain into China*” (N.N., 2019).

Digitalization has two perspectives: (1) digitalization of manufacturing and supply chain processes and (2) digitalization of the product. While the former perspective has been covered in the literature in great detail, the latter one has been discussed much less. In the past years, electronics in cars have changed from various uncoupled electronic control units to highly integrated in-car networks. The vision today is the “*connected car*” interacting with other vehicles and roadside infrastructure via both built-in and brought-in smart devices (Coppola and Morisio, 2016). The emergence of apps in the car, a “*smartphone on wheels*” (Werle, 2015), can be traced to various reasons such as (1) the ongoing trend to be always connected and rely on services mediated by apps (Hofmann *et al.*, 2014), (2) IoT-approaches to improve driving comfort and increase safety by monitoring relevant parameters like tire pressure (Zhang *et al.*, 2016), or (3) business models aiming at making use of automotive “big data” (Murphy *et al.*, 2013).

Dealing with app developers as suppliers is a new challenge for the automotive industry. First, app markets tend to be diverse and less controllable because apps can be built and distributed in various ways, which might lead to a loss of technical control (Lengyel *et al.*, 2015). Also, the innovation models are based on co-creation and open-innovation approaches (Dametto, 2018) to an extent that is unknown for any other component or system of the car. Lastly, the business models that can be built on the "connected car" vision seem to be very diverse and are not yet fully understood (Mikusz *et al.*, 2017).

THEORY FRAMEWORK OF THE STUDY

Over the years, the ongoing externalization of operations has led to supply networks as the predominant way of organizing the production of goods (Harland, 1996). Several authors, e.g. Choi et al. (2001), Surana et al. (2005) and Pathak et al. (2007), have suggested to use the theory of complex adaptive systems (CAS) as the underlying theory of supply networks. Holland (1992) defines CAS as large systems with many simultaneous interactions and three main characteristics: "*evolution, aggregate behavior, and anticipation*". Evolution is the basic means of adaptation, and "aggregate behavior" underpins that, in the supply network context, the appropriate perspective is not the isolated view on individual stakeholders but a holistic view on the supply network as an entity. Its stakeholders anticipate structural shifts in the market and, by their response, trigger a feedback mechanism that impacts the market situation.

For this paper, we assume that adaptation of supply networks can be explained using a combination of Punctuated Equilibrium and Evolutionary Economics (fig. 1), as suggested by Ketchen and Hult (2007). Punctuated Equilibrium (PE), developed by Eldredge and Gould (1972), assumes stability as the normal state of an ecosystem. The ecosystem works on maintaining the stable state, the equilibrium, but rare dramatic events in the environment can bring it out of balance (punctuate it). The ecosystem responds with new species that adapt to the new environment and subsequently finds a new equilibrium. PE emphasizes a discontinuous change process: In the equilibrium phase only small, incremental improvements are made while the organization's deep structure (core beliefs and values; products, markets, technology, and competitive timing; distribution of power; and organizational structure and the nature of its control system) remains untouched (Prevel Katsanis and Pitta, 1995). The deep structure only changes in the revolutionary phase following the punctuation: Then, a strategic reorientation (Tushman and Romanelli, 1985) is necessary to regain competitive advantage.

Evolutionary Economics (EE), developed by Nelson and Winter (1982), deals with selection pressure in markets. Resembling natural selection in ecosystems, supply networks that do not respond with appropriate innovations to the changing environment risk their survival (Geels, 2014). EE comprises three concepts: (1) *organizational routine*, i.e. well-proven behavioral, process and technological patterns, (2) *search*, i.e. continuously evaluating the organizational routine and looking for better alternatives, and (3) *selection environment*, the markets in which an organization operates under mutual influence (Nelson and Winter, 1982). "*Adaptation through selection*" is a process in which innovation increases diversity, while selection due to, for instance, competition and regulation reduces it. The literature shows only a few applications of EE in the supply chain field, for instance to logistics capabilities that provide competitive advantage (Olavarrieta and Ellinger, 1997), outsourcing (Mahnke, 2001) or the management of sea ports (Notteboom *et al.*, 2013).

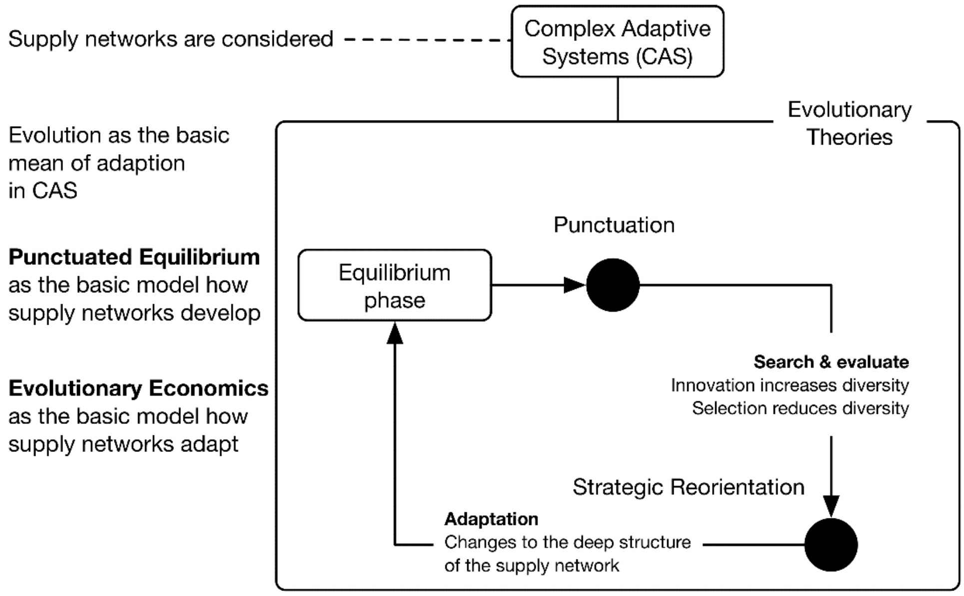

Figure 11: Theory framework

RESEARCH METHODOLOGY AND DESIGN

Data was collected in four in-depth interviews in the German automotive industry: two with senior managers of carmakers (labeled OEM-A and OEM-B, respectively), two with senior managers and executives of tier-1 suppliers (T1S-A, T1S-B). All interview partners are responsible for strategic supply network design and management. A field manual guided the interviews, which was prepared on the basis of both literature review and theory framework. The field manual comprised three main sections: (1) How do supply networks adapt? (2) Does the theory framework fit into this picture? and (3) How does the firm respond to electric mobility and digitalization, respectively? The interviews were conducted and audio-recorded between October 2017 and March 2018. The transcriptions were processed with qualitative content analysis (Mayring, 2000) using the *QCAmap* online tool with a two-step coding process (initial coding table, which was then complemented inductively).

ANALYSIS OF INTERVIEWS

T1S-A is one of the largest German automotive suppliers. On the one hand, the firm aims at reducing process-related complexity by centralizing supply network decisions and harmonizing IT systems, on the other hand the complexity of collaboration is increased, e.g. by a higher degree of specialization and cultural diversity in the teams and regular cross-team meetings. The idea is to match the increasing complexity in the market environment with an increasing complexity of the organization’s capabilities. A campus-like centralization of all supply network teams supports communication and coordination across teams and helps to change the mindset towards openly accepting change as a necessary condition for survival.

The managers responsible for the various material segments are the key for collecting data, sensing long-term changes in the supply market environment and develop adaptation strategies. Any approach to measuring success has to balance the firm’s short-term with its long-term interests: “*If the company is still alive in 2030, we know that it has worked*”. This is reflected in the idea that the company must be attractive for suppliers and patronize an ecosystem in which the supplier network can survive, e.g. by providing attractive terms of payment and long-term contracts to ensure financial stability of suppliers as well as by avoiding a one-sided concentration of risks.

On the demand side, the current focus is on those business units that are connected to the powertrain and therefore are directly impacted by the electric mobility trend. These business units develop scenarios, including extreme ones, and analyze the respective impacts on their strategies. The business units systematically observe new technologies and test the waters for new products and services, team up with suppliers in a co-evolutionary way, including spinning-off innovative products into market niches (resembling the theory framework's search & evaluate process).

As in PE, the supply network is characterized by long phases of stability and a few revolutionary events. Revolutionary events stand out by their extraordinary speed of change. The firm sees the electric mobility trend still in the equilibrium, as sales volumes in this segment are low. A tipping point would be an innovative battery system (cheap, high capacity, and fast rechargeable).

Digitalization is about to change procurement. After decades of organizational stability, it is expected that data analysts and market intelligence specialists will play a new and important role in the procurement organization. However, it is not clear if this is just an accelerated phase of the equilibrium or a first sign for revolutionary change.

T1S-B provides solutions to the automotive industry, for which it is also strong in the after-sales market, but also to other industries. Adaptability of a supply network is "*ultimately hard to measure*", but certainly classical KPIs focusing on inventory or lead time are not appropriate. The firm needs to provide an ecosystem for the suppliers to survive, e.g. by guaranteeing fair prices for the supplied goods. Innovation in the automotive industry is more driven by tier-1 suppliers than by the OEMs, i.e. the search & evaluate process is rather established bottom-up than top-down.

The major impact of digitalization is that it automates and centralizes processes that have been done before manually and were not coordinated globally. To increase its agility, the firm is establishing an automated, real-time matching of production equipment (technical capabilities, capacity), human resources (capabilities, capacity) and products (technical requirements, demand) across its global production network. Suppliers are selected also because of their abilities to provide data for this matching process and smoothly integrate results from it into their own order fulfillment and manufacturing execution systems.

As the products of the company are less influenced by the developments toward an electrical powertrain, the firm is able to just observe this trend from afar. Howsoever, electric mobility is seen in a still evolutionary development that would require certain technological and infrastructural breakthroughs, e.g. with respect to charging, to reach a tipping point. Even then, the battery-powered electrical powertrain would still have to face competition from rival solutions like the fuel cell. On the contrary, digitalization is seen as already in a revolutionary phase as it is beginning to change the deep structure of the supply network.

Within **OEM-A**'s procurement organization, the material segments (e.g. body or interior equipment) are responsible for identifying fundamental changes to which the supply network needs to adapt. In addition, a central unit covers cross-segment issues.

The company recognizes that both electric mobility and digitalization will lead to reorganization projects. The supply network will change because new technologies and suppliers enter the market. As a consequence, also the firm's supply management organization has to undergo some restructuring, even though the core processes will remain stable. Digitalization will bring about new business models like selling data generated by cars.

The operational planning for electric mobility is based on different scenarios (each forecasting up to ten years) for the market penetration of electric engines. The materials segments have to identify the scenarios' impacts on their respective portfolios. In order to stabilize the supply network, the firm aims at establishing long-term partnerships with suppliers. This is also reflected in looking at the supply network as an ecosystem, in which suppliers must be able to survive. Suppliers are continuously checked whether they can cope with the trend toward electric mobility with respect to both technology and innovation as well as for their financial stability in a changing market. To reduce the impact of the electric mobility trend, the firm is developing flexible car architectures that can accommodate combustion as well as electric engines. The firm has also set-up scenarios for alternative drives, e.g. for fuel cells, even though the focus is still on battery-powered engines.

In general, a revolutionary development is seen as "*an accelerated evolutionary one*". The development toward electric mobility still follows evolutionary patterns. The firm, however, is aware that punctuation can happen suddenly if the cost-benefit-ratio for consumers changes substantially. Likewise, a breakthrough of the fuel-cells technology would be a, though very different, punctuation event.

Digitalization is going to have a much higher impact on the organizational structure. The new suppliers, which are emerging because of the "autonomous driving/connected car" trend, are different from the traditional suppliers: apps provided independently from hardware, lower initial product maturity levels accompanied by frequent software updates, much quicker time-to-market, and a growing interest to be paid by data generated by the "connected car" instead of money. However, the development of digitalization is seen as following evolutionary patterns. A punctuation event would be that technology acceptance of autonomous driving reaches a tipping point. This tipping point is supposed to be far away, as is a proper nationwide roadside infrastructure supporting autonomous driving.

OEM-B's procurement is organized by material segments as well. The firm usually works with mid-range requirement planning cycles covering two years. For special issues like electric mobility this range is extended to three to four years. The trend toward electric mobility will not only change the supply network but also the firm's internal organizational structure: Electric vehicles "*have less components but need more raw materials*", specialists for the involved technologies and materials need to be integrated, and the responsibilities for the components of the electric powertrain have to be consolidated. The most visible sign of the electric mobility trend in the supply network is a request for quotation for batteries based on the extended mid-term requirement planning scenarios. In R&D, the electric mobility trend has sparked projects for a flexible architecture for electric vehicles, which also considers alternatives to the battery (e.g. fuel cells). Currently, electric mobility is mostly driven by laws and regulations fostering environmental protection, not by customer demand. The development is evolutionary as (1) the small but increasing demand for electric vehicles comes on top of a still growing demand for cars driven by combustion engines and (2) the development of (synthetic) e-fuels, an alternative drive technology, already shows promising progress. However, suppliers need to be carefully monitored if they are able to contribute to the electric vehicle and are fit and financially stable enough to survive a fast transition.

Digitalization will have a higher impact on the organizational structure, as "*new stakeholders like app and web developers as well as start-ups have to be integrated and cooperation within the supply network will change*". Procuring software apps is a new challenge. In the past, software was an integral part of a device. Today, in many cases, devices and apps are purchased separately. Hence the company has pooled and consolidated car digitalization issues as a new segment in its procurement organization. Likewise, the firm needs to build-up human resources in R&D for integrating digital technologies into car architectures and developing concepts for making use of the data generated in the "connected car". The new type of suppliers that is emerging requires new forms of collaboration, as the firm's established supply management platform is too complicated for small companies. The development of digitalization is considered following revolutionary patterns, as it is faster than what the company can cover easily: "*It is going to overtake us*".

	T1S-A	T1S-B	OEM-A	OEM-B
electric mobility	**E**	**E**	**E**	**E**
digitalization	unclear	**R**	**E**	**R**

E: Trend is following evolutionary patterns

R: Trend is following revolutionary patterns

Figure 12: Interviewees' evaluation of electric mobility and digitalization

CONCLUSIONS AND FURTHER RESEARCH DIRECTIONS

All interviewees agree that the trend toward electric mobility is following evolutionary patterns (fig. 2). The interviews revealed the stabilizing factors keeping the supply network in an equilibrium with respect to electric mobility: The trend is mainly driven by regulators, sparse charging infrastructure, low consumer demand because of a non-convincing cost-benefit analysis, and upcoming alternative technologies that challenge the powertrain concept of a battery-powered electric motor.

For digitalization the picture is less clear, but the majority agrees that this trend at least has the potential to punctuate the equilibrium. The OEM's are consonant with each other about the impact of digitalization on both the supply network and their organizational structure. OEM-A having a focus on "autonomous driving" as the main force behind this trend still sees the lack of roadside infrastructure as a key limiting factor for digitalization. However, all OEMs have to cope with the consequences of the conceptual change of the car architecture that is triggered by the vision of the car as a "smartphone on wheels", which is not limited to autonomous driving. Irrespective of the impact on a company's products, digitalization changes the way a company works internally and collaborates with both its supply network and its customers.

The theory framework for this study – a combination of Punctuated Equilibrium and Evolutionary Economics – has proved to be a useful concept for understanding the mechanisms of supply network adaptability. Originally proposed by Ketchen and Hult (2007) to be applied discretely to SCA, the interviews suggest that a combination of both models is a viable approach.

For future research, the supply network's adaptability with respect to digitalization should be in the focus. More precisely, it should be analyzed (1) how the new type of suppliers emerging can be best integrated into the supply network, (2) how the supply network can be formed as an ecosystem that helps both manufacturers and their supply network to survive a punctuation event, (3) how fundamental changes can effectively be sensed in an organization that strives for stability, and (4) how the innovation and selection process that precedes a new equilibrium can be best organized.

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SUPPLY CHAIN TRACEABILITY AND BLOCKCHAIN - ISSUES AND CHALLENGES

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Purpose
Blockchain technology is viewed by many businesses as the main technological innovation borne out of a wave of digital crypto-currencies. It is currently believed that this new technology has the potential to improve efficiencies, security and trust across a range of marketplaces, however as with most radical disruptive technologies, considerable 'hype' exists surrounding Blockchain declaring that it will have important Supply Chain Management applications. This paper seeks to contextualise a range of issues to assist understanding why from proof-of-concepts are difficult to scalable industry-wide applications.

Design/methodology/approach
This paper is set out in sections, namely; a systematic review of literature of blockchain publications from 2009 to date, with an extended focus on the 'traceability' to gain a cursory insight into any important emergent issues before highlighting a range of key factors to consider when developing blockchain supply chain pilots.

Findings
It is clearly evident that a myriad of research opportunities exist for blockchain applications in areas of; systems integration, technology adoption, alignment with supply chain model and frameworks, cost-to-serve and return on investment analysis, change management, authentication/certification and most importantly operational considerations.

Value
We conclude that the migration of proof-of-concept to scalable industry-wide applications will be difficult, if not impossible while the highlighted complex areas remain unaddressed

INTRODUCTION

Blockchain technology is viewed by many businesses as the main technological innovation borne out of a wave of digital crypto-currencies, the most notable being Bitcoin (Min, 2019). This new technology is currently believed to have the potential to improve efficiencies, security and trust across a range of marketplaces, most notably in the financial sector and supply chain management (Tapscott, 2016).

As with most radical disruptive technologies, considerable 'hype' exists surrounding Blockchain with the publication of numerous editorials and social media including Twitter comments and YouTube videos, most of which declare that it will have important Supply Chain Management applications (Baker, 2017). Whilst some venture capitalists and multinationals are already funding projects in various supply chain verticals, (for example diamonds (Kemp, 2017), maritime logistics (Wolfgang, 2017), raw material provenance (Wallace, 2016; Kochar, 2017) and healthcare (Krawiec, 2017), limited research with empirical evidence have been undertaken to either define or scope the tactical and operational issues that blockchain technology must resolve before being an enabler of pragmatic improvements in supply chains.

This paper aims to use a systematic review of the extant literature to hypothesise, using some issues identified with another emergent supply chain technology of the 1990's, RFID (Visich, Li et al. 2009), that many industry sectors will have limited success migrating from proof-of-concept to scalable industry-wide applications, while many complex areas remain unaddressed.

This paper is set out in sections, namely; a systematic review of literature of blockchain publications from 2009 to date, with an extended focus on the 'traceability' to gain a cursory insight into any important emergent issues. Further observations and trends in industry observations are supported from cited references. The paper concludes by outlining key factors to consider when transferring blockchain related project pilots to industry-scale applications.

LITERATURE REVIEW

It is recognised that Blockchain technology is a relative new innovation, consequently for this literature review exercise, a broad general search was applied to identify as many journals as possible who have published relevant articles in the period 2009 to present day. Broad high level two keyword searches, 'Blockchain' AND 'an extra word' - provenance, traceability, transparency, RFID, IoT and literature. Limited exclusion criteria was applied across via SciMago and Scopus databases, and Google Scholar.

To provide context to the following sections and discussion it is important to provide definitions for 'Provenance', 'Transparency' and 'Traceability'.

- **Provenance**
  From the French provenir, "to come from", in supply chain terms it is the chronology of the ownership, custody or location of a historical object that helps to confirm authenticity and value. An example would be a manufacturer's Certificate of Analysis (CoA) or perhaps an official stamp and/or serial number. When applied to a blockchain context, this provenance represents an immutable record every time ownership is transferred.
- **Transparency**
  The act of recording the business processes that have been applied to the product during its residence in the supply chain. For example, whilst quality of production is clearly important, the notion of quality under time-of-production is another element that cannot be sidestepped. This encompasses human rights, worker rights, labour rights, working conditions, environmental impact and similar elements involved in the supply chain that are not tangible. These data points represent important business conditions and are not transitory data related to the product per se.
- **Traceability**
  Is the capability to trace an item (both in terms of forward and reverse logistics) as it transverses the supply chain. Multiple data points such as driver manifests, shipping container codes, and ambient temperature data, all quite unrelated to the product characteristics, can be collected and added to a blockchain. Recently the absence or incompleteness of traceability has been behind different social and environmental sustainability crises, tragedies and scandals affecting industries as powerful and diverse as food, toys, meat production, apparel and pharmaceuticals

(Garcia-Torres, 2018). It is for these reasons that block chain has gained significant attention and focus as being a potential solution to address traceability issues.

The search of the extant literature resulted in six systematic blockchain papers, each of which reflected a specific area of interest. The areas were (i) Reviewing the current status, classification and open issues on applications (Cosino et al., 2019), (ii) Highlighting the use of blockchain within cities (Shen et al., 2019), (iii) Assessing if/how blockchain technology may disrupt existing business models (Nowinski, 2017), (iv) Consideration of supply chain management integration issues (Queiroz, M., Telles, R. et al., 2019), (v) Adoption challenges in both India and the USA (Querios M., 2019) while (vi) sort to provide an insight into the implications of blockchain technology for future supply chains (Wang et al., 2018), which was of particular relevance as it has applied a systematic and definitive definition of applied 'traceability'.

Since 2015 there has been a dramatic increase in the number of quality peer-reviewed articles, however almost all journals still feel it necessary to describe the details of blockchain technology – this may not be required to the same extent in in future journals since referencing previous work should be sufficient. Notwithstanding this positive development, as is highlighted in past studies, there is still a strong need for the generation of supply chain case studies for this nascent technology.

Initially the 'Transparency' of products was the first key driver for blockchain research (Tapscott, 2016). However, over the past couple of years, the focus is moving towards 'Provenance', with articles dealing with this concept emerging at a significant and increasing rate.

Year	Publication by Blockchain plus extra KeyWord				Total
	Provenance	Traceability	Transparency	Literature	
2014	-	-	1	-	1
2015	-	-	1	-	1
2016	8	2	17	-	27
2017	43	18	108	1	169
2018	163	81	308	3	552
2019	48	21	92	2	161
2020	1		1	-	2
Total Articles	**263**	**122**	**528**	**6**	**913**
% Articles by Type	**28.8%**	**13.4%**	**57.8%**	**0.7%**	**100.7%**

Table 1 – 'Search Criteria' by 'Publication Year'

The exponential increased of papers on both provenance and transparency is highlighted in Table 1, however, it is speculated the scarcity of studies on supply chain traceability (Sander, 2018; Xiwei, 2019) is predicted to only marginally increase for the remainder of 2019, meaning the applicability of traceability on blockchain is less studied or reported. Transparency was the initial focus of publishing interest, and continues to be the key driver for blockchain research, where its research maturity is evidenced by publication in books and book chapters (Table 2).

Type	Provenance	Traceability	Transparancy	Total
Article	73	29	170	272
Article in Press	4	4	12	20
Book	1	-	13	14
Book Chapter	6	1	17	24
Conference Paper	152	66	264	482
Conference Review	10	15	9	34
Editorial	1	-	5	6
Review	16	4	33	53
Other	-	3	5	8
Grand Total	263	122	528	913

Table 2 – 'Publication Type' by 'Year'

The focus on the development of a 'Traceability' methodology may be a key determinant if blockchain is to ultimately succeed as the ideal product tracking and recall system. For example there are numerous data collection opportunities throughout a supply chain vertical, therefore research is first required to map the essential data collection elements required and with what collection mode e.g. RFID, IoT, scanners, OCR etc. for both forward and reverse logistics, before defining a recall traceability methodology.

By and large the examples of blockchain in supply chain were rudimentary in nature and the literature papers raised similar concerns in regard to the maturity of such study e.g. "that there is a great concern about the infancy of blockchain technology and the paucity of understanding on how it is applicable" (Shen, 2019; Querios, 2018).

Blockchain-enabled applications are very diverse (Shen, 2018), and this author briefly discussed how blockchain could be potentially applied to drug and food supply chains, while Cartier (2018) outlined a logical description of how the pre-and post-application of blockchain technology solved numerous provenance and traceability issues experienced in the gemstone industry.

Galvez (2018) and Cartier (2019) discussed examples of how smart contracts and the adoption of radio frequency identification (RFID) technology, more commonly addressed in IoT discussions, and how they were potential pathways for the development and subsequent adoption of blockchain in the logistics industry. In these two papers, it was speculated that, in a practical sense, a singular blockchain technology is not the immediate solution to pressing supply chain problems, but the appropriate combination of a selection of other emerging technologies can provide the providence, traceability and transparency required for goods traversing complex supply chains.

DISCUSSION

Defining a blockchain solution for a supply chain requires both technically and operationally generated knowledge. It appears that the notions of provenance, traceability and transparency (PTT) are often incorrectly and inappropriately applied, since it is clear that in many situations that they are often not synonymous.

In Cartier's (2018) a logical description of how the pre-and post-application of blockchain technology solved numerous provenance and traceability issues experienced in the gemstone industry was outlined however more interestingly, this was the only article that included a glossary of correctly defined supply chain management activities, and for this reason this paper represents a significant source for future reference.

As a consequence, the following proposes a 'new' model to locate/contextualised the terminology into three business structures, namely the Ownership, Corporate and

Operational Layers where Ownership Layer equates to Provenance, and Corporate Layer refers to Transparency whilst Operational Layer entails Traceability activities.

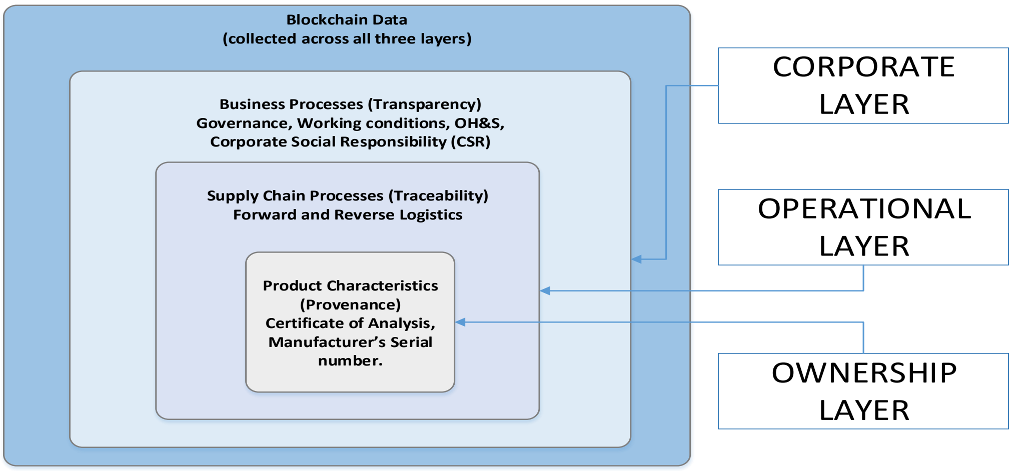

Figure 2 – Blockchain PTT Hierarchy in Supply Chain Management

The term 'supply chain' can be sometimes be referred to via a number of terms. For example in some countries it is described as 'industrial engineering' however terms such as these were not present in the literatures 'Keywords'. The only keyword that did exist was 'Supply' i.e. Supply Chain Management which when applied resulted in just nine journals, less than 1%, of the total journal count. This suggests that most studies to date are by researchers are not aligned to the supply chain discipline.

It is speculated this limited focus is likely to be a contributing factor in the blockchain community's knowledge of the supply chain vertical. It strongly suggests that further studies by researchers must be conducted by or including the supply chain practitioners to focus where and how blockchain can be practically applied in the supply chain.

Blockchain and supply chain framework

It was noted there is a lack of adherence to theoretical models (Way, 2018) with only one reference was made to the 'Council of Supply Chain Management Professionals' (CSCMP). Further, whilst it is agreed that models exist, Queiros, M., Wamba, S. (2019) stated "…the common approaches found in the literature were either conceptual, framework proposals or case studies…which lacked understanding of how the enabler's organisations need to adopt them when concerned with behaviour, barriers and implementation benchmarks" The extant literature showed limited adherence to any existing supply chain frameworks hence it is speculated that this is one reason why the industry is unsure how to adopt the technology. Consequently linking future research to well-defined supply chain frameworks such as the SCOR Model[2], could lead to improved industry understanding of block chain adoption conceptual roots, and would ideally lead to more innovative, viable and scalable industry solutions.

Systems Integration

[2] Supply-chain operations reference model is a process reference model developed and endorsed by the Supply Chain Council as the cross-industry, standard diagnostic tool for supply chain management

Across the literature searches and case studies, no contributions made reference to the range of existing supply chain management software applications such as NFC, WMS, TMS and ERP[3], which indicates the lack of systems integration of the blockchain technologies. It is speculated there is still a heavy focus on creating a new and sole data repository, which implies that blockchain is being represented as a replacement strategy rather than a complimentary technology solution. Numerous 'grey' literature propose that blockchain is not a 'solution by itself' but is part of a network of applications; this implies that there are still significant research opportunities in this field of study.

Technology Acceptance

Information and communication technologies that changed the conventional processes and business models such as Uber and AirBnB are popularly described as "disruptive", and in most literature reviewed, blockchain is no exception. However, the key focus of today's Supply Chain Manager is on applying pragmatic solutions to resolve critical operational issues in the business, hence, describing blockchain as a 'disruptive' technology is the antithesis of what is a supply chain manager needs to engage with on a day-to-day basis. This paradoxical situation suggests that both the literature and presentations at conferences, trade shows and information days, will need to re-market blockchain technology to encourage adoption by supply chain professionals. Evidence of disillusionment are surfacing as blockchain pilots stall, at least because of blockchain immaturity (Leonard, May 2019).

One such way to engender stakeholders' interest in order to keep them abreast of the digital age, Querios (2018) referenced seminal studies in the area relating to 'Perceived Usefulness' (PU) and 'Perceived Ease-of-Use' (PEOU). There is clearly an opportunity to further understand how this approach may assist in this investigation's primary research question regarding the best way to consider how blockchain could be applied.

"A major barrier to large-scale implementation a block chain in the supply chain is participation. Unlike finance insurance applications, in order to employ blockchain technology to gain efficiency and transparency in supply chains, or players have to cooperate" (Cosgrove, 2019). In this respect, this paper proposes a **new** term, the concept of '*Blockchainge Management'*, derived from the merging of the words 'Supply Chain', 'Blockchain' and 'Change Management' which will form pivotal role in any up-scaling of blockchain solutions, just as Change Management does with most IT and Supply Chain implementations. Both people and process mapping for both the 'baseline' and 'to-be' supply chain operations must be a major consideration when migrating from proof-of-concept to industry-scale applications.

Trust in Blockchain

One key tenant of the advantages of blockchain is that it provides trust in an otherwise trustless business environment. Notwithstanding this important issue, the study by Querios (2018) highlighted that within the context of supply chain, trust has no effect on behavioural intention to adopt the technology. Potentially therefore, this key selling point for blockchain adoption is clearly not resounding with practitioners. It appears that the focus towards showing how this IT platform can impact business via improving

[3] Commonly used software application or technologies in supply chain management – NFC – Near Field Communication WMS – Warehouse Management Systems, ERP – Enterprise Resource Planning, TMS – Transport Management Systems

authenticating traded goods, lowering transaction costs and encouraging the sharing a crucial data (Nowinski, 2017) is mandatory.

Authentication

Blockchain is an append-only database, meaning that once data is committed to the chain, the process is irreversible. Consequently, collection procedures and associated monitoring hardware (such as IoT, RFID, and temperature probes[4]) will present a key challenge in developing means and rules for authentication (Nowinski, 2017). In addition, the quotes "Data without meaning is useless" and "Remember, forge chains that have a meaning for customers" (Montecchi, 2019), provide excellent reminders, when developing blockchain solutions, to clearly understand what data points in the supply chain need to be recorded. For example the sections on the chemical analysis of food (Galvez, 2018) and the gemstone trade (Cartier, 2019) demonstrated how chemical analysis results could be added to a blockchain to provide provenance confidence, and therefore significant commercial benefit. It has been proposed that it would be beneficial for the discipline to develop a "Universal Evaluation Model" (Galvez, 2018). The "Assurance Wheel of Provenance Knowledge" suggested by (Montecchi, Plangger et al. 2019) as a new data collection model designed to allow customers to determine what product data and component ingredients are required to be collected. Similarly, for transaction records to be useful, other supply chain management techniques of both life-cycle analysis (LCA) and standardisation of key performance indicators (KPIs) are now being proposed (Rusinek, 2018). Hence, any scaling from a blockchain pilots to industry-deployment must the thoroughly considered to avoid collecting irreversible data records.

CONCLUSION

It is important to note that while numerous references discuss block chain's applicability to supply chain management, there was a notable absence of any cost-to-serve modelling which is a fundamental requirement before a supply chain will take on any new technology. In short, any innovation in this discipline must be focussed towards cost reduction. It is fundamental activity which cannot be overlooked both at the pilot stage and more importantly prior to considering industrialisation of any solution. Clearly this represents an avenue for further investigation.

Also there is evidence of a limited common understanding of the subtle differences between provenance, traceability and transparency, and potentially how this impacts any deployment strategy. The question of how well understood the supply chain management discipline is within the burgeoning blockchain field also needs to be established. We are asserting here that only when the nuances of the supply chain industry are well understood, and key operational and business objectives are defined, should a blockchain solution pilot commence. Without this step, it is anticipated it would be exceedingly difficult to appropriately scale a pilot into an industrial-scale application.

It is clearly evident that a myriad of research opportunities exist for blockchain applications in areas of; systems integration, technology adoption, alignment with supply chain model and frameworks, cost-to-serve and return on investment analysis, change management, authentication/certification and most importantly operational considerations.

[4] RFID (Radio Frequency Identification) and temperature monitors, are hardware technologies used capture or store datum points which when transferred or saved on the Internet are loosely grouped as the IoT (Internet of Things).

The initial hypothesis proposed is valid, in that, the migration of proof-of-concept to scalable industry-wide applications will be difficult, if not impossible while the many aforementioned complex areas remain unaddressed.

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LINKING BLOCKCHAIN ADOPTION IN SUPPLY CHAINS TO JOB OUTCOMES, FIRMS AND INTERFIRM IMPACTS

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Purpose
Blockchain technologies are expected to bring important changes to the supply chain management (SCM) and logistics industries. This is mainly because of their high transformational capabilities. However, extant literature is limited in the availability of blockchain adoption and outcomes in the SCM. This study aims to bridge this knowledge gap, develop a research model that investigates the relationship between blockchain adoption and two organisational outcomes (job satisfaction and job performance) as well as two inter-organisational outcomes (SCM transparency and blockchain benefits).

Design/methodology/approach
We developed a research model based on the diffusion of innovations, the Technology Acceptance Model, the SCM and emerging literature on blockchain. The study was validated using data collected from 738 supply chain professionals in India and the USA. We analysed the model by means of structural equation modelling.

Findings
The findings identified major differences in behaviour in blockchain adoption, in job outcomes, and in blockchain perceived benefits in the two countries. Additionally, this study found that complexity and compatibility have a non significant effect on the behavioural intention to adopt blockchain in both countries.

Value
This study is one of the first empirical investigations on blockchain adoption in supply chain and its related benefits (e.g., job satisfaction, job performance, and supply chain benefits).

Research limitations/implications
With regards to the limitations of this study; scarcity of extant literature which impedes reliable comparison tasks, low potential for generalising our findings as more investigations are needed in other emerging and developed countries are some of the main limitations.

Practical Contribution
Our study suggests that, managers need to consider job performance and job satisfaction as mediators of blockchain adoption and perceived benefits, while integrating the differences that may arise in this regard across countries. In addition, our findings suggest that, in emerging economies like India, these relationships do not need any mediation, which implies that perceived benefits are directly predicted by blockchain adoption. Notwithstanding, in the USA, mediation is necessary, and managers should consider these effects in their blockchain projects

INTRODUCTION
The unprecedented digital disruptions introduced in the Industry 4.0 era supported the emergence of highly disruptive cutting-edge technologies (Liao et al. 2017; Pan et al. 2017). In this regard, blockchain is a paramount and disruptive technology that is already provoking substantial changes in traditional business models. Since the introduction of

blockchain technologies by Nakamoto (2008) in the cryptocurrency market, it has remained a buzzword.

Very few studies have analysed the behaviour of supply chain professionals with regards to blockchain adoption by considering and comparing perspectives from different countries (Kamble, Gunasekaran, and Arha 2018). Consequently, there is still a gap in the understanding of blockchain adoption and of organisational supply chain benefits. The objective of this study is to minimise this gap, notably by shedding more light on the issue while answering the following questions: *What is the role of blockchain adoption among supply chain professionals in different countries? What are the job outcomes and organisational supply chain benefits provided by blockchain adoption? Is the adoption behaviour the same across countries?* To answer these questions, this study developed a conceptual model combining well-known constructs from the Technology Acceptance Model (TAM), the Diffusion of Innovations (DOI) theory, the emerging literature on blockchain, and supply chain management. Supported by these classic studies (Rogers, 1983; Davis 1989; Venkatesh *et al.*, 2003), we provided evidence showing the link between blockchain adoption in supply chain, and its outcomes. Our findings identified major differences in behaviour in blockchain adoption, in job outcomes and in blockchain perceived benefits in the two countries. Additionally, this study found that complexity and compatibility have a non significant effect on the behavioural intention to adopt blockchain in both countries. These results bring important implications from managerial and theoretical lenses.

THEORETICAL BACKGROUND AND RESEARCH MODEL

Diffusion of Innovation Theory and Technology Acceptance Models

The Diffusion of Innovation (DOI) theory (Rogers, 1983) defines innovation as ‘an idea, practice, or object that is perceived as new by an individual or other unit of adoption’, and diffusion as ‘the process by which an innovation is communicated through certain channels over time among the members of a social system’. These definitions show that communication is an essential tool through which new ideas are spread (Rogers, 1983). The DOI consecrated five constructs that explain the innovations’ characteristics at the individual level. Namely: relative advantage, compatibility, complexity, trialability, and observability.

Regarding the Technology Acceptance Model (TAM), it was proposed by Davis (1989) as a model to understand IT adoption behaviour, considering the individual level. TAM was developed based on the Theory of Reasoned Action (TRA) (Azjen and Fishbein, 1980), with a focus on the technology field. Concerning the TAM variables, two constructs are responsible for understanding the intention to use, perceived ease of use (PEOU), and perceived usefulness (PU). Furthermore, the TAM influenced and supported the development of other robust IT adoption models (Venkatesh and Davis, 2000; Venkatesh *et al.*, 2003; Venkatesh, Thong and Xu, 2012). Figure 1 shows the proposed research model derived from the extant literature concerning DOI, TAM, supply chain and the emerging blockchain literature.

Constructs from DOI

Complexity

Complexity refers to ‘the degree to which an innovation is perceived as relatively difficult to understand and use’ (Rogers 1983). In addition, complexity works as an obstacle for the implementation of innovations (Y. M. Wang, Wang, and Yang 2010; Michaelides et al. 2013), while increasing the workload of the workers (Rajan and Baral 2015). According to Rogers (1983), complexity and the adoption rate are negatively related. This leads us to formulate the following hypothesis:

H1: Complexity negatively affects the behavioural intention to adopt blockchain.

Compatibility

Compatibility refers to ‘the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters’ (Rogers 1983). In other words, compatibility is related to the organisation's practices, considering the fact

that they integrate new IT systems to their current systems and work practices (Hung, Tsai, and Chuang 2014). Also, there is an interesting debate about inter-organisational relationships and knowledge management (Chong et al. 2013). In this study, compatibility reflects the level of integration of blockchain into the organisations' current IT systems and its impact on workers' style and preference. Hence, this study proposes the following hypothesis:
H2: Compatibility positively affects the behavioural intention to adopt blockchain.

Relative Advantage
Relative advantage refers to 'the degree to which an innovation is perceived as being better than the idea it supersedes' (Rogers 1983). In this context, organisations need to understand and consider the advantages obtained from technology adoption (Y. M. Wang, Wang, and Yang 2010). Thus, firms that perceive higher relative advantages in blockchain technology are more willing to adopt it. Therefore, this study proposes the following hypothesis:
H3: Relative advantage positively affects the behavioural intention to adopt blockchain.

Constructs from TAM
Perceived Ease of Use and Perceived Usefulness
PEOU refers to 'the degree to which a person believes that using a particular system would be free of effort' (Davis 1989), and PU refers to 'the degree to which a person believes that using a particular system would enhance his or her job performance' (Davis 1989). Recently, Kamble, Gunasekaran, and Arha (2018) approached these constructs in order to understand the blockchain adoption in the Indian supply chain context. In line with previous studies (Kamble, Gunasekaran, and Arha 2018) and (Miao, Wu et al. 2017), this work considers PEOU as a predictor of the PU. In addition, attitudes towards a system predict the intention to use it (Kamble, Gunasekaran, and Arha 2018).Thus, we propose the following hypotheses:
H4: PEOU positively affects the behavioural intention to adopt blockchain.
H5: PEOU positively affects PU.
H6: PU positively affects the behavioural intention to adopt blockchain.
H7: Behavioural intention to adopt blockchain positively affects adoption.

Blockchain and Supply Chain Outcomes Constructs
Blockchain benefits, Job Performance, and Job Satisfaction
Blockchain perceived benefits refer to the degree to which the organisation perceives blockchain as yielding benefits. Perceived benefits can enhance the supply chain in order to provide more improved products and services (Lin 2014; Ranganathan, Teo, and Dhaliwal 2011). The integration of blockchain to supply chain is known to give rise to a number of significant benefits and improvements. Enhancements include cooperation (Aste, Tasca, and Di Matteo 2017), security (Kshetri 2018; Tian 2017), transparency (Kshetri 2018), and product traceability (R. Y. Chen 2018; Lu and Xu 2017; Biswas, Muthukkumarasamy, and Tan 2017), among others. On the other hand, job performance outcomes refer to the successful use of technology in worker related activities, including efficiency. In the context of blockchain and supply chain, job performance can be enriched by the elimination of intermediary processes (Kim and Laskowski 2017) and the reliability and security of information sharing (Tian 2017) across the supply chain. Similarly, the characteristics of job satisfaction can change at the technology implementation phase (Bala and Venkatesh 2013), that is, job demands and control tend to be remodelled. Consequently, job satisfaction among workers can change considerably, and cutting-edge technologies can play a role in improving job satisfaction (Zhong et al. 2017). Thus, blockchain in supply chain can remodel entire supply chain activities (Kshetri 2018), and workers' satisfaction with their jobs. Therefore, we propose the following hypotheses:
H8: Adoption positively affects blockchain benefits.
H9: Adoption positively affects job performance.
H10: Adoption positively affects job satisfaction.
H11: Job satisfaction positively affects blockchain benefits.

H12: Job satisfaction positively affects job performance.
H13: Job performance positively affects blockchain benefits.
H14: Blockchain benefits positively affect supply chain transparency.

Mediators
Previous studies highlighting the relationship between job satisfaction and job performance as mediators are scarce. To the best of our knowledge, the emerging literature on blockchain has not yet considered this level of mediation. On the other hand, Sang et al. (2012) studied the implementation of green supply chain management practices and organisation performance; taking in to consideration job satisfaction and operational efficiency as mediators in business performance. The results were highly supported, indicating the power of the indirect effect of these variables on organisations' performance. As a result, we propose the following hypotheses:
H15: Job performance, as a mediator, influences the relationship between blockchain adoption and blockchain's perceived benefits.
H16: Job satisfaction, as a mediator, influences the relationship between blockchain adoption and blockchain's perceived benefits.

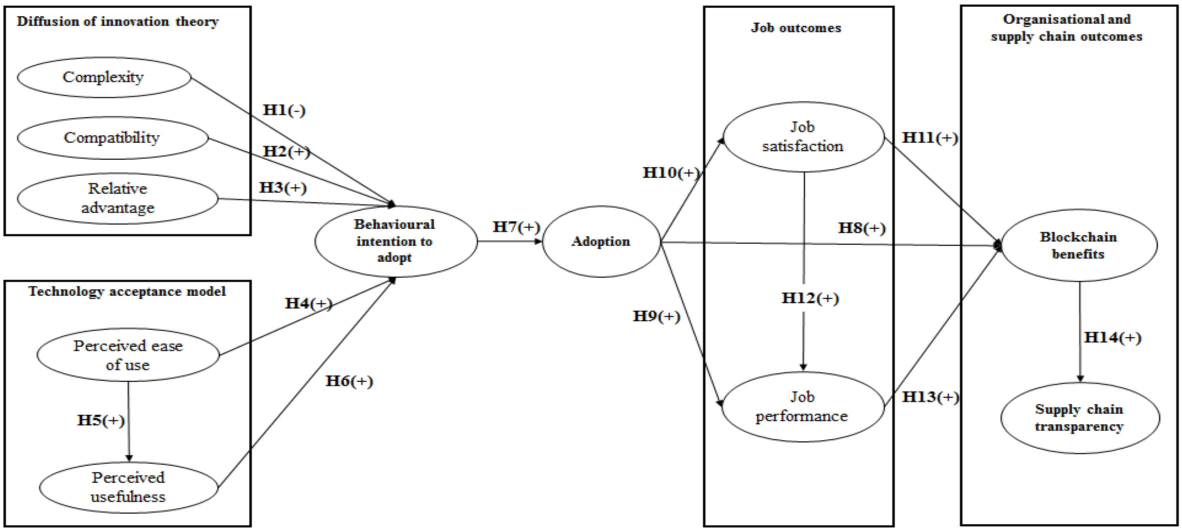

Figure 1. Research model

Data Collection and Samples
We collected data through a leading market research firm in different industries from supply chain professionals in India and the USA. The survey instrument was developed for the items validated from extant literature (Y. M. Wang, Wang, and Yang 2010; Rajan and Baral 2015; Hung, Tsai, and Chuang 2014; Davis 1989; Aloysius et al. 2016; Huang, Liu, and Chang 2012; Kamble, Gunasekaran, and Arha 2018; Lin 2014; Ranganathan, Teo, and Dhaliwal 2011; Bala and Venkatesh 2013). The scales were measured by a 7-point Likert Scale ranging from 1 (strongly disagree) to 7 (strongly agree). We received 344 (241 males and 103 females) and 394 (285 males and 109 females) valid questionnaires from India and the USA respectively. Regarding the demographic profiles of the participants, it is interesting to point out that the gender responses from both countries are similar. In India (70.1% of males and 29.9% of females) and in the USA (72.3% of males and 27.7% of females).

RESULTS AND DISCUSSION
Reliability Tests
We assessed the reliability of the questionnaire by means of the Cronbach's Alpha and composite reliability. All values reported in Table 1 were higher than the threshold of 0.70 acknowledged by literature (Nunnally 1978; Hair Jr. et al. 2017). Therefore, the measurement of all constructs confirmed their reliability. We performed a factor analysis test for each country. In line with the literature (Hair et al. 2017), all values were higher

than the threshold of 0.70 (Hair et al. 2017). In addition, the average variance extracted (AVE) for each construct was higher than the 0.50 threshold (Y. S. Wang, Yeh, and Liao 2013; Q. Wang et al. 2016). In other words, when the value outperforms 0.50, it means that the construct explains more than half of the indicators' variance (Hair et al. 2017). Moreover, the discriminant validity was measured to identify if the constructs are distinct from the others (Fornell and Lacker 1981). Thus, the AVE square root for each construct has to be greater than the correlations between the construct and all other constructs (Fornell and Lacker 1981).

Construct	Variable	Loadings		CA		CR		AVE	
	Label	India	USA	India	USA	India	USA	India	USA
BADOP	BADOP1	0.849	0.883	0.821	0.887	0.894	0.930	0.737	0.816
	BADOP2	0.873	0.914						
	BADOP3	0.853	0.913						
BINT	BINT1	0.878	0.930	0.840	0.921	0.904	0.950	0.758	0.863
	BINT2	0.878	0.931						
	BINT3	0.856	0.927						
COMP	COMP1	0.855	0.891	0.830	0.882	0.898	0.927	0.746	0.809
	COMP2	0.867	0.914						
	COMP3	0.869	0.895						
CPLX	CPLX1	0.883	0.889	0.844	0.873	0.906	0.922	0.763	0.798
	CPLX2	0.877	0.891						
	CPLX3	0.859	0.898						
JPERF	JPERF1	0.854	0.906	0.818	0.895	0.892	0.934	0.733	0.826
	JPERF2	0.860	0.905						
	JPERF3	0.854	0.915						
JSAT	JSAT1	0.877	0.925	0.849	0.915	0.909	0.946	0.768	0.855
	JSAT2	0.867	0.915						
	JSAT3	0.885	0.934						
PBENF	PBENF1	0.790	0.877	0.837	0.898	0.891	0.929	0.671	0.765
	PBENF2	0.818	0.886						
	PBENF3	0.853	0.887						
	PBENF4	0.816	0.848						
PEOU	PEOU1	0.849	0.868	0.853	0.907	0.901	0.935	0.694	0.782
	PEOU2	0.836	0.893						
	PEOU3	0.825	0.888						
	PEOU4	0.822	0.886						
PU	PU1	0.823	0.888	0.847	0.907	0.897	0.935	0.686	0.782
	PU2	0.815	0.892						
	PU3	0.861	0.873						
	PU4	0.813	0.884						
RAVAD	RAVAD1	0.803	0.851	0.860	0.906	0.899	0.930	0.642	0.727
	RAVAD2	0.777	0.863						
	RAVAD3	0.852	0.863						
	RAVAD4	0.786	0.854						
	RAVAD5	0.785	0.833						
SCTRAN	SCTRAN1	0.812	0.852	0.865	0.917	0.902	0.938	0.649	0.751
	SCTRAN2	0.797	0.876						
	SCTRAN3	0.787	0.882						
	SCTRAN4	0.821	0.867						
	SCTRAN5	0.809	0.855						

Table 1: Reliability and validity tests

Note: CA = Cronbach's Alpha; CR = Composite Reliability. BADOP = Blockchain adoption; BINT = Blockchain intention to adopt; COMP = Compatibility; CPLX = Complexity; JPERF = Job performance; JSAT = Job satisfaction; PBENF = Blockchain perceived benefits; PEOU = Perceived ease of use; PU = Perceived usefulness; RAVAD = Relative advantage; SCTRAN = Supply chain transparency.

Hierarchical Regression Analysis

Our proposed model combined DOI, TAM, blockchain and supply chain outcomes to explain 55.1% of variation in blockchain adoption in India and 59.5% in the USA. These results are in line with a recent blockchain adoption study (Kamble, Gunasekaran, and Arha 2018), the results of which achieved 68.7% of variance in the behavioural intention to use blockchain. In addition, the independent constructs explained 59.5% of variance in the blockchain perceived benefits, and 45.5% of variance in supply chain transparency in India, and 60.4% and 56.4% for the same in the USA. Therefore, the organisational and supply chain outcomes were satisfactorily explained by the independent variables.

Structural Equation Model

We employed the SmartPLS software (Ringle, Christian M., Wende, Sven, & Becker 2015) to test all hypotheses of the model. Table 2 presents the results of the test for data from India and the USA.

H	Path	India	U.S.	India	U.S.	India	U.S.	India	U.S.
		Coefficient		SD		t statistics		p values	
H1	CPLX -> BINT	0.063	0.074	0.043	0.059	1.376	1.243	0.169	0.214
H2	COMP -> BINT	0.091	0.185	0.077	0.096	1.119	1.909	0.263	0.056
H3	RAVAD -> BINT	0.265	0.339	0.061	0.117	4.348	2.827	0.000	0.005
H4	PEOU -> BINT	0.285	0.328	0.074	0.108	3.934	3.110	0.000	0.002
H5	PEOU -> PU	0.761	0.801	0.032	0.028	23.985	28.641	0.000	0.000
H6	PU -> BINT	0.164	-0.092	0.078	0.103	2.132	0.878	0.033	0.380
H7	BINT -> BADOP	0.671	0.691	0.043	0.039	15.663	17.745	0.000	0.000
H8	BADOP -> PBENF	0.380	0.308	0.070	0.077	5.479	4.036	0.000	0.000
H9	BADOP -> JPERF	0.429	0.61	0.080	0.051	5.345	11.985	0.000	0.000
H10	BADOP -> JSAT	0.659	0.587	0.041	0.042	15.827	14.044	0.000	0.000
H11	JSAT -> PBENF	0.208	0.183	0.075	0.054	2.780	3.368	0.005	0.001
H12	JSAT -> JPERF	0.335	0.116	0.073	0.061	4.551	1.900	0.000	0.058
H13	JPERF -> PBENF	0.295	0.411	0.077	0.073	3.749	5.594	0.000	0.000
H14	PBENF -> SCTRAN	0.679	0.754	0.036	0.031	18.722	24.017	0.000	0.000

Table 2: Statistics for path coeficients

Mediation Analysis

A mediation analysis was performed according to previous literature (Hair Jr. et al. 2017). For instance, neither H15 nor H16 were supported in the Indian context, which means that JPERF does not mediate the relation between BADOP and PBENF (β = 0.257, p = 0.067), and that JSAT does not produce any effect on mediation between BADOP and PBENF (β = 0.102, p = 0.326) in India. And on the contrary, all mediation effects were valid in the USA, meaning that JPERF mediates the relation between BADOP and PBENF (β = 0.345, p = 0.000) and that JSAT mediates BADOP and PBENF (β = 0.109, p = 0.016) in the American context.

IMPLICATIONS AND CONCLUSION

In line with previous relevant literature (Q. Wang et al. 2016; Kamble, Gunasekaran, and Arha 2018), our proposed model explained 55.1% and 59.5% of the variation in blockchain adoption in India and the USA respectively. Also, the organisational supply chain outcomes were explained in terms of variation at 59.5% and 60.4% for blockchain perceived benefits in India and the USA, and at 45.5% and 56.7% for supply chain transparency for the same countries. Thus, the validated model, and consequently our study, brings considerable contributions to theory and practice. The results of tis study can unlock essential insights for scholars and practitioners interested in advancing research on our robust model, whether in blockchain contexts or in other adoption technology areas, considering the organisational outcomes.

Contrary to what we were expecting from the negative effect of complexity (H1) on the behavioural intention to adopt blockchain, this hypothesis was rejected for the two countries under study. In other words, complexity is not a good predictor of the BINT, which contradicts the findings of other studies in technology adoption (Y. M. Wang, Wang, and Yang 2010; Lean et al. 2009). Also, compatibility was not found to be a significant predictor of the BINT, which is consistent with previous studies (Lean et al. 2009).
Our findings showed that the relative advantage (H3) and the perceived ease of use (H4) were good predictors of the behavioural intention to adopt blockchain in both countries. These results are in line with recent literature on technology adoption (Q. Wang et al. 2016). In the same way, hypotheses H7, H8, H9, H10, H11, H13 and H14 were supported.This means the following: (i) behavioural intention exerts positive effect on blockchain adoption (H7); (ii) blockchain adoption has a positive effect on blockchain perceived benefits (H8); (iii) blockchain adoption exerts a positive effect on job performance (H9); (iv) blockchain adoption has a positive effect on job satisfaction (H10); (v) job satisfaction is a good predictor of blockchain perceived benefits (H11); (vi) job performance exerts a positive effect on blockchain perceived benefits (H13); and (vii) blockchain perceived benefits performs positive effect on supply chain transparency. These results strongly contribute to advancing literature and serving as a reliable benchmark for other studies on blockchain adoption and supply chain benefits in emerging and developed countries.
Concerning the implications for practice, it should be recalled that managers need to consider job performance and job satisfaction as mediators of blockchain adoption and perceived benefits, while integrating the differences that may arise in this regard across countries. Our findings suggest that in emerging economies like India, these relationships do not need any mediation, which implies that perceived benefits are directly predicted by blockchain adoption. Notwithstanding, in the USA, mediation is necessary, and managers should consider these effects in their blockchain projects. From a theoretical point of view, there is a need to investigate these effects in other countries thoroughly. With regard to the limitations of this study, the main ones are the scarcity of extant literature, which impedes any reliable comparison task; and a low potential for generalising our findings, as more investigations are needed in other emerging and developed countries. Finally, our proposed model and the findings obtained appear as an important contribution to literature.

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E-COMMERCE ORDER FULFILMENT: THE JINGDONG MODEL

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Purpose
The Chinese e-commerce market is the biggest and fastest-growing in the world. Though China's internet penetration is only 53% (2016 figure), close to 16% of all retail sales in China were from e-commerce, compared with UK (14.5%), US (7.1%) and South Korea (11.2%), all of which have internet penetration exceeding 85%. More significantly, the ecommerce market of China, already home to two of the world's most-noted online retailers – TMALL and Jingdong (also known as JD.Com) - is driven by the ubiquitous smart phones.
Despite the significance of Chinese e-commerce, the majority of the e-commerce fulfilment publications have been based on the experiences of companies in the western developed economies. The operational practices of China's e-commerce giants have not been systematically documented, though there are no shortages of news clips, promotional videos and online materials about different aspects of China's e-commerce successes. This study reviews the operational processes of Jingdong, examining how it organizes its logistical processes to meet the large volumes of online consumer orders with delivery speed and accuracy, to the satisfaction of its customers. Its objective is to build a theory of ecommerce fulfilment, a logistical phenomenon fast becoming a supply chain norm as Industry 4.0 takes hold.

Design/methodology/approach
Relying exclusively on secondary data sourced from the internet, this paper systematically pieces together the vast array of fragmented information on the Chinese ecommerce giant, Jingdong, to form a process model of ecommerce order fulfilment based on the company's logistical operations. Given the paucity of academic studies on Chinese ecommerce practices, in particular Jingdong's, this study will adopt an inductive grounded theory approach to develop research propositions.

Findings
The study found that Jingdong's success in the Chinese ecommerce market is the outcome of a tightly-woven network of online-offline operations geared to satisfying the logistical needs of individual customers. Jingdong is not only quick in embracing the latest in technological innovations but also invests in research and innovations in ecommerce fulfilment operations. Its order fulfilment processes feature an efficiently orchestrated, centrally monitored, locally-controlled robotic systems strategically blended with human intervention at critical articulation points. Leveraging on customer analytics to continuously refine its last-mile delivery operations, the company places undue emphasis on offering an unparallel, uniquely individualized, purchase-receiving, as opposed to product-delivery, experience to all customers.

Value
The Jingdong's ecommerce model, as demonstrated by many of its promotional videos, has been an eye-opener to the logistics and supply chain community, in both academia and professional practice. This paper offers an incisive synthesis on these well-illustrated

operational information to identify the theoretical underpinnings of Jingdong's ecommerce order fulfilment practice.

Research limitations/implications
This study contributes to the growing literature on ecommerce order fulfilment within an Industry 4.0 ecosystem driven by mobile phones in a country that is setting the pace, and norm, for future retailing. Understanding the processes put in place by one of its ecommerce giants to meet the evolving challenges of this new ecosystem offers refreshing insights for theory development.
A major limitation of this study is that it is drawn exclusively from secondary data sources. Future studies would benefit from an ethnographic investigation of Jingdong's ecommerce order fulfilment process.

Practical Contribution
Jingdong's ecommerce order fulfilment operations are in a class of their own. With China taking the lead in propelling ecommerce (or more appropriately m-commerce) to the next level of social shopping in an Industry 4.0 ecosystem, findings from this study could provide an insightful aid not only to budding ecommerce entities worldwide but also to companies eyeing a piece of the lucrative Chinese m-commerce market.

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BIG DATA OF IOT IN INTELLIGENT MANUFACTURING SUPPLY CHAIN: OPPORTUNITIES AND CHALLENGES

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Purpose
It is obvious that industrial data has increased on a large scale over the last two decades, manufacturing is entering the era of industrial big data and big data-driven intelligent manufacturing. While Internet of Things (IoT) data would be indispensable part of industrial big data in intelligent manufacturing supply chain [1]. The aim of this study is to review the state-of-the-art of IoT big data in intelligent manufacturing both from theoretical and practical perspectives to explore opportunities and challenges of extraction of big data value. Firstly, we briefly provide an overview of big data of IoT in intelligent manufacturing. Then, we highlight the importance of utilization of IoT big data in intelligent manufacturing supply chain. The issue of value-adding of big data of IoT is proposed. Secondly, we discuss some opportunities and challenges on big data of IoT in intelligent manufacturing. Thirdly, we explore how manufacturing enterprises behave to improve the level of intelligent manufacturing in terms of extracting the value of big data of IoT.

Design/methodology/approach
In this study, we integrate the content analysis method and in-depth interview together. More precisely, based on content analysis, we firstly conduct a comprehensive literature review on IoT big data in intelligent manufacturing supply chain. Then, we make in-depth interviews with different manufacturing enterprises. Through exploring the gaps between the actual problem facing by manufacturing enterprises and the theoretical study, we discuss the opportunities and challenges on the extraction of big data value in intelligent manufacturing.

Findings
In this study, we can understand the gaps between theoretical research and practical application in the utilization and valuation of industrial IoT big data. We identified key opportunities, challenges and knowledge gaps. Some suggestions are given to improve the intelligent level of manufacturing in terms of utilization of IoT big data.

Value
Industrial big data is an important strategic resource for the transformation and upgrading of manufacturing industry [2]. While IoT would be the new and fastest-growing sources of industrial big data [3]. Therefore, the utilization of IoT big data, in particular big data valuation would be the key in implementing intelligent manufacturing supply chain. The results of this study will provide some suggestions from the practical and theoretical perspectives. For instance, some measurements should be done for manufacturing enterprises to enhance the application of IoT and the big data analytics. In addition, the requirement of specific techniques, tools and methods to improve the extraction of value of IoT big data is given.

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A MULTI-CRITERIA KEY OPINION LEADER SELECTION MODEL FOR DIGITAL MARKETING IN E-COMMERCE BUSINESS

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Abstract

Purpose of this paper: This paper describes a Multi-criteria Key Opinion Leader Selection (MKOLS) model for digital marketing in the Business to Consumer (B2C) e-commerce business. It aims at selecting an appropriate Key Opinion Leader (KOL) in supply chain to target different customer segmentations based on branding position and product feature.
Design: The MKOLS model makes use of the data collected from the social media platform and e-commerce business environment for decision making in the KOL selection problem. A hybrid approach with decision tree analysis and fuzzy analytic hierarchy process (FAHP) is introduced for multi-criteria decision making. Due to the limitation of FAHP in handling a large number of decision alternatives, decision tree analysis is integrated into the model for classifying KOLs into different groups before pairwise comparisons.
Findings: To demonstrate the feasibility of the proposed model, a case study is conducted in an American-brand headphone company. The tailor made MKOLS model helps to facilitate the KOL selection process so as to target young consumers in the online supply chain e-commerce platform.
Value: In the era of digitalization, supply chain planners face tremendous challenges in transforming their operation strategies through e-platform. Traditional marketing strategies are no longer able to attract the young generation effectively via television, print and broadcasting media. Adopting inappropriate promotion strategies will waste company resources due to the lack of a suitable platform to connect with young customers, and will narrow the target market. Therefore, choosing appropriate communication channel, i.e. KOL, for catching young peoples' attention is critical. This paper contributes to a practical approach for identifying KOL for digital marketing, which is an emerging trend in today's e-commerce market.

1. INTRODUCTION

In recent years, there has been increasing use of social media platforms to attract potential customers in the Business to Consumer (B2C) e-commerce environment. This scenario generates a challenge for supply chain planners to upgrade and transform their marketing strategies via digital exposure to reach the public, especially for the young generation of users who are familiar with internet services and digital activities (Killian and McManus, 2015). While the usage rate of the Internet is increasing and covers most of the age group, it is beneficial for the development of digital marketing in the supply chain. Digital marketing can be classified into online and offline channels. Traditional marketing via television and broadcasting media belongs to offline channels, while online digital marketing via websites, social media, mobile and search engine optimization, is a recent trend in promotion (Kolter et al., 2016). Differing from traditional offline marketing strategies, promotion on the Internet provides direct interaction with the target customers.

Facing diverse social media platforms, choosing an appropriate communication channel, the Key Opinion Leader (KOL), for catching public attention, is critical. KOLs usually define themselves as experts in specific areas. They have developed a strong social network with a wide range of audiences and followers, who are willing to listen to their advice and recommendations, in social media platforms. In order to maintain a high popularity, KOLs are always active on social media and blogs, and interact with their followers frequently. Political figures, columnists and social media celebrities are examples of KOLs (Weeks et al., 2017). However, KOLs are usually not well-known to the public. Without a systematic approach for considering multi-criteria in decision making, it is challenging to select an appropriate KOL suitable to the companies or the products. In addition, companies usually have specific requirements in targeting different customer segmentations, based on the branding position and product features. A large number of choices of KOLs makes it difficult to choose the right one. Therefore, in this paper, a multi-criteria KOL identification (MKOLS) model is proposed to select a suitable KOL for promotion in the e-commerce supply chain. This paper is organized as follows. Section 2 covers the past literature related to digital marketing in the e-commerce supply chain, KOL selection, and decision making approaches in classification and multi-criteria analysis. Section 3 presents the design of the MKOLS model. Section 4 presents a case study to illustrate how the proposed model works, followed by the results and discussion in Section 5. Finally, the conclusions are drawn in Section 6.

2. LITERATURE REVIEW

With the fast advance in information technology, B2C e-commerce retailing is the trend in today's supply chain management. Instead of focusing on operations planning, the e-commerce environment brings new attention in exploring business opportunities in the downstream supply chain through online platforms. In the era of digitalization, customer behaviour changes, which increases the difficulties in fulfilling their expectations and demands. Customers can search for relevant product information on the web, compare different products based on peer review comments, and then place an order at either the online shop or physical store. At the same time, the marketing strategy has to be upgraded from offline channels to digital marketing in order to link customers in an effective way. According to Godey et al. (2016), a successful marketing strategy can outperform competitors in terms of profit making and brand image establishment. By connecting companies and potential customers, the social media network provides a platform to promote products and services in an informal and interactive environment.

Making use of KOL in the e-commerce supply chain is an up-to-date marketing strategy for attracting people who always use social media. According to Bamakan et al. (2018), opinion leaders are the information providers who have knowledge in a particular product domain. They are willing to communicate and have the ability to influence others. KOL selection is a crucial activity which affects the success of the promotion strategy. In order to identify a KOL, Li et al. (2013) considered the expertise, novelty, influence, and activity of KOLs. Aghdam and Navimipour (2016) evaluated the trust value between the opinion leaders and their followers. Later, Jain and Katarya (2019) identified opinion leaders in online social networks, both global and local communities. However, it was found that most attention was paid in identifying opinion leaders. Limited research focused on how to select a suitable KOL for achieving the ultimate target.

With the ability to consider multiple criteria at the same time, the fuzzy multiple criteria decision-making (MCDM) approach provides a systematic flow to solve the e-commerce problems in selecting the most suitable KOL. It is commonly used to solve complex real world problems, and explicitly evaluate multiple and conflicting criteria for alternative approaches (Gavade, 2014). Fuzzy Analytical Hierarchy Process (FAHP), a fuzzy MCDM approach, is the extension of AHP which deals with the fuzziness of data in decision making. Wang et al. (2012) addressed the inadequacy of pure quantitative decision making process using the traditional AHP, and stated that the application of fuzzy logic is useful in tackling the situation when the criteria are qualitative and difficult to quantify. Although FAHP is able to convert the input from linguistic judgement for determining the alternatives based on multiple criteria, the major drawback is the long computational time in the evaluation process. The pair-wise comparison process become huge if the number of alternatives increases. Therefore, in order to reduce the complexity, decision tree analysis is proposed to first classify the alternatives into groups before pair-wise comparisons. Decision tree analysis is widely used in classification and describes sequences of interrelated decisions. From the marketing and promotion perspective, a company can make use of decision tree analysis for making direct marketing decisions, or selecting effective strategies (Karim and Rahman, 2013). According to Min et al. (2011), decision tree analysis is a promising tool in attribute reduction which enables the categorization of customers into pre-defined groups with similar behaviour patterns in the form of tree structure. Therefore, by integrating decision tree analysis with FAHP, it enables consideration of multiple criteria in decision making, while the efficiency of the computational process can be increased. Hence, this study contributes to a practical approach for identifying KOL for digital marketing which is an emerging trend in today's e-commerce market.

3. DESIGN OF THE MULTI-CRITERIA KEY OPINION LEADER SELECTION MODEL

In order to select the most appropriate KOL for promotion in the e-commerce business, a Multi-criteria Key Opinion Leader Selection (MKOLS) model is presented in this section. The design of the MKOLS model is shown in Fig. 1, and consists of three modules: data collection, decision analysis for classification, and multi-criteria KOL selection.

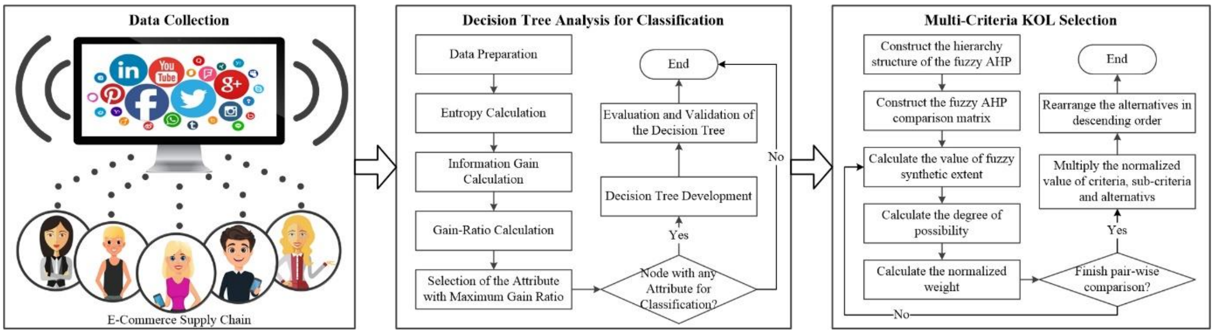

Fig. 1. Design of the Multi-criteria Key Opinion Leader Selection (MKOLS) model

3.1 Data Collection

In this module, data related to the background of KOL and social media platforms are collected. Currently, social media platforms such as Facebook, Instragram, Youtube and Twitter are widely used on the Internet. By using these platforms, KOL can share the updated news via text or video, and communicate with their followers through live broadcasting. Therefore, data such as the number of followers of each KOL, the number of views in live broadcasting, the number of responses of each post shared by the KOL, can be collected for analysis. In addition, interviews and site visits to the case company are required to understand the requirements and in defining the criteria of KOL selection.

3.2 Decision Tree Analysis for Classification

After identifying a set of KOLs, decision tree analysis is conducted in classifying them into different groups, based on their characteristics. The decision tree is a common data mining technique in decision making. In this study, the J48 decision tree is used, which consists of four basic steps.

(i) Identify the attributes (S) and the total number of samples (P) for each attribute. There are m class labels: $C_1, C_2, \ldots, C_m$ and each class has P_i samples where $1 \leq i \leq m$. Count the number of samples in each class for data preparation before calculation.

(ii) Calculate the entropy to reflect the model's degree of chaos. The entropy of S relative to each attribute classification is calculated using (1).

$$\mathrm{E(S)} = \sum_{i=1}^{m} -\frac{Pi}{P}\log_2\frac{Pi}{P} \qquad (1)$$

(iii) Calculate the information gain using (2). The information gain of each attribute is used to measure the effectiveness of attribute classification. $V(A)$ is the set of all possible values that each attribute may take. S_i is a subset of S where attribute A takes its i^{th} value. The step is repeated for each attribute.

$$G(S,A) = E(S) - \sum_{i \in V(A)} \frac{|Si|}{|S|} E(S_i) \qquad (2)$$

(iv) After calculating all the information gains of the attributes, the attributes with the highest information gain is selected as the most favourable attribute (root node), and branches are created according to its possible values. The nodes of the decision tree refer to various attributes of the data, while the branches between the nodes represent the possible values of each feature.

After implementing the above steps, the derived model is represented in a tree structure. It can be easily converted into rules for classification. The classification accuracy can be evaluated by the fact data and the percentage of tuples in the correct levels. Therefore, the company can assign a class label to new KOLs according to the derived decision tree.

3.3 Multi-Criteria KOL Selection

In this module, an extent analysis method on FAHP is used for KOL selection. It is able to consider multi-criteria which allows the manager to compare each KOL based on a number of criteria before making a decision. Six steps are included for KOL selection,

(i) Construct the fuzzy AHP hierarchy to decide how KOLs are evaluated. The alternatives, criteria and/or sub-criteria are identified in the form of a hierarchy structure to achieve the goal of KOL selection.

(ii) Prepare the fuzzy AHP pair-wise comparison matrix. After developing the hierarchy, a comparison matrix is constructed by comparing the importance of each criteria with respect to the goal. A questionnaire is designed for the interviewee to compare the importance of the criteria (C_i). Since the response given by the interviewee in KOL selection consists of vague values, a set of triangular fuzzy numbers *N* in terms of the lower bound (l_{ijk}), most possible number (m_{ijk}) and upper bound (u_{ijk}) are used for representing the i^{th} and j^{th} criteria of the k^{th} respondent. After the questionnaires are collected, a *t* x *t* pair-wise comparison matrix is constructed. Table 1 shows the pair-wise comparison results for *t* criteria with *k* responses. An average value of the responses from k decision makers are used as an input for KOL selection.

Table 1. Pair-wise Comparison Results for *t* Criteria with *K* Responses

	C_1	C_2	…	C_t
C_1	$(1,1,1)$	$K^{-1}\left(\sum_{k\in K} l_{12k}, \sum_{k\in K} m_{12k}, \sum_{k\in K} u_{12k}\right)$	…	$K^{-1}\left(\sum_{k\in K} l_{1tk}, \sum_{k\in K} m_{1tk}, \sum_{k\in K} u_{1tk}\right)$
C_2	$K^{-1}\left(\sum_{k\in K} {u_{12k}}^{-1}, \sum_{k\in K} {m_{12k}}^{-1}, \sum_{k\in K} {l_{12k}}^{-1}\right)$	$(1,1,1)$	…	$K^{-1}\left(\sum_{k\in K} l_{2tk}, \sum_{k\in K} m_{2tk}, \sum_{k\in K} u_{2tk}\right)$
⋮	⋮	⋮	⋱	⋮
C_t	$K^{-1}\left(\sum_{k\in K} {u_{1tk}}^{-1}, \sum_{k\in K} {m_{1tk}}^{-1}, \sum_{k\in K} {l_{1tk}}^{-1}\right)$	$K^{-1}\left(\sum_{k\in K} {u_{2tk}}^{-1}, \sum_{k\in K} {m_{2tk}}^{-1}, \sum_{k\in K} {l_{2tk}}^{-1}\right)$	…	$(1,1,1)$

(iii) Calculate the value of fuzzy synthetic extent S_i^h for criteria *i* in the h^{th} level of hierarchy using (3).

$$S_i^h = \sum_{j=1}^{t} N_{ij}^{t} \otimes \left(\sum_{i=1}^{t}\sum_{j=1}^{t} N_{ij}^{t}\right)^{-1} \quad (3)$$

(iv) Calculate the degree of possibility (*P*). With the fuzzy synthetic extent values, the degree of possibility of one criteria over another, $S_i = (l_i,\ m_i,\ u_i) \geq S_j = (l_j,\ m_j,\ u_j)$ is calculated using (4). The minimum degree of possibility of S_i over S_j for each element C_i, where i ≠ j, is then calculated using (5).

$$P(S_i \geq S_j) = \begin{cases} 1 & m_i \geq m_j \\ \frac{l_j - u_i}{(m_i-u_i)-(m_j-l_{j2})} & m_i \leq m_j, u_i \geq l_j \quad, i \neq j \\ 0 & Otherwise \end{cases} \quad (4)$$

$$d(C_i) = minP(S_i \geq S_j) \quad \forall j, i \neq j \quad (5)$$

(v) Calculate the normalized weight of each element in the k^{th} level of the hierarchy using (6). The steps iii to v are repeated for all sub-criteria and decision alternatives.

$$w(C_i^k) = d(C_i^k) \times \left(\sum_{i=1}^{n} d(C_i^k)^{-1}\right) \quad (6)$$

(vi) Rank the decision alternatives based on their priority weight. The normalized weight vectors of criteria, sub-criteria, and alternatives are multiplied with each other to obtain the priority weight of all decision alternatives. The KOL with the largest priority weight will be selected.

4. CASE STUDY

To demonstrate the feasibility of the proposed model, a case study is conducted in an American-brand headphone company, which manufactures and sells professional headphones to their customers, with good sound quality and an attractive outlook. As a fashionable headphone, the headphone design of the case company is stylish and elegant, using Italian design concepts, which can attract customers who have high regard for the headphone's outlook. The company also offers tailor-made decoration pieces for customers who wish to own a unique headphone. Since it is noticed that the e-commerce market is growing rapidly and the sales from the online platform keep increasing, the case company has also started to plan for promotion in the e-commerce platform. Therefore, a pilot study is conducted to illustrate how the MKOLS model is applied.

4.1 Decision Tree Analysis for Classification

In this step, the decision tree approach was used to classify KOLs into seven types based on three categorical attributes. They are target customers, recognition and brand level. Target customers refer to the specific age-group of followers that the KOL focuses on. Recognition determines whether the KOL is well-known internationally. If the KOLs are active and famous all over the world, they are classified as having international recognition. On the other hand, the KOLs are defined as local if they are only active in their own country or region. Brand level is defined depending on their value. Depending on the data attribute value of each KOL, the decision tree analysis is conducted using software WEKA. The attribute having the largest gain ratio among all the attributes is selected as the node attribute in the ultimate decision tree. With 10-fold cross validation, the dataset is divided into 10 pieces, and each is held out in turn for testing, with the remainder for training. It can reduce the variance of the estimate. From the result, the correct classification is higher than 90%, which indicates that the result is acceptable. Fig. 2 shows the decision tree for KOL classification. By comparing the gain ratio for the attributes, the target customer has the highest gain ratio, and hence is selected as the first split in the construction of the decision tree. Three branches, i.e. all, middle-aged and young, are created by the split. As shown in the figure, KOLs with middle-aged target customers belong to Group 1. For KOLs targeting all customers, they can be further divided into four groups, i.e. Group 2 to Group 5, based on their recognition and brand level. In targeting young customers only, the KOLs who have local or international recognition would be classified into Group 6 or Group 7 respectively. Based on the promotion needs of the newly launched headphone, the manager can go through the decision tree and select a group of potential KOLs for marketing purpose.

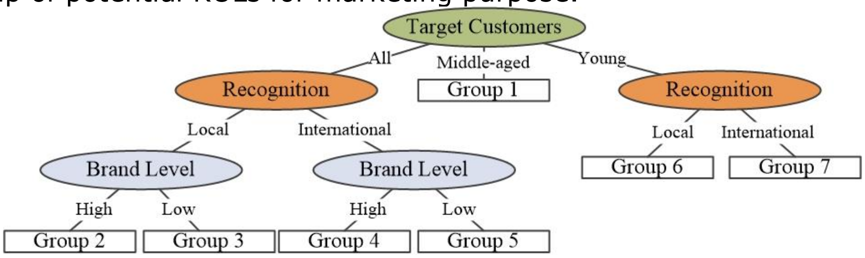

Fig. 2. Decision tree analysis for classifying KOL into groups

4.2 Multi-Criteria KOL Selection

After selecting a group of potential KOLs, multi-criteria analysis is conducted to select the most suitable KOL for promotion. Fig. 3 shows the hierarchy structure for KOL selection in the e-commerce business. It consists of four levels: goal, criteria, sub-criteria and decision alternatives. The goal is defined as KOL selection, which is to select an appropriate KOL for new product promotion. Five criteria are defined in Level 2, Popularity (C_1), Influence (C_2), Social Media Management (C_3), Personality (C_4) and Cost (C_5). Except Cost (C_5), sub-criteria are further identified in the hierarchy structure for KOL selection.

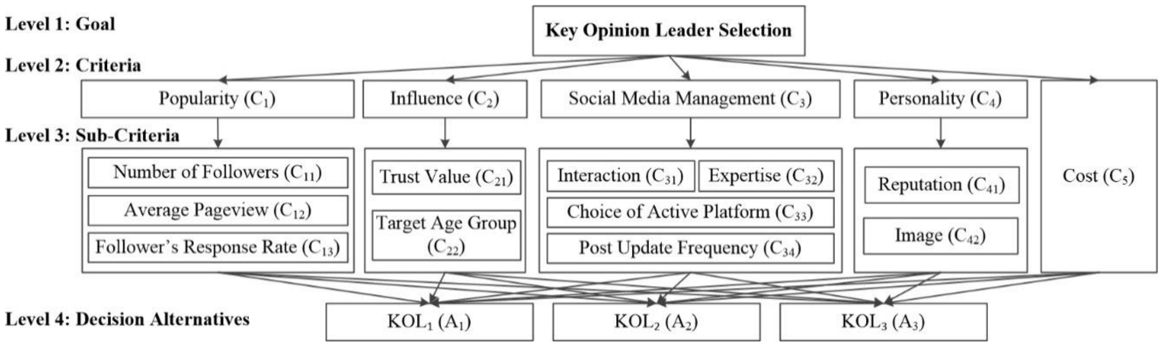

Fig. 3. Hierarchy structure for KOL selection in e-commerce business

Popularity (C_1) refers to the state of being liked and supported by followers and the general public. The KOL is said to have high popularity if he/she is widely recognized by most target customers. To measure the extent of popularity, three sub-factors are identified, including the number of followers (C_{11}), average page-view (C_{12}), and the follower's response rate (C_{13}). In the e-commerce industry, KOLs build their own peer marketing network by attracting people to follow their sharing posts or social media webpage. Therefore, by measuring the number of followers, we can determine whether the KOL is popular in the peer group so that the message can be spread to a large number of people. For the average page-view, it measures the number of times that the social media page is visited by the general public. There is a larger chance of the message reaching the target consumers with high average page-view rates. Lastly, the follower's response rate measures whether the follower replies to the message delivered by the KOL. A higher response rate suggests that the KOL can attract the followers' attention on the products being promoted.

Influence (C_2) refers to the effect brought by the content shared by the KOL. Two sub-criteria, trust value (C_{21}) and target age group (C_{22}), are defined. Trust value (C_{21}) is an important measure in digital marketing, which determines if the KOL is able to build trust with the followers. The KOL can achieve successful promotion easily if he/she can maintain a higher extent of consumer trust. For the target age group (C_{22}), each KOL usually has his/her own target group of followers. Some KOLs focus on the teenager market, while some may target mature adults. The level of influence may not be the same for different age groups.

Social Media Management (C_3) provides a unique criteria in the e-commerce business environment. Due to the increasing popularity of social media, KOL can communicate with the public using social media. It includes four sub-criteria: interaction (C_{31}), expertise (C_{32}), choice of active platform (C_{33}) and post update frequency (C_{34}). Interaction (C_{31}) determines whether a frequent interaction is conducted with the followers. For expertise (C_{32}), although most KOLs have similar practices in digital marketing, i.e. to share the content online, or to have live broadcasting to communicate with their followers, their expertise/focus areas are different. KOLs usually have their own specific focus areas, such as beauty, travel and tourism, or electronics products. The promotion strategy in social media varies with different focuses. Therefore, choosing a KOL with relevant expertise would increase the chance of success in promotion. For the choice of active platform (C_{33}), there are many social media platforms on the Internet, including Facebook, Instagram, Youtube, Snapchat and Twitter. These platforms have different characteristics: some can share time sensitive photos and videos while some can attract attention using status updates and hashtags. In addition, KOLs may manage more than one social media platform to reach target audiences. Lastly, the post update frequency (C_{34}) measures the number of times that the KOL would update the social media page. It could maintain the popularity if the KOL updates his/her page more frequently.

Personality (C_4) refers to the internal characteristics of a KOL. It can be divided into reputation (C_{41}) and image (C_{42}). Reputation (C_{41}) determines whether the KOL has built a good reputation for branding promotion in the industry. For image (C_{42}), depending on personal character, the KOL establishes a different self-image so as to attract the attention of the public. The KOL is preferred if his/her image matches the needs of the brand.

Cost (C_5) is the last criterion for KOL selection. It determines if a reasonable cost can be used to invite the target KOL for promotion. This cost includes all related expenses for promotion, such as equipment cost for video shooting and live broadcasting, and the remuneration of the KOL.

After identifying the hierarchy structure for KOL selection, the key decision makers, i.e. two senior marketing managers in the case company, are invited to make the judgement on the choice of KOL based on the given criteria. The average value of their feedback is used as the input to construct the pairwise comparisons matrix. Fig. 4 shows the pairwise comparison of (a) five criteria to goal; (b) sub-criteria to corresponding criteria; (c) alternatives to sub-criteria/criteria, in KOL Selection. By following the steps of the extend analysis method of FAHP, the normalized weight values of the 3-level comparison are obtained. Table 2 shows the summary of the normalized weight values. The weights of each criteria and sub-criteria are calculated to determine the most important. By multiplying the criteria weighting and the alternatives with respect to each sub-criteria, the overall weight values of each KOL can be obtained.

	C1			C2			C3			C4			C5		
C1	1	1	1	2	3	4	0.33	0.5	1	1	2	3	3	4	5
C2	0.25	0.33	0.5	1	1	1	0.33	0.5	1	1	2	3	1	2	3
C3	1	2	3	1	2	3	1	1	1	1	2	3	1	2	3
C4	0.33	0.5	1	0.33	0.5	1	0.33	0.5	1	1	1	1	1	2	3
C5	0.2	0.25	0.33	0.25	0.33	0.5	0.33	0.5	1	0.33	0.5	1	1	1	1

(a) Pairwise Comparison of the Five Criteria to Goal

	C11			C12			C13		
C11	1	1	1	0.33	0.5	1	0.33	0.5	1
C12	1	2	3	1	1	1	0.33	0.5	1
C13	1	2	3	1	2	3	1	1	1

(b)(i) Pairwise Comparison of Sub-Criteria to Popularity (C_1)

	C21			C22		
C21	1	1	1	1	2	3
C22	0.33	0.5	1	1	1	1

(b)(ii) Pairwise Comparison of Sub-Criteria to Influence (C_2)

	C31			C32			C33			C34		
C31	1	1	1	0.33	0.5	1	0.33	0.5	1	1	2	3
C32	1	2	3	1	1	1	0.33	0.5	1	3	4	5
C33	1	2	3	1	2	3	1	1	1	1	2	3
C34	0.33	0.5	1	0.2	0.25	0.33	0.33	0.5	1	1	1	1

(b)(iii) Pairwise Comparison of Sub-Criteria to Social Media Management (C_3)

	C41			C42		
C41	1	1	1	1	2	3
C42	0.33	0.5	1	1	1	1

(b)(iv) Pairwise Comparison of Sub-Criteria to Personality (C_4)

	A1			A2			A3		
A1	1	1	1	0.33	0.5	1	1	2	3
A2	1	2	3	1	1	1	4	5	6
A3	0.33	0.5	1	0.17	0.2	0.25	1	1	1

(c)(i) Pairwise Comparison of Alternatives to C_{11}

	A1			A2			A3		
A1	1	1	1	2	3	4	1	2	4
A2	0.25	0.33	0.5	1	1	1	0.25	0.33	0.5
A3	0.25	0.5	1	2	3	4	1	1	1

(c)(ii) Pairwise Comparison of Alternatives to C_{12}

	A1			A2			A3		
A1	1	1	1	0.2	0.25	0.33	1	2	3
A2	3	4	5	1	1	1	0.17	0.2	0.25
A3	0.33	0.5	1	4	5	6	1	1	1

(c)(iii) Pairwise Comparison of Alternatives to C_{13}

	A1			A2			A3		
A1	1	1	1	0.33	0.5	1	2	3	4
A2	1	2	3	1	1	1	3	4	5
A3	0.25	0.33	0.5	0.2	0.25	0.33	1	1	1

(c)(iv) Pairwise Comparison of Alternatives to C_{21}

	A1			A2			A3		
A1	1	1	1	0.2	0.25	0.33	2	3	4
A2	3	4	5	1	1	1	1	2	3
A3	0.25	0.33	0.5	0.33	0.5	1	1	1	1

(c)(v) Pairwise Comparison of Alternatives to C_{22}

	A1			A2			A3		
A1	1	1	1	1	2	3	0.17	0.2	0.25
A2	0.33	0.5	1	1	1	1	4	5	6
A3	4	5	6	0.17	0.2	0.25	1	1	1

(c)(vi) Pairwise Comparison of Alternatives to C_{31}

	A1			A2			A3		
A1	1	1	1	1	2	3	0.2	0.25	0.33
A2	0.33	0.5	1	1	1	1	2	3	4
A3	3	4	5	0.25	0.33	0.5	1	1	1

(c)(vii) Pairwise Comparison of Alternatives to C_{32}

	A1			A2			A3		
A1	1	1	1	2	3	4	0.17	0.2	0.25
A2	0.25	0.33	0.5	1	1	1	1	2	3
A3	4	5	6	0.33	0.5	1	1	1	1

(c)(viii) Pairwise Comparison of Alternatives to C_{33}

	A1			A2			A3		
A1	1	1	1	0.17	0.2	0.25	1	2	3
A2	4	5	6	1	1	1	0.33	0.5	1
A3	0.33	0.5	1	1	2	3	1	1	1

(c)(ix) Pairwise Comparison of Alternatives to C_{34}

	A1			A2			A3		
A1	1	1	1	1	1	1	2	3	4
A2	1	1	1	1	1	1	4	5	6
A3	0.25	0.33	0.5	0.17	0.2	0.25	1	1	1

(c)(x) Pairwise Comparison of Alternatives to C_{41}

	A1			A2			A3		
A1	1	1	1	2	3	4	0.17	0.2	0.25
A2	0.25	0.33	0.5	1	1	1	3	4	5
A3	4	5	6	0.2	0.25	0.33	1	1	1

(c)(xi) Pairwise Comparison of Alternatives to C_{41}

	A1			A2			A3		
A1	1	1	1	0.25	0.33	0.5	0.17	0.2	0.25
A2	2	3	4	1	1	1	3	4	5
A3	4	5	6	0.2	0.25	0.33	1	1	1

(c)(xii) Pairwise Comparison of Alternatives to C_5

Fig. 4. Pairwise Comparison of (a) Five Criteria to Goal; (b) Sub-Criteria to Corresponding Criteria; (c) Alternatives to Sub-criteria/Criteria, in KOL Selection

Table 2. Normalized Weight Values of 3 Levels Comparison

Criteria with respect to Goal	Sub-criteria with respect to Criteria	Criteria Weighting	Alternatives with respect to Sub-criteria (KOL_1, KOL_2, KOL_3)
(C1) 0.321	(C11) 0.200	(C11) 0.064	0.24, 0.75, 0
	(C12) 0.351	(C12) 0.113	0.56, 0, 0.43
	(C13) 0.449	(C13) 0.144	0.13, 0.36, 0.49
(C2) 0.203	(C21) 0.692	(C21) 0.140	0.38, 0.61, 0
	(C22) 0.308	(C22) 0.062	0.35, 0.64, 0
(C3) 0.292	(C31) 0.218	(C31) 0.064	0.10, 0.46, 0.43
	(C32) 0.365	(C32) 0.106	0.22, 0.35, 0.41
	(C33) 0.349	(C33) 0.102	0.28, 0.18, 0.53
	(C34) 0.069	(C34) 0.020	0.18, 0.55, 0.25
(C4) 0.156	(C41) 0.692	(C41) 0.108	0.33, 0.66, 0
	(C42) 0.308	(C42) 0.048	0.22, 0.34, 0.42

(C5) 0.029	/	(C5) 0.029	0, 0.58, 0.41

5. RESULTS AND DISCUSSION

By adopting the MKOLS model, it is found that KOL_2 had the highest value among the three alternatives. Hence, the case company should invite KOL_2 for promoting the newly launched product to the target customers. Besides, it is worth to investigate which criteria/sub-criteria have a high weights during FAHP analysis. As shown in Table 2, the overall weights of all criteria in KOL selection are given. Among all 12 criteria/sub-criteria, the follower's response rate (C_{13}) and trust value (C_{21}) have the highest weights contributing to 14.4% and 14% of total weights respectively. It implies that the case company concerns as to whether the KOL has a high follower's response rate in the social media platform, so that the promotion can be delivered to the public and arouse their interest. In addition, the KOL with high trust value implies that the followers tend to believe the opinion delivered from the KOL. Hence, it could influence the followers to make a purchase by providing positive feedback to the promoted product.

In this study, decision tree analysis is performed before using the FAHP approach. This is because the computation time of FAHP greatly depends on the number of alternatives involved in the hierarchy. The more alternatives involved, the longer is the time needed to obtain the answer. Therefore, by conducting decision tree analysis, a list of KOLs can be classified into groups based on their characteristics. One group consists only of a small number of KOLs for selection. It could effectively shorten the time required to conduct pair-wise comparison.

6. CONCLUSIONS

Due to the rapid development of e-commerce in recent years, increasing attention has been paid to invite KOL in digital marketing so as to attract young customers. By establishing a peer network on the Internet, KOLs can make use of social media platforms to express their opinion in products and share used experience to the public. Therefore, selecting an appropriate KOL for catching young people attention is critical. In this paper, a multi-criteria key opinion leader selection model is proposed to evaluate the suitability of KOL for promotion. A pilot study was conducted in an American-brand headphone company to illustrate how the proposed model can be applied in selecting KOL for headphone promotion. By integrating the decision tree analysis and multi-criteria analysis using FAHP, it is found that the computational time in conducting pair-wise comparison is greatly reduced. To conclude, this paper contributes to a practical approach for identifying KOL for digital marketing which is an emerging trend in today's e-commerce market.

ACKNOWLEDGMENTS

The authors would like to thank the Engineering Doctorate Programme, Faculty of Engineering of The Hong Kong Polytechnic University for inspiring the development of this project.

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SMART HOME DEVICES AND B2C E-COMMERCE: A WAY TO REDUCE FAILED DELIVERIES

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Abstract

Purpose

B2C e-commerce is fast spreading all over the world. If compared to the offline market, it opens new challenges for companies, and one of these is higher complexity of the logistics activities. In particular, one of the most critical processes in the logistics field, due to its impact on both costs and service level, is the last-mile delivery – i.e. the "final leg" of the order fulfilment, aimed at delivering the products to the final consumer. More in detail, a very significant issue is that of the failed deliveries, i.e. the deliveries not accomplished due to the absence of the customer. They both imply high costs for e-commerce players – that need to re-schedule them – and have a negative impact on the satisfaction of customers. A way to face this issue could be scheduling the deliveries based on the probability to find customers at home. A promising alternative for gathering data on the customer presence is represented by Internet of Things devices, whose diffusion has been significantly growing in recent years.

Design/methodology/approach

The solution presented in this paper aims at building presence profiles of customers based on data collected through smart home devices (e.g. smart home speakers) able to detect people presence at home during the day and along the week. In addition, the work develops the analytical formulation of a Vehicle Routing Problem that schedules deliveries, aimed at reducing not only the travelled distances – as it happens in traditional VRPs – but also the number of failed deliveries. More specifically, the routing algorithm is composed by two sub-stages. First, it carries out a pre-allocation of customer orders to specific time-windows, based on the probability of the customers to be at home when deliveries are performed. Second, the algorithm finds the sequence of customers to be visited during the day that optimises the routing.

Findings

The application of the model to a case in Milan shows that the proposed solution implies a significant reduction of missed deliveries – about -16% – with respect to the traditional operating mode (in which the probability of finding the customer at home is not considered while scheduling the deliveries). Accordingly, even if the pre-allocation of customers based on probability increases the total travel time, the average delivery cost per parcel decreases.

Value

This work provides both academic and managerial implications. On the academic side, it contributes to the literature while developing an innovative probability-based Vehicle

Routing Problem that, differently from other existing works, exploits new technological trends (e.g. the diffusion of smart-home devices). On the managerial side, it proposes a novel solution for scheduling B2C last-mile deliveries that relies on the use of smart home devices, and that has a significant impact in both reducing operating costs and increasing service level

INTRODUCTION

B2C e-commerce has been significantly growing during the last decade, and the number of online shoppers has been increasing in different industries and markets. This widespread trend is expected to continue in the future, also due to the changing shopping behaviour of customers (van Duin et al., 2016). In 2018 online sales have been worth more than €2,500 billion worldwide. China, Europe and USA are the major markets and together account for about 85% of the overall value (B2c eCommerce observatory, Politecnico di Milano).

Despite the intangible nature of online transactions, the management of logistics plays a crucial role in determining the success of companies selling products online (Mangiaracina et al., 2015). Moreover, the logistics service offered by e-tailers has emerged to be one of the key factors influencing the customers' decision to shop at them (Morganti et al., 2014). Within the logistics field, it is the last-mile delivery (LMD) that has captured the attention of both academics (whose contributions on the topic have been flourishing) and practitioners (who have been striving to find strategies to efficiently and effectively manage it). LMD represents the "last stretch" of the order fulfilment, aimed at delivering the products ordered online to the final consumers (Lim et al., 2018), either at their home or at a collection point (Gevaers et al., 2011). It has a significant impact on both efficiency – since it is very expensive – and effectiveness – since it constitutes the interface with the final customer, who directly perceives the associated service level performances.

The dominant B2C delivery mode is represented by the so called "attended home delivery", that requires the customers to be at home to collect the parcel and sign a delivery receipt before the courier leaves for the next destination (Han et al., 2017). This being the context, the eventual absence of the customer makes couriers not able to accomplish the delivery. This phenomenon – "failed deliveries" – is addressed by both academic and managerial efforts, since it has strong negative effects on LMD performances. On the one hand, it implies high costs for e-commerce players, which need to re-schedule the deliveries; on the other hand, it significantly affects the satisfaction of customers, who do not receive their parcel.

A possible way to reduce the occurrence of this problem could be scheduling the deliveries based on the probability to find the customers at home. A promising alternative for gathering data on the customer presence is represented by Internet of Things devices, and more in detail by smart-home devices, whose diffusion has been significantly growing in recent years also in less mature markets. Considering for example Italy, in 2018 IoT market has registered a 32% growth with respect the previous year, while, focusing on smart-home devices, the value increases up to +35% (Osservatorio Internet of Things, Politecnico di Milano).

This trend and the ability of smart-home objects to easily collect data thus generate new opportunities to exploit the potentialities of such devices in improving the LMD performances, from both the efficiency and the effectiveness perspectives.

LITERATURE REVIEW

The ever increasing number of online shoppers is very demanding in terms of delivery effectiveness (Agatz et al., 2011) and the quality of logistics services has become crucial in improving customer satisfaction (Qu et al., 2015). Among the most relevant performances for B2C deliveries, there are both speed and punctuality. On the one hand, once customers place an order, they are not willing to wait too much before receiving their parcels (Xu et al., 2008). On the other hand, many e-shoppers are interested in receiving their parcels at the most convenient time for them (Yang et al., 2017) and delivery delays may strongly affect their intention to repeat the purchase in the future (Qiu et al., 2011).

Besides effectiveness, efficiency of LMD is a very challenging issue for both retailers selling online and logistics operators. As a matter of fact, the last stretch of the order fulfilment is the most expensive part of the delivery process, and the related costs may amount up to half of the overall logistics costs (Vanelslander et al., 2013).

One of the most discussed issue of LMD inefficiencies is that of the failed deliveries, which occur when a home delivery is not completed since the customer is not there to collect the parcel. There is strong agreement in recognising how failed deliveries strongly impact on both efficiency – increasing the operative costs faced by companies – and effectiveness – reducing the service level seen by the customer (Wu et al., 2015). As a matter of fact, on the one hand, missed deliveries must be assigned to a subsequent delivery tour, and sometimes two or even three attempts may be necessary to succeed (Gevaers et al., 2011), thus increasing the operative costs faced by companies. On the other hand, they reduce the service level seen by the customer (Wu et al., 2015), who cannot promptly receive the products. In addition, missed deliveries also have environmental implications: their re-scheduling may increase the vehicle flow, with negative impacts on traffic, congestion and CO_2 emissions (Kedia et al., 2017).

These being the premises, scientific literature shows many attempts to develop strategies aimed at maximising the so called "hit rate", i.e. the rate of successful deliveries, and more in general at improving LMD performances.

Some authors propose the introduction of unattended delivery modes, such as parcel lockers (lockers usually grouped into structures located in public places, where customers are able to retrieve their parcel using a one-time password) or pickup points (institutions such as stores providing storage services) (Wang et al., 2014). Both these solutions allow to perform the delivery without the need of the customer being present to collect the parcels, and to increase the delivery density, while aggregating many deliveries in the same point of destination. The same advantages may be reached through the implementation of another innovative option proposed by more recent studies, i.e. in-car delivery: parcels are delivered within the trunk of the customer's car while it is parked in public places, such as supermarkets. Some novel initiatives may be found still relying on geo-localisation of the customers themselves through the GPS embedded in their smartphones: after issuing the orders, customers wait for parcels to be delivered in their hands wherever they are.

Nonetheless, home delivery still represents the first choice of the majority of e-customers, and thus still gains the interest of both practitioners and academics. Some authors propose e-commerce players to rely on the crowd, i.e. to outsource the deliveries to a network of "common" people, who typically grant higher flexibility. Among them, Akeb et al. (2018) suggest implementing a solution for which, in case customers are not at home, parcels may be collected by a neighbour, who will deliver them to the recipient in a subsequent moment. Another research line consider the so called time-windows management and on-appointment deliveries: customers choose a specific time-window (from 1 up to 2 hours) during which the parcels will be delivered (Agatz et al., 2013). Though, when customers choose the preferred delivery time option, they influence the sequence of the destinations to be reached in the tour and, as a consequence, companies are not able to optimise the delivery route (as it instead happens in traditional VRP tours).

A last emerging and promising trend takes into account data mining and data analytics tools for those data about the customer presence at home, in order to schedule deliveries and consequently improve the success rates (Florio et al., 2018; Pan et al., 2017).

OBJECTIVES AND METHODOLOGY

This work proposes a solution aimed at reducing missed deliveries through the understanding of the customer presence profiles, based on data collection performed by smart home devices (e.g. smart speakers), which are technically able to detect people presence at home. The main goals of the research are two. First, understanding how the probability distribution to find customers at home may be integrated in the Vehicle Routing Problem. Second, evaluating the effect on both effectiveness (hit rate) and efficiency (LMD cost) of implementing such a solution with respect to traditional VRPs. In other words, the following research questions have been addressed:

RQ1 How can customers home attendance profiles be integrated in the VRP for LMD?

RQ2 What is the impact of this innovative VRP on LMD performances?

In order to answer these research questions, two main steps have been carried out. First, an analytical model – based on both the travelled distance and the expected probability to find the customer at home – has been developed. It aims at maximising successful deliveries and computing the associated delivery cost and hit rate. Second, the model has been applied to a realistic scenario in Milan area, where costs and hit rates have been computed both for the proposed innovative VRPAP (Vehicle Routing Problem with Availability Profiles) and for the traditional VRP cases, to compare the performances of the two options. Three methodologies have been implemented to support the model development and application: literature review, semi-structured interviews with practitioners (both e-commerce retailers and logistics service providers, such as express couriers) and the analysis of secondary sources.

MODEL DEVELOPMENT

The proposed solution is based on five different ways through which smart-home devices may detect the presence of one customer at home:

(i) Home Assistant interaction with customers or detection of any conversation in the house;

(ii) smart appliances interaction with customers or detection of customer presence (e.g. thermostat);

(iii) smartphone pairing with the Home Assistant via Bluetooth connection;

(iv) smartphone pairing with the Home Assistant via Wi-Fi connection;

(v) smartphone localisation detection via GPS.

These interactions can be monitored in a discrete way (unit of analysis: one minute), and the customer home attendance is marked as positive if at least one of the five conditions is verified. Based on the collected data, customer home Availability Profiles (APs) may be built (associating to each moment of the day the probability of the customer being at home), and periodically updated. The APs of those customers to be visited in a delivery tour have to be provided in input to the VRP, to let the algorithm select the optimal sequence of deliveries (i.e. the sequence maximising the hit rate).

VRPAP (Vehicle Routing Problem with Availability Profiles)

The VRPAP algorithm is composed by two sub-stages.

(i) First, the algorithm performs a pre-allocation of customers to different time-windows (in which the day is divided) based on their APs, maximising the probabilities to find the customers at home.

(ii) Second, the algorithm finds the overall sequence of customers to be visited during the day to optimise the routing. More in detail, it first considers separately the clusters – i.e. the output of the pre-allocation phase – and then defines the optimal sub-routing for each of them. The sub-routing corresponds to the sequence of customers minimising the following multi-objective function, which includes both the probability of failed deliveries and the travel time.

$$\min \left\{ \left[\sum_{k=1}^{K} \sum_{i=1}^{N} \sum_{j=1}^{N} C_{var} \delta_{3,ijT_wk} DistDc_{ij} \left(1+\varphi_{jT_w}\right) \right] (1) \; + \; C_{ve} \cdot \sum_{k=1}^{K} g_k \, (2) \right\}$$

The first element of the formula (1) computes the overall variable cost of the delivery tour for each used van k, which depends on the following:

- T_w: unit of time considered for the optimisation (i.e. in which the daily delivery time is divided and for which the probability of the customers to be at home are estimated);
- C_{var} variable cost per minute for each travelling vehicle k (including fuel and driver);
- $\delta_{3,ijTwk}$: Boolean optimisation variable that indicates whether an arch i-j (connecting two subsequent customer locations i and j) is travelled by van k within the time interval Tw (i.e. if the vehicle moves from the i-th customer to the j-th customer during Tw);

- $DistDc_{ij}$: travel time between each couple of i-j customers. Since the routing is defined for each cluster, this travel times are reported into matrixes that are different for each cluster (i.e. there is one matrix for each time-window, associated to the customers to be visited in that time-window).
- φ_{jTw}: estimated probability of unsuccessful home delivery for the i-th customer visited during Tw (i.e. estimated probability that the delivery has to be rescheduled in a subsequent delivery tour). The higher this probability, the higher the associated distance to be travelled in order to successfully deliver the order to the i-th customer. It works as a penalty that deters the scheduling of deliveries in moments in which they will most likely fail.

The second element of the formula (2) represents the fixed cost for each used vehicle: the "activation" cost per van (C_{ve}) is multiplied by the total number of vans $g_{k.}$ g_k is an array of k Boolean variables, to which the algorithm associates the value 1 in case van k is used during the tour, 0 otherwise.

Once the sub-routings that minimise the cost function have been defined for all the clusters of customers, the overall daily routing is derived based on the combination of the sub-routings in subsequent time-windows (the ending point – i.e. the last customer to be visited – for cluster C_i is set as the departing point for cluster C_{i+1}).

Once the LMD problem has been solved, the associated performances may be computed, both in terms of hit rate and cost. The cost per delivery is estimated dividing the overall cost (fixed cost of the van + variable cost depending on the travelled time) by the number of successful deliveries.

MODEL APPLICATION

The main goals of the model application are to evaluate the effect of the proposed VRPAP on LMD performances, in terms of both efficiency (delivery cost) and effectiveness (hit rate), and to compare it with a traditional (i.e. only based on distances) VRP. The model has been applied to a realistic context in Milan (Italy). The used two-step methodology (development of analytical model and implementation to a realistic context) is widely adopted in literature dealing with LMD innovations (e.g. Qi et al., 2018).

The context of application has been defined based on the following assumptions and data (which were mainly derived from interviews to logistics service providers – express couriers – but also relying on literature and secondary sources).

- The total considered planning horizon is 2 days with 8 working hours each (from 9 a.m. to 1 p.m. and from 2 p.m. to 6 p.m., considering a 1-hour break between 1 p.m. and 2 p.m.). This is line in with fast e-commerce deliveries, which are typically accomplished within two days from the moment the order is issued. Each working day has been divided in 4 2-hours slots (corresponding to the clusters for the pre-allocation), associated to 16 customers each. The time bucket considered for the optimisation (and thus for the computation of the customers' attendance probability) T_w is 30 minutes.
- The delivery area is a 5 km^2 area in Milan (Italy), in which the total number of customers to be visited in two days is 128. These destinations are served by one transit point, located outside the delivery area – 3.3 km far from the perimeter, in correspondence of a real e-commerce depot. The distances between the depot and the customers, and those among the different customers – needed to build the travel time matrix $DistDc_{ij}$ – are the real ones, estimated thanks to integration of Google Maps API in the spreadsheet used for the computations.
- Customers have been clustered according to three main Aps profiles: (α) people receiving products in a place where the delivery is almost always successful, e.g. house with concierge or offices, (β) people who issue orders based on when they are expected – barring unforeseen circumstances that may still occur – to be at home to collect the parcel and (γ) people who place orders independently from the probability of incurring

in failed deliveries. The split of the customers into these three groups and the corresponding values of home attendance probabilities are reported in Table 1.

Customer	% of total number of customers	Average home attendance probability
α	50%	99%
β	30%	83%
γ	20%	53%

Table 1: Customers' profiles

- The performances and characteristics of the van are the following: fuel consumption 7 l/100km; fuel cost 1.52 €/litre; average speed 23.6 km/h; fixed daily "activation" cost per van 150€; variable cost per minute 0.05€/minute.

Based on these data and these assumptions, the LMD problem has been solved both through a traditional VRP (only aimed at minimising the travelling distances/time) and through the innovative VRPAP (considering both the minimisation of distances and the maximisation of the probability to find the customer at home).

	Traditional VRP	Innovative VRPAP
Total travelled time [min]	408	446
Average hit rate [%]	82	97.9
Delivery cost [€/parcel]	3.05	2.57

Table 2: Results of the model application

Table 2 shows the results of the application to the base case scenario, which lead to two main considerations. First, the total travelled time per tour is higher in the innovative VRPAP case with respect to the traditional VRP. In fact, the objective function of the traditional VRP minimises the overall travelled distance – and consequently the associated time – for a specific delivery tour. The VRPAP combines instead the distance minimisation with the hit rate maximisation. Accordingly, if a customer is associated to a very low probability to be at home in a specific moment of the day, the delivery is moved to a previous/subsequent time-window (where this probability is higher), even if it results in a higher travelled distance. Second, the innovative VRPAP allows to significantly reduce missed deliveries with respect to the traditional operating mode (97.9% successful deliveries vs 82%), thus improving effectiveness performances.
The positive effect stemming from the reduction of missed deliveries overcomes the disadvantage linked to the higher travelled time, and implementing the VRPAP thus results to be beneficial. As a matter of fact, the delivery cost per parcel – which is estimated dividing the total cost by the number of successfully accomplished deliveries – is lower in the innovative VRPAP case with respect to the traditional VRP (about -16%).

CONCLUSIONS

This paper proposes and evaluates the performances of an innovative solution that collects data about customers' presence at home and integrates them in scheduling last-mile deliveries. A VRP has been designed that first clusters customers based on the probability of finding them at home, and then defines the optimal sub-routes – i.e. the sequences of customers to be visited – for each cluster. Based on these results, the algorithm finds the overall optimal routing (RQ1). The application of the model to realistic cases in Milan (Italy) has shown that the proposed solution implies a significant reduction of missed deliveries with respect to the traditional operating mode, in which the probability of finding the customer at home is not considered while scheduling the deliveries (RQ2).
This work provides both academic and managerial implications. On the academic side, it contributes to the literature developing an innovative probability-based Vehicle Routing Problem that, differently from other existing works, exploits new technological trends (i.e. the diffusion of smart home devices). On the managerial side, it proposes a novel solution

for scheduling B2C last-mile deliveries with a significant impact in both reducing operating costs and increasing the service level.

This work has some limitations, which could be overcome through further developments. First, the model considers just one way to integrate the two optimisation objectives (probability maximisation and distance minimisation), in which the pre-allocation is only based on the probability to find the customers at home. It could be useful to evaluate other ways to pre-allocate customers, for instance including also the evaluation of the distances among customers to create clusters. Second, results of the model application rely on the definition of three clusters of customers, whose percentage are considered as fixed. Further research efforts could be aimed at evaluating the effect on the LMD cost per parcel of potential variations in the percentages of customers belonging to the different classes.

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EVOLVING TOWARDS A SMART FACTORY OF THE FUTURE WITHIN SUPPLY CHAINS: SELECTED CASES OUT OF THE ALPINE SPACE

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Abstract
Factory of the Future (FoF) is an immanent paradigm within the field of supply chain management. It is about the use of innovative and emergent digital technologies within supply chain operations and captures the whole organization towards a new corporate culture of interdisciplinary cooperation, collaboration and knowledge exchange. It transforms single organizations from "ordinary" manufacturers and isolated production-islands to fully integrated stakeholders of service networks, supply- and value chains. This article at hand investigates into the Factory of the Future paradigm. Based on 96 case study interviewees, conducted in five Alpine Space countries (Austria, Germany, France, Italy and Slovenia), it explores and descriptively presents the path towards a smart Factory of the Future.

Introduction
Since the emergence of the fourth industrial revolution, supply chains stakeholders experience increased innovation activities towards internally and externally interconnected Factories of the Future (FoF). FoF, as represented within this article at hand, is a vision that blurs traditional boundaries in organizations: it is a "new industrial revolution" [1] and requires a re-design of organizational and operational structures [2], incl. the increased integration of all supply chain stakeholders equally into supply chain services and processes [3]. Objective of FoF's are not only to be smart and technologically mature but highly performing, environmentally friendly and clean as well as social sustainable [4]. Within this article, FoF's are considered as service systems that again consist of a variety of heterogeneous service systems (network of independent but interrelated service systems). Service systems are the main abstraction of the theory of Service Science [5] and, related to Alter [6] a bundle of resources: system participants, information, technologies, processes & activities, products/services, customers, environment, strategies and infrastructure. In this sense, service systems exist to produce goods and/or services for service customers.

Due to the fact that strategies to evolve to a smart FoF are not sufficiently understood, the research motivation and purpose of this article is to explore and describe the path how an ordinary" manufacturer and isolated production-islands evolve to a fully integrated stakeholder in global service networks and supply chains. The empirical base of this article consists of 96 case study interviews conducted within the Interreg Alpine Space BIFOCAlps project. BIFOCAlps main objective is to boost collaboration and synergies among main actors of the Alpine Space Region innovation system for a sustainable, smart and competitive development of Factories of the Future within the region. This research is accompanied by research question about **how ordinary supply chain stakeholders can innovate and evolve to smart Factories of the Future**. Subsequent to this article, this research question is split into three clusters of interest: investment into digital technologies, ability in perceiving and facing the path towards digital transformation and knowledge transfer and collaboration towards the innovation and evolution towards smart Factories of the Future.

This article is structured among three sections. Section two presents applied the research design and research process. Section three presents a narrative literature review about the theory of Service Science, the co-authors literately access towards the Factory of the Future paradigm. This section's objectives are to present the status quo at a glance as well as the interconnection of Service Science and Factory of the Future. Section four presents the case study analysis. This section is about the descriptive presentation of the findings and value of conducted case study research. Section five concludes this article at hand and provides a short outlook for future research.

Research design

This research is guided by the case study approach of Eisenhardt (1989) [7] and Eisenhardt & Graebner (2007) [8]. Case study research, as Eisenhardt & Graebner [8] highlight, typically exploits opportunities to explore a significant phenomenon under rare or extreme circumstances. It is embedded in rich empirical data and "can richly describe the existence of a phenomenon" [8]. Following this case study approach, we first decided to conduct a narrative literature review about FoF's and its theoretically field of Service Science. The findings out of this literature review support to case study research: to go into the case study partners' organizations with a well-defined knowledge and, additionally, to ask (more) targeted questions (what is known, why does it differ, etc.).

The empirical base of this article at hand consists of 96 heterogeneous organizations within the field of manufacturing (industrial organizations, academic institutions and regional policy maker organizations in the Alpine Space: Austria, France, Germany, Italy and Slovenia). Managers out of these organizations have been interviewed by use of semi-structured interview-guidelines about a) investment into digital technologies, b) ability in perceiving and facing the path towards digital transformation and c) knowledge transfer and collaboration towards the innovation and evolution towards smart Factories of the Future. The interviews are conducted in 2017 and last ~1,5h each.

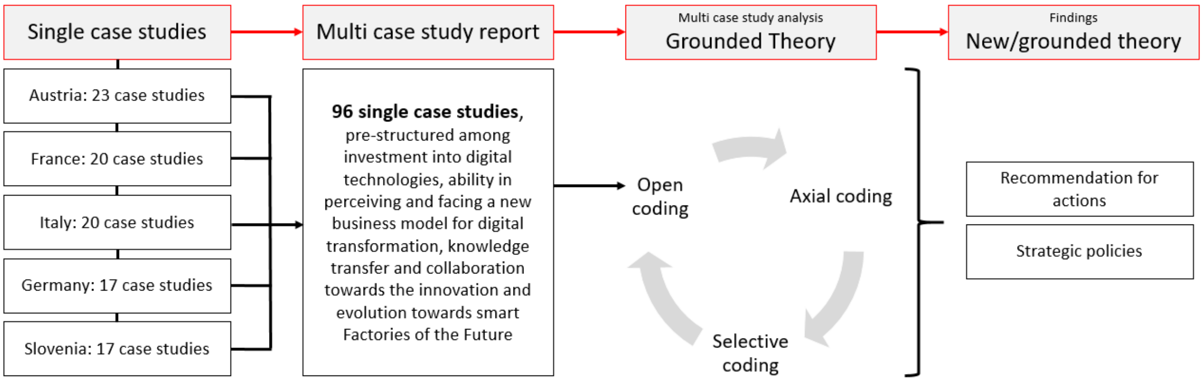

Figure 13: Research Design

As depicted in figure 1, all 96 single case study reports are merged to one multi case study report, which reflects the unit of analysis of this article at hand. This multi case study report experienced a structured analysis by use of the Grounded Theory methodology (e.g. [9]–[11]) and its open-, axial- and selective coding scheme. Open coding, as used in this scholarly article, is an indiscriminate coding to break-up of data and information through analytical crystallization of (described) phenomena and its characteristics. This coding scheme gives an unstructured access to data and compiles a variety of unconnected concepts and categories. Axial coding is the compilation of a phenomenon-oriented connection-related model. Aim of the axial coding scheme is to compile and to compare constantly qualified relations between previous observed concepts and categories. The selective coding scheme aims to integrate developed theoretical concepts into core categories [9]–[11]. The coding have been conducted with Atlas.ti – a specialized software for quantitative and qualitative research.

Body of knowledge at a glance: Service Science and Factory of the Future

Service Science is a relatively new academic discipline in the field of information system research ([12], [13]). This discipline is multidisciplinary and combines, according to Maglio & Spohrer, "organization and human understanding with business and technological understanding to categorize and explain service systems" [14] (*socio-technological orientation [12]*). Service systems, the main abstractions within this theory [5], are socio-technical systems [12] and "dynamic value cocreation configurations of resources (people, technology, organizations, and shared information)" [14].

Service systems are both: providers and clients of service that are connected by value propositions in value chains, value networks, or value-creating systems [14]. Value creation in service systems is enabled via the configuration of actors and resources [12] as well as the interaction within and between. While Wieland, Polese, Vargo, & Lusch (2012) [15] differentiate between "Goods-" and "Service-" design (the traditional perspective vs. service as fundamental basis of economic exchange [5])), Alter ([6], [16]) represents the perspective that all systems are works systems – no matter what they produce (because it is not important for work/service systems [6]). In Alter's perspective, service systems are work systems and thus vice versa [17]. Service systems are service-oriented because they exist to produce products and services for customers [18].

The concept of service systems support to understand ICT-, ICT reliant- and non-ICT systems in organizations. Service systems seem to be everywhere [19] or in the perspective of Maglio & Spohrer: "The smallest service system centers on an individual as he or she interacts with others, and the largest service system comprise the global economy […]" [14]. Information systems, projects, self-service systems and automated systems as well as – *object of investigation in this article* – Factories of the Future are special cases of work systems.

Factories of the Future, as the association of German engineers in collaboration with the American society of mechanical engineers [21] highlight, is a "product" of continued adoption of advanced manufacturing technologies into industrial processes. FoF's base upon the extended enterprise approach wherein business stakeholders (suppliers, customers and other business partners) are pro-actively involved [22]. This approach toward the collaboratively creation of value is major principle in the discipline of Service Science. FoF is a global trend[5] and an emergent field of organizational investments. As, for example, McKinsey&Company [23] identifies, FoF captures investment opportunities into new materials, product design, manufacturing technologies, IT and business models. These categories covers a broad range of innovative technologies, such as advanced robotics, additive manufacturing, digital manufacturing, big data, internet of things, etc. [21]. Additionally, FoF aims to implement flatter management structures accompanied with highly skilled and IT liberate workforce [22]. Thus, the FoF paradigm is an excellent example of a socio-technical service system: a service system wherein people and/or machines perform processes and activities using information, technology, and other resources to produce products and services – the essence of Service Science.

Case study analysis: findings & value

Based on this literature review and/or similar/extended knowledge, researchers of particular BIFOCAlps project partners entered the empirical field of manufacturing. In total, researchers interviewed 96 representatives of organizations within the field of manufacturing. Of major interest within these interviews are the case study partners' investment into digital technologies, ability in perceiving and facing the path towards digital transformation and knowledge transfer and collaboration towards the innovation and evolution towards smart Factories of the Future. As already identified within the

[5] Initiatives identified, e.g. USA (Advanced Manufacturing Program), European Union (European Factories of the Future Research Association), Germany & German speaking countries (Industry 4.0), Great Britain (Factory 2050), Japan (Science & Technology roadmap), South Korea (Vision 2025).

BIFOCAlps project, critical success factors towards a Factory of the Future are strategy, technology, capacity for innovation, ecosystem support for innovation and skills and change management [24]. The applied case study reserach goes beyond this critical success factors. It explores individual activities and explores recommendation for actions and strategic policies. This section presents achieved research results: it contributes to both – practice and academe – and presents new theory about the innovation and evolution toward a FoF and contributes to a better understanding how "ordinary" organizations within the field of manufacturing can become a smart FoF.

Investment into digital technologies

As the empirical research turns out, all case study partners are aware about ongoing digitalization resp. the digital transformation in their particular field of business. Most case study partners already got in touch with emergent Industry 4.0 technologies as, for example, artificial intelligence, augmented and virtual reality, 3D printing, autonomous driving as well as technologies captured under the roof of Internet of Things (IoT): sensors, cameras, interconnectivity of artefacts and objects, RFID, NFC, additive manufacturing, predictive maintenance, etc. Target, as observed is not only to establish the Factory of the Future but also a smart office and administration: thus, the development of a new corporate culture towards digital innovation and digital transformation in organizations.

The case studies reveal a broad repertoire of investment opportunities into digital technologies. The easiest form of investment are the renewals and replacements of IT and its infrastructure. Examples of investments into digital technologies, as observed in the case studies, capture the exchange of desktop computers with mobile devices (laptops), exchange of ERP server-client technologies with ERP cloud technologies, opening of proprietary IT systems and development of interfaces for increased (real time) data exchange (with service customers and suppliers; horizontal and vertical data integration; ERP/MRP integration, integration of IoT and other technology into ERP and MRP), modernizing of the organization's tools (e.g. microprocessors into machines, communication tools), extension of existing production facilities, etc. Additionally, case study partners started to re-design, re-work and optimize software. Development of new software and software frameworks is essential part in the case study partners' digitalization strategy. Activities include data management, master data management, data transparency, modularization of software, wireless communication, etc.

Data, as it turned out in the case study interviews, are important to enable interacting/networking machines: human-to-machine (and vehicles), machine-to-machine (and vehicles), machine-to-human communication and machine learning as well as simulation, artificial intelligence, virtualization, design and optimization: product, service and process configuration, in-house logistics, etc. within particular organization. As especially observed in French case studies – but not only restricted to these cases –, the majority of French case study partners focus on "cobotization" and "robotization" (e.g. the automated loading of trucks, automated high-rack warehouses,). Taken together, this automation shall enable "batchsize one" manufacturing. This target value is about the highest individuality towards customer requirements accompanied with the most effective conversion of production facilities and manufacturing machines.

Digitalization towards a Factory of the Future, as the case studies turn out, are seen as means to keep and to enhance effectivity and efficiency of production facilities and manufacturing machines. Key to success is much about predictive maintenance. This technology aims to anticipate production machine maintenance thus to reduce and avoid machine downtimes and breakdowns. Predictive maintenance is in close relation to remote diagnostic solutions, which is a technology that has been mentioned in case studies too.

To better cooperation and collaborate with service customer, service suppliers and the service environment, some case study partners invested into digital platforms, such as a customer relationship platform and digital networks. Additionally, few case study partners collaborate with "digital trendsetters": Microsoft, IBM and other "big names" within IT and technology business.

Investment into emergent digital technologies are of strategic importance. As observed, technologies are on organizational radars and captured in strategic IT-maps. However, a critical issue, as observed in the case studies, is the financial limits (especially of SME's) and the amortization of investment. For example, a manufacturer for packaging material mentioned that because of financial limits they only could digitalize one production machine. But this does not make much sense: "To digitalize one production machine and leave the other machines untouched would only create double of work and maintenance – accompanied by complementary technologies". A solution to cope at least financial risks is the self-organization within strategic partnerships and research spin-offs, as for example a case study partner in Austria reports. As observed in the case studies, case study partners not exclusively invest into digital assets but also into the human factor, health and work ergonomics. Investments include, as the examples highlight, continuous education, training qualification of managers and employees towards Factory of the Future paradigm, knowledge dissemination channels, terminals in shop floors, safety and security, etc.

However, some case study partners also recommend that ongoing digitalization also have its dangers. Case study partners exemplified the increase of complexity in IT and its infrastructure, cybersecurity issues and lack of appropriate knowledge workers.

Ability in perceiving and facing the path towards digital transformation

As observed in conducted case studies, the abilities in perceiving and facing the path towards digital transformation are that manifold as the case studies are. Paths capture a broad repertoire of strategies and activities and include, for example, organizational agility, ergonomics, paperless, process improvements, product innovation, working directly with the customer etc.

A major chance that the majority of case study partners started to capitalize are increased servitization: putting the customer into the center of economic trade. Examples include, the full integration of customers into operations, development of customer satisfaction processes (increase of quality; guarantee of quality), professionalization towards customer demands (interaction and knowledge exchange with customers on real time basis), product-, service- and process innovation (due to customers requirements) as well as smart contracts. Customer interaction, as identified in literature review, is key principle in Service Science: value, according to this theory, is always co-created in service provider and service customer relationships. Within observed case studies, the approach of customer integration is accompanied with product-, service- and process innovation and digitalization. Examples include the integration into ERP systems, development of interfaces to exchange real time data, customer relationship platforms, digital networks, etc. Customer interaction and integration, as identified in literature review and observed in case studies, lead to increased service performance and productivity as well as decreased lead times. Service interaction between service provider and service customer in organizations thus lead to increased speed to market.

The increased digitalization of organization, as observed in the case studies, also support to increase collaboration with the organizational environment. As examples highlight, case study partners are able to increase supplier interaction and collaboration, development of strategic partnerships (cooperation, alliances, spin-off organizations), conduction of collaborative projects with FoF stakeholders (e.g. start-ups and entrepreneurs, consults), development of new business models (in finance, rental services, etc.), adaption of standards, change in technologies and awareness. It further increases the development of competitive processes, practices and routines. Examples include the implementation of additive manufacturing processes, predictive maintenance processes, big data and data analytic processes, interconnectivity with organizational resources (e.g. machine to machine communications, human – machine interfaces, etc.), renewal, change and adaption of organizational resources (exchange of old technologies), development of software and software frameworks, automation/robotization of processes, development of use cases, routines and best practices.

Knowledge transfer and collaboration towards the innovation and evolution towards FoF
As the majority of the case studies highlight, networking, cooperation and collaboration is major pillar in innovation and evolution towards a Factory of the Future. Networking, cooperation and collaboration activities, as observed in case studies, consist on development, maintenance and expansion of partnerships of all kinds: customer networks to include the customer's feedback, supplier networks and industry networks to tap business innovation, research and development (R&D) networks and networks with universities and research institutions to launch research projects, and many further more. Pro-activity in R&D, as the case studies highlight, is essential within case study partner organizations: as observed, the majority of case study partners perform internal and external R&D projects as well as started to organize themselves in strategic R&D spin-off organizations. The advantage of such spin-off organizations are the shared costs and risks in research projects.

To pro-actively disseminate information, knowledge and expertise about emergent technologies (towards increased digitalization in FoF's), some case study partners provide and maintain educational facilities, e.g. internal colleges and training centers. Within these facilities, managers and employees get trained and educated about renewals and innovation of particular organizations' product, service and process level as well as emergent (*internet*) technologies and trends. However, case study partners that do not have the financial strength to run such educational facilities organize themselves, as observed in the case studies, organize themselves in (internal/external) strategic workshops, tailored working groups and business meetings (*in cooperation with quadruple helix actors, e.g. [25]*). The implementation of an internal idea management could be observed in one single case study. Such system can act as collection point for internal system participants for ideas and innovation.

An important activity, as the case studies show, are the collaboration with entrepreneurs and start-up organizations. People within these organizations, as the case study interviews argue, are considered as innovative thinking people and can provide new approaches and new solutions from a different perspective towards particular organizational challenge. External collaboration and cooperation, as observed, is characterized by collaborative projects, excursions and benchmarking. A case study partner in Austria, for example, continuously invites befriended organizations for company excursion. In turn, this case study partner takes advantages out of invitations in return. A common issue is the hiring of appropriate managers and employees. As observed in the case studies, managers and employees need mature skills and competences towards the FoF paradigm: IT, technology, service thinking, system thinking, etc. Further activities, for example, include experimentation (at home), hiring of eternal consultants, participation in research projects (e.g. Interreg, H2020, etc.).

Conclusion
This article at hand is about a case study research about the Factory of the Future paradigm in manufacturing section in the Alpine Space. Researchers of the Interreg Alpine Space BIFOCAlps project investigated into 96 organizations located in Austria, Germany, France, Italy and Slovenia. This article at hand supports scholars and practitioners to manage, engineer and design the system's evolution towards a smart, technologically mature, highly performing, environmentally friendly and clean as well as social sustainable FoF.

As already identified in the BIFOAlps project, critical success factors to evolve to a FoF are strategy, technology, capacity for innovation, ecosystem support for innovation and skills and change management [24]. However, this article goes beyond. By use of Grounded Theory methodology for case study analysis, this article explore and describe the path how an "ordinary" manufacturer and isolated production-islands evolve to a fully integrated stakeholder. As the case study analysis turns out, IT and its infrastructure need to be ready for new and emergent FoF technologies. Activities not only include the replacement of hardware but also investments into re-design, re-work and optimization of software as well as cloud-based technologies. Data, especially master data management must be kept clean to effectively collaborate with FoF technologies (e.g. IoT, predictive maintenance, additive manufacturing, virtual and augmented reality, robotics/cobotics, etc.). Also, activities include the extension of systems: the shift from proprietary ERP systems towards open, interactive and collaborative systems. This again enables the deepened cooperation and collaboration with service customers, service supplies and the service environment as source for increased service interaction and value co-creation. Further, important to evolve to a FoF is to network, cooperate and collaborate in service partnerships, networks, alliances and spin-offs. R&D spin-offs, as some cases highlight, enable to share financial burdens and risks about the research into FoF technologies. However, a successful implementation of the FoF paradigm requires the participation of all system participants: top managers and employees as well as its continuously education, training and qualification towards Factory of the Future technologies.

Outlook & future research

In continuation of this reserach at hand, the co-authors will further deep in into the Industry 4.0 and Factory of the Future paradigm and will conduct a case study survey about the Technology Maturity Level Index (TML) of organizations within the Interreg Central Europe region. The TML, according to Schumacher et al. (2016) [26], is model that can assist with the difficult task of reflecting on the current capabilities regarding Industry 4.0 and the subsequent decision on respective strategies and action plans. This research is supported by the **4Steps project** – a project towards the research of the application of Industry 4.0 in SMEs, increased flexibility in manufacturing, mass customization, increased speed, better quality and improved productivity – to support the successful implementation of smart specialization strategies and to apply Industry 4.0 to all the industrial sectors identified by each regions [27].

Acknowledgement: the BIFOCAlps

This case study research is co-financed by the Interreg Alpine Space (2018) [11] project BIFOCAlps. BIFOCAlps is an Industry4.0 and Factory of the Future related project with the aim to boost innovation in Factory of the Future value chain in the Alps.

BIFOCAlps project is tackling a common challenge to many Alpine Space (AS) regions: due to globalization, many enterprises in Manufacturing Sector (MS) are not as competitive as wished in global markets, resulting in increased levels of unemployment, abandoned facilities and remaining plants that need new products and new processes. On the other hand, AS has a strong R&D sector and specialization on Industry 4.0 and Factory of the Future (FoF) technologies. BIFOCAlps main objective is to boost collaboration and synergies among main actors of the Alpine region innovation system for a sustainable, smart and competitive development of the value chain of the MS towards the FoF. The main outputs will be (1) a map of the MS at transnational level, to understand existing and potential best practices and technologies along MS value chain; (2) a methodology for enhancing FoF long-term sustainability through innovation and knowledge transfer and (3) guidelines of strategic actions for policy makers based on an impact indicator system, to monitor and allow evaluation of performance in line with regional smart specialization strategies. PPs and target groups are relevant stakeholders in the field of Industry 4.0 and FoF, which are involved in the policy-making affecting R&D and MS growth, in the MS value chain and in the FoF research field. They will mostly benefit from project activities and outputs. The innovative approach integrates a "bifocal" view (considering both upand

down-stream value chain) and the transversal competences of the business, research and policy actors at transnational level. It will allow to gather best case scenarios of the AS and to integrate and implement them in the generalized methodology, which will build on previous results and will be transferable at cross-national and cross-sectoral level aiming to connect value chain and boost competitiveness of the whole AS in the long term. Find more information under http://www.alpine-space.eu/projects/bifocalps/en/home

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ANALYSIS OF IOT ADOPTION FROM A SUPPLY CHAIN COLLABORATION PERSPECTIVE

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Purpose

Internet of Things (IoT) connects numerous sensors, actuators and data processors, thus provides solutions to problems arising from information asymmetries and complexities in supply chains (Ng et al., 2015). Although the application of IoT will be the future of supply chain management, the main barrier against implementing it still lies in inter-firm issues. Despite the increasing importance of supply chain visibility, information sharing in practice is not widespread, which can be attributed to trust and confidentiality issues (Ali et al., 2017). Considering this problem, this paper aims to highlight opportunities and challenges that can be posed by the adoption of IoT. More specifically, it investigates current logistics practices where IoT is used and then analyses the examples through a supply chain collaboration lens, by focusing on the impacts of this technology adoption across supply chain entities.

Design/methodology/approach

Two case studies, including a case of using temperature control sensor and a case of transporting a particle accelerator component, are conducted to depict in-use applications of IoT in inter-firm settings. An analysis using a CIMO (Context-Intervention-Mechanism-Outcome) framework highlights why and how technological advancement is needed and to what extent supply chain entities can be affected by the IoT. Further analysis demonstrates the benefits and risks of data sharing within a supply chain by the IoT adoption. The data is collected via interviews, focus groups, and direct participant observations.

Findings

IoT adoption is a practical solution to multiple logistics issues, spanning from monitoring temperature fluctuations and mechanical shocks to knowing the precise delivery time and route quality. However, its impacts were varied across supply chain entities because the relevance and usefulness of the data depend on specific entities. In a similar vein, the perception of benefits and risks from data sharing was different when involving costs for investment and responsibilities for any logistics glitches. Consequently, several propositions were drawn to discuss collaboration issues when IoT is adopted to logistics operations.

Value

This paper addresses the issues arising from the IoT adoption, by taking a supply chain collaboration perspective to identify the hurdles which lead to slow implementation of the IoT in logistics through studying multiple case studies.

Research limitations/implications

The paper contributes to the emerging area of the IoT in logistics and supply chain management by exploring the main issues behind implementing these practices across companies in the networks. It will also provide relevant knowledge to on-going discussions on the power asymmetry and failure in data sharing since the introduction of the Electronic Data Interchange (EDI) (Webster, 1995).

INTRODUCTION

Information and communication technology (ICT) has improved the efficiency, visibility and safety of logistics and supply chain operations. One of the trends in logistics management during the last decade was the Internet of Things (IoT) (Hoffman and Rüsch 2017). IoT connects numerous sensors, actuators and data processors, thus provides solutions to problems arising from information asymmetries and complexities in supply chains (Ng et al. 2015). A fundamental part of IoT in logistics systems is the connectivity which is enabled by using smart tags such as RFID in combination with sensors to enable items transmit data about their status and location in an automated or semi-automated form. The changes created by IoT make disruptions to the value chain and create significant new opportunities that makes companies rethink all their practices (Porter and Heppelmann 2014).

On the other hand, ICT has increased complexities in supply chains and the dependence of logistics operations on information systems (Trienekens et al. 2012). Despite the increasing importance of supply chain visibility, information sharing in practice is not widespread, which can be attributed to trust and confidentiality issues (Ali et al. 2017). Indeed, several organisational factors affect the implementation of innovative information technology in SCs mainly due to the integrated nature of supply chains including the management of material, information and financial flows among multiple actors (Olhager 2002). As a result, risks as well as benefits related to implementation of inter-organisational information systems are shared between actors of a SC (Hellström et al. 2011).

Supply chain collaboration thus holds a key to implementing IoT across a supply chain mainly due to IoT's property of information sharing. However, this very crucial aspect of IoT is not explored in current literature. A large portion of IoT-based initiatives stay in pilot level due to lack of collaboration which can be due to lack of compatibility of information systems between companies or inter-organisational barriers such as lack of trust among companies. To address the research gap, this paper aims to highlight opportunities and challenges that can be posed by the adoption of IoT. More specifically, it investigates current logistics practices where IoT is used and then analyses the examples through a supply chain collaboration lens, by focusing on the impacts of this technology adoption across supply chain entities.

INTERNET OF THINGS

Internet of things is built on the concept of smart objects which are complex systems that combine hardware, sensors, data storage, microprocessors, software, and connectivity in myriad wayside (Porter and Heppelmann 2014). One advantage of IoT is providing higher levels of inter-organisational track and trace which leads to more control on the flow of transported objects including products, packages, load units and vehicles through different logistics processes (Shahin 2010). 'Smart' or 'Intelligent' products and vehicles are the concepts and phrases created to describe the potential of technologies such as RFID, global system for mobile communications/global packet radios services (GSM/GPRS) and web technology to create high-level tracking and tracing of transportation objects (Meyer et al. 2009). These technologies have different advantages and weaknesses and companies select them based on a variety of criteria including the readability, data storage capabilities, compatibility with the information systems they are using and of course the costs associated with using them. They are not just used by companies for management of internal operations, such as inventory and warehouse management, asset management, loading or unloading (Buyurgan et al. 2010), but also used in inter-organisational operations (Kelepouris et al. 2007).

An important aspect of IoT is the information architecture which enables control of the movement of objects among different facilities owned by different companies in a SC (Xu 2011). To create IoT in inter-organisational environments, therefore, enabling tracking and tracing objects will entail a system to store information about products throughout the SC and to enable data sharing between companies and their information systems (Cimino et al. 2005). Several studies have investigated applications of RFID and opportunities created by using it for effective and efficient tracking and tracing (Kelepouris et al. 2007; Costa et al. 2013). Although it is proven that application of RFID can lead to different types of improvements for different processes, its adoption is still limited because of various technical and economic obstacles related to it (Costa et al. 2013). Information sharing in the inter-organisational context is one of the challenges.

INFORMATION SHARING IN SUPPLY CHAIN

Information sharing in a supply chain can provide clear benefits in various ways. Information is one of inventory reduction enablers, which can minimise stock level with better forecasting and collaborative planning (Lee and Whang 2004). Bullwhip effects can be also prevented if the vendors have sufficient information on the actual sales data. In a similar vein, response time to customer's requirements can be considerably reduced while increasing the overall operational performance of a supply chain (Lee et al. 2010). In these studies, information sharing has been regarded as one of virtues that supply chains should pursue. Studies on supply chain collaboration also emphasises the importance of information sharing as a driver of a successful collaboration. For instance, representative collaboration concepts, such as Collaborative Planning Forecasting and Replenishment (CPFR), Efficient Consumer Response (ECR), Vendor Managed Inventory (VMI), Collaborative Transportation Management (CTM) and Continuous Replenishment (CR), will essentially require information sharing between supply chain partners.

However, other researchers have also identified barriers and challenges that firms will encounter when information will be shared. There are two notable studies which comprehensively suggested these information sharing barriers. Firstly, Pujura et al. (2011) reviewed literature and identified 11 main factors that inhibit information sharing, and then proposed a hierarchical structure of these factors using interpretive structural modelling. This research showed that lack of top management commitment and poor understanding of SCM concept are fundamental reasons for information sharing failure. These can in turn lead to lack of strategic planning, lack of organisational structure, lack of culture and lack of IS/IT as driver barriers. These factors affect dependent barriers, such as lack of integration guidelines, lack of information flow, lack of trust, lack of understanding cost sharing benefits and lack of SC measures. Secondly, Khurana et al. (2011) created six categories for 40 information sharing barriers, which are managerial barriers, organisational barriers, financial barriers, technological barriers, individual barriers and social-cultural barriers. In their analysis using fuzzy-AHP, it was found that financial barriers are the most critical factor followed by technological and organisational barriers.

METHODOLOGY

Two case studies are conducted to depict in-use applications of IoT in inter-firm settings. In these two case studies, a special telematics tracking device was used as an example of IoT. An analysis using a CIMO (Context-Intervention-Mechanism-Outcome) framework highlights why and how technological advancement is needed and to what extent supply chain entities can be affected by the IoT. Further analysis demonstrates the benefits and risks of data sharing within a supply chain by the IoT adoption.

The first case study is about wine transportation from Bulgaria to Sweden. Vineyard A in Bulgaria produces around 25 tons of grapes every year, which is sufficient for making 20,000 bottles of wine. The wine is trucked from Bulgaria by a transportation company to its distribution centre in Sweden, covering more than 3,000 km and very different ambient conditions. To ensure the quality of wine, this company has adopted a telematics tracking device which is connected to the main database, to check the real-time temperature of shipment. The second case study is about transportation of components for particle accelerators from Sweden to France. Particle accelerator components are extremely sensitive to mechanical shocks, making it very challenging to ship the components over long distances. To minimise the exposure to shocks, the components are placed carefully on a rig standing on shock absorbing bumpers. Still, to assure the quality, the sender and receiver must show that the components haven't been exposed to any shocks during the shipment. This evaluation can be possible by a special telematics tracking device on the truck which can store and transmit the shock data to the database.

ANALYSIS – CASE 1

Quality wine is an expensive product that needs to be handled correctly in the entire way from production until consumption. To preserve the quality of the wine, it shall not be exposed to temperatures outside the range between +18 °C to +28 °C, which is relatively easy to achieve during warehouse storage. However, ensuring full temperature control during the entire shipment, including load and unload operations, is often more challenging and costly. To ensure that the quality of the wine is not reduced during the transport, Vineyard A needs visibility into transport-related temperature variations and movements. The temperature is monitored to detect any deviations outside the allowed +18 °C to +28 °C range. Having access to near real-time information about the wine shipment's position is important to ensure a high delivery precision. Knowing exactly when the products arrive means that the unloading process can be optimised, and the products can be directly moved into proper storage conditions.
In this case, temperature and GPS position data were reported from a telematics tracking device. The device was capable of measuring temperature and position at a user defined sampling rate. Data from the T&T device was automatically sent via GPRS to a web-based application, giving near real time updates on the shipment parameters. Figure 1 shows the visualisation of the data which were transmitted to the database. This case shows that below benefits of having this IoT were realised:

- Increased position visibility made it possible to verify the operations of the transportation company and to inform the distribution centre about the upcoming delivery; and
- The product quality could be ensured by monitoring its temperature along the entire supply chain.

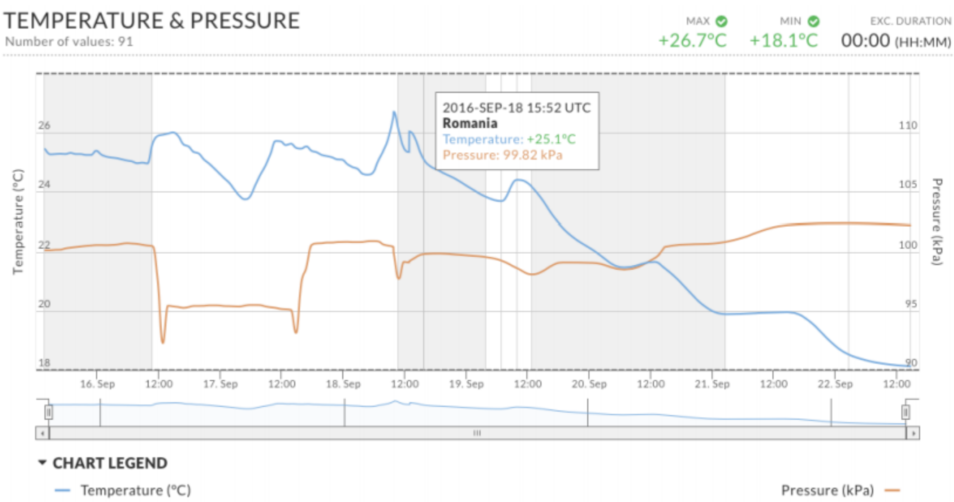

Figure 1: Visualised temperature data of Case 1

Qualitative interviews with entities in this SC were followed to analyse this shipment by a CIMO framework (see Table 1). Context (C) here means problems encountered by this SC, and Intervention (I) is the solution to the context, invoked by Mechanism (M) and resulting in Outcome (O). The contexts, interventions and mechanism are clear-cut in this case. Firstly, the case company spotted fluctuations in temperature whilst transport, thus tried to intervene this situation with real-time temperature measurement via an installing temperature sensor. Secondly, unreliable delivery time was another problem, which can be fixed by information on real-time truck positions that can be obtained by installing a GPS sensor.

Context (C)		Fluctuation of temperature during transport	Unreliable delivery time
Intervention (I)		Real-time temperature measurement	Real-time vehicle position data
Mechanism (M)		Installing a temperature sensor	Installing a GPS sensor
Outcome (O)	**Shipper**	Quality of shipment Clear liability for cargo damage	Clear liability for delay in cargo delivery
	Transport Company	More care for cargo temperature	Increased delivery reliability
	Consignee	Quality of shipment	Better prepared for product reception

Table 1: CIMO analysis of Case 1

However, the outcomes were varied for entities in this supply chain. For instance, shippers and consignees can ensure quality of shipment by checking real-time temperature data. If the temperature is kept within 18-28 °C, they can conclude that there was no damage to the product during the transit. In a similar vein, this data can clarify who should be liable for cargo damage. This can help reducing unnecessary disputes between shippers and consignees. Also, the location data can make consignees better prepared for product reception. This means that they can save time and money by allocating an appropriate bay and space in a warehouse based on the precise delivery time. On the contrary, transport companies will not have obvious benefits from this data sharing. As an indirect effect, service level can be increased because they will be more aware of cargo temperature and transit time. However, sharing of real data including low performance can lead to liability issues and losses of customers. In addition, transporter companies' performance can be easily evaluated by the data, which means any faults or defects in the sensor can invoke false blames.

ANALYSIS – CASE 2

Quantitative data for this case was collected using a similar set-up as described in the above case. A telematics tracking device capable of measuring acceleration and GPS-position at a user defined sampling rate was mounted onto the particle accelerator component cradle. Acceleration was used for measuring mechanical shocks. While temperature changes are slow and continuous in its nature, mechanical shocks are unexpected and disruptive. Hence measuring the acceleration with a constant sampling rate is very unlikely to capture any events (the shock must coincide with the sampling). This was overcome by having the device to continuously measure the acceleration and report it at either the set sampling intervals or when its value exceeds a predefined threshold.

Figure 2 shows the example of pressure data captured over time. Acceleration, pressure, position and time can be analysed at the same time by combining this data with GPS data. The key findings were summarised as below:

- The system continuously monitored and determined that no excursions in terms of mechanical shocks exceeding the thresholds occurred during the entire transport, thereby ensuring the quality of the product; and
- The system successfully notified the personnel at the destination of the upcoming delivery.

Figure 2: Visualised Pressure Data of Case 2

Subsequent interviews were analysed by a CIMO framework. There were three problem contexts identified in this case; (1) mechanical shocks during transit, (2) lack of knowledge on route quality and (3) unreliable delivery time.

Context (C)		Mechanical shocks during transit	Lack of knowledge on route quality	Unreliable delivery time
Intervention (I)		Real-time measurement of mechanical shock	Real-time positioning combined with shock measurement	Real-time positioning
Mechanism (M)		Installing acceleration sensors	Installing GPS sensors coupled with accelerator sensors	Installing GPS sensors
Outcome (O)	**Shipper**	Quality of product	None	None
	Transport Company	None	Route decision	Increased delivery reliability
	Consignee	Quality of product	None	Better prepared for product reception

Table 2: CIMO analysis of Case 2

In a similar vein to Case 1, the outcomes are found to be different across the entities in this supply chain. The sensor can record mechanical shocks during the transit by installing acceleration sensors. This can ensure the quality of the product from the shipper's and consignee's viewpoint, but there were no clear benefits to the transport company; rather this information can be used to seek liability of the transport company. On the other hand, knowledge on the route quality acquired by GPS sensors coupled with accelerator sensors can enable transport firms to find the safest route to transport the product. Real-time positioning data collected by GPS sensors can increase delivery reliability for transport companies and make consignees to be better prepared for product reception.

DISCUSSION AND CONCLUSION

IoT adoption is a practical solution to multiple logistics issues, spanning from monitoring temperature fluctuations and mechanical shocks to knowing the precise delivery time and route quality. However, its impacts were varied across supply chain entities because the relevance and usefulness of the data depend on specific entities. In a similar vein, the perception of benefits and risks from data sharing can be different when involving costs for investment and responsibilities for any logistics glitches. Table 3 summarises the benefits and risks in each data sharing situation discussed in previous cases.

Case	Data sharing Demand	Data sharing benefits	Data sharing risks
1	Shipper data shared with consignee	All stakeholders can be confident with the quality of the delivered product by having the data collected from the transport company.	Defects/faulty calibration of the T&T sensors can lead to false blames.
	Shipper and distribution centre share data collected by the transport company	The distribution centre knows exactly when the wine arrives based on the shared data from the transport company	Truck drivers will be under pressure to meet the estimate time of arrival.
2	Transport company data shared with research and test facility	By being handed data from the transport company, the research and test facility can be confident that the components are intact after the transport.	Defects/faulty calibration of the T&T sensors can lead to false blames.
	Transportation company data shared with consignee	The distribution centre knows exactly when the product arrives based on the shared data from the transport company	Truck drivers will be under pressure to meet the estimate time of arrival.

Table 3: Benefits and risks of data sharing

Adoption of IoT can pose several challenges at the intra- and inter-organisational levels. Within an organisation, IoT can create data management challenge, data mining challenge, privacy challenge, security challenge and chaos challenge, to name a few (Lee and Lee 2015). The challenges at the inter-organisational level will include these intra-firm challenges, but one critical difference can be found. According to Yates and Benjamin (1991) in their old research on EDI, this challenge is referred to as 'virtual vertical integration'. In line with this, Webster (1995: 39) argued that: "*Proprietary EDI systems may be part of a strategy used by corporations to establish or reinforce domination over their trading partners, who are required to use the proprietary system and trade on the terms dictated by the hub company. This strategy can be linked to the classic strategy of vertical integration. It replicates the control of the vertically integrated organization, without actually requiring the ownership of subordinate companies. Instead, control over these subordinate trading partners can be achieved through electronic linkages*." This argument will be still valid even when 'EDI' is replaced with 'IoT'.

Information sharing in supply chains is inhibited mainly by two factors; one is data availability and the other is data sensitivity. Data availability issues stem from incompatible database, lack of information sharing culture, insufficient investment in database and so on. Data availability can be dramatically increased if IoT is adopted to supply chains because real-time data sharing can be realised with interactions of sensors and a platform to interface data from sensors. Contrarily, data sensitivity issues are grounded on data confidentiality, mistrust, short-term commitments and liability risks. As can be seen in the previous cases, entities in the supply chains have different levels of benefits and risks. In particular, transport companies will see less benefits; furthermore, their employees (truck drivers) will be under great pressure due to real-time information sharing. In fact, every reefer container has already equipped a temperature recorder so that reefer experts can monitor and control the temperature. However, this data will not be readily available to customers even upon request because this data can be used for critical evidence for cargo claims in transactional relationships.

This does not mean that adoption of IoT will be far-off due to data sensitivity issues. Rather, it emphasises that there will be two approaches to adopting IoT in a supply chain. The first approach is that a powerful entity in a supply chain coercively invite other members to IoT acceptance. The second approach is that IoT is adopted to established supply chain partnerships where the data can be utilised for aligned goals and performance improvement. As a consequence, IoT adoption cannot be just technological advances, but also be a matter of supply chain collaboration because collaboration means "*diverse entities working together, sharing processes, technologies, and data to maximise value for the whole group and the customers they serve*" (Foster and Sanjay 2005:31).

This paper addresses the issues arising from the IoT adoption, by taking a supply chain collaboration perspective to identify the hurdles which lead to slow implementation of the IoT in logistics through studying multiple case studies. The paper contributes to the emerging area of the IoT in logistics and supply chain management by exploring the main issues behind implementing these practices across companies in the networks. It will also provide relevant knowledge to on-going discussions on the power asymmetry and failure in data sharing. Future research can expand this discussion in different settings of IoT adoption and find out solutions to information sharing across the supply chain.

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LOGISTICS SUPPORT MODEL FOR CROSS-BORDER E-COMMERCE BETWEEN JAPAN AND CHINA

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Purpose
The market size of Cross-Border E-Commerce towards China is rapidly expanded. Many Japanese retailers try to enter it. On the other hand, this change showed up some problems on custom clearance. Therefore, Chinese government revised custom institutions. Some logistics service providers modify their support system to fit these changes for retailers. This paper analyzes current situation of Cross-Border E-Commerce from Japan to China and some Cross-Border E-Commerce support models, and then we examine appropriate commodity for each model.

Design/methodology/approach
Firstly, we survey current situation of Cross-Border E-Commerce researches in Japan and China. Based on these researches, we construct some types of Cross-Border E-Commerce logistics system. Each model has characteristics of logistics and marketing. We analyze what kind of commodity fit each model from logistics and marketing perspective.

Findings
We define 4 types of Cross-Border E-Commerce support models (EMS, Bonded Area, Consolidated Air -Chinese EC site- and Consolidated Air -Japanese EC site-) based on JETRO (2016). In Cross-Border E-Commerce market toward China, it is said that large part of it is EMS model. However, it is difficult to check custom clearance of a lot of EMS. Chinese custom tries not to miss collecting taxes by promoting other 3 types of models. In this paper, we focus on these models.
The advantages of Bonded Area model are short lead-time, low cross-border logistics cost and big ability to attract consumers (This is because Bonded Area is mainly used Chinese E-Commerce retailers such as Alibaba for Cross-Border E-Commerce). On the other hand, the disadvantage of that are high inventory cost, risk of unsold inventory and management cost for EC site. Therefore, appropriate items of this model are top selling and large volume (or heavy weight) such as paper diaper.
The advantages of Consolidated Air are low inventory cost and risk of unsold inventory. The disadvantage of that are long lead-time, high cross-border logistics cost. In the case of Chinese EC site, big ability to attract consumers is also advantage and high management cost for EC site is also disadvantage. In the case of Japan site, management cost is low but small ability to attract consumers. Therefore, momentary trend items which has enough volume of sales to manage Chinese popular EC site are fit for Consolidated Air -Chinese EC site- model. In the case of Consolidated Air -Japanese EC site- model, niche items are suitable.

Value
This paper suggests international logistic model of Cross-Border E-Commerce for Japanese E-Commerce retailers and logistics service providers. Cross-Border E-Commerce market situation toward China is drastically changing. Therefore, we hope this paper is valuable not for current market participants but for potential ones.

INTRODUCTION

Recently, many E-Commerce (EC) retailers expand not only their domestic customers but foreign ones. This movement is caused by consumers' demand to purchase foreign products which is sold more expensive price or rarely sold in their country, so-called "Cross-Border EC".

Especially, the market size of Cross-Border EC towards China is rapidly expanded. Many Japanese retailers try to enter that attractive market. However, there are some logistics problems in Cross-Border EC even if the distance between Japan and China is not so long. Moreover, this market expansion also shows up some problems on custom clearance. Therefore, Chinese government revised custom institutions. Some logistics service providers modify their support system to fit these changes for Japanese retailers.

This paper analyses current situation of Cross-Border EC from Japan to China and some Cross-Border EC logistics support models, and then we examine appropriate commodity for each model.

DEFINITION OF CROSS-BORDER EC

European Commission defines Cross-Border EC as "any purchase made by consumers from retailers or providers located in a country other than the country in which a particular consumer is resident" in European Commission(2008). This definition includes purchase of goods or services from foreign retailers or providers via online shopping site. However, it does not include purchase of foreign them from ones located in a country where consumer is resident.

On the other hand, Ministry of Economy, Trade and Industry of Japan (METI) defined Cross-Border more widely. METI's definition adds distribution styles such as purchase made by consumers from their domestic retailers or providers. This is because that some sales of Japanese goods provided as Cross-Border EC by Chinese online shopping site even if those goods were entered in China through general trade.

Our research objectives are clarification of logistics problem in Cross-Border EC and analyse logistics support models from Japan to China. Thus, our target is Cross-Border EC for goods. In addition, we define Cross-Border EC based on European Commission(2008). However, we add distribution style via Bonded Area to that definition in this paper. This is because that some Chinese trade and tax policies are determined by custom clearance type.

CROSS-BORDER EC MARKET BETWEEN JAPAN AND CHINA

Chinese Cross-Border EC Market

World EC market becomes bigger and bigger. Above all, China is the biggest EC market in the world. According to METI(2019), Chinese B to C EC market size is $1,526.7 billion. It is approximately three times bigger than United States one (Figure.1). In addition, China is also highest retail EC sales ratio. According to eMarketer(2016), China is also highest retail EC sales as a percentage of total retail in 2015 (15.9%).

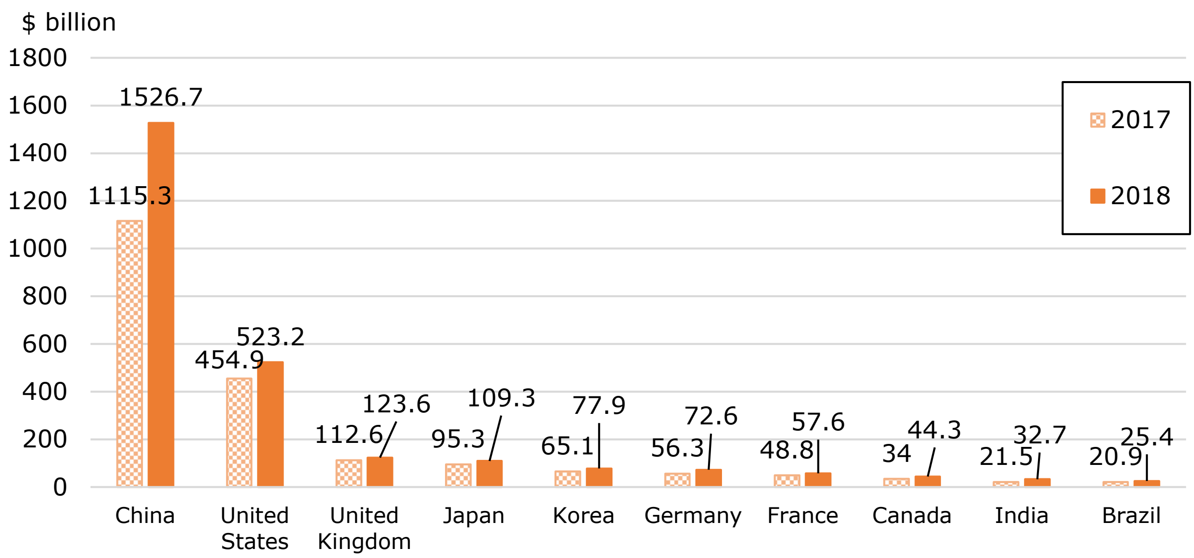

Figure.1 World B to C EC Market 2017/2018

Source: METI(2019), Original data is eMarketer, Nov2018

Cross-Border EC market (Purchase) size is approximately $189 billion in 2015 according to UNCTAD(2017). In 2015, United States and China are two big market in Cross-Border EC market. Now, the estimation of China may bigger than United States (that of Japan is only $2 billion) (Figure.2). Paypal and Ipsos(2018) also suggests 42% Chinese respondents have purchased goods via Cross-Border EC, compared with United States (34%) and Japan (6%). Thus, China is both the biggest Cross-Border EC market and has the potential for further development.

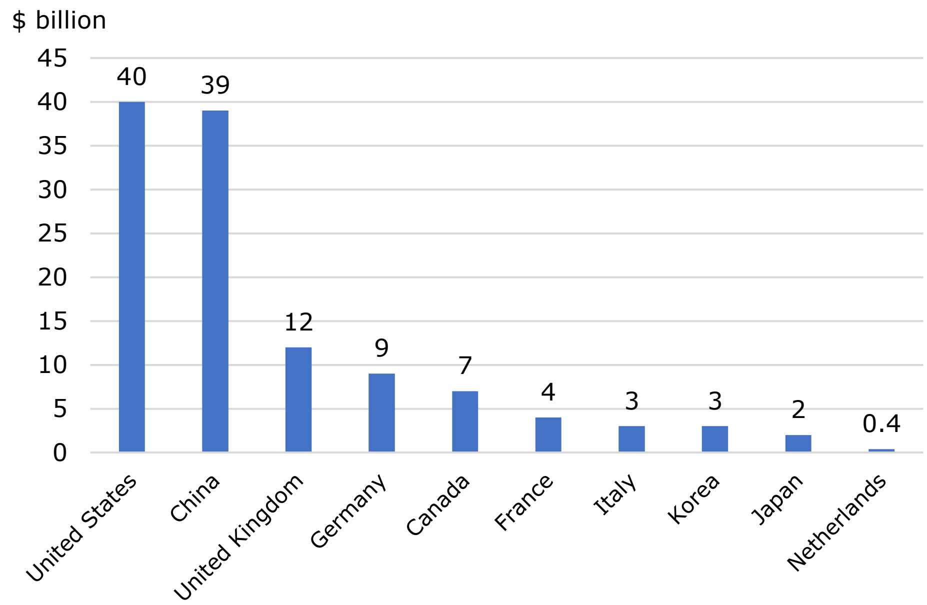

Figure.2 Estimate of Cross-Border B to C EC Purchases, 2015

Source: UNCTAD(2017)

According to Japan External Trade Organization (JETRO) (2018), Chinese consumers purchased Japanese goods because of following reasons (multiple answers), "The goods are not sold at Chinese store." (69.1%), "Lead time is short." (45.0%), "I think the goods are not imitations." (42.6%), "I have been influenced by reviews of friends and so on." (24.8%), "I purchased the goods during my Japan trip and I have liked them from that time." (21.6%) and "The prices of goods are cheap." (17.9%). In addition, that survey also shows that Chinese consumers think following factors are important when they use Cross-Border EC, "Quality" (69.6%), "Brand" (58.6%), "Safety" (56.8%), "Price" (54.5%), "Reviews" (11.6%). These questionnaires suggest that Chinese consumers think quality and rarity are more important than price.

Japanese Cross-Border EC Suppliers

JETRO(2019) suggests that 52.8% of firms which have used EC for sales answered have used it for overseas sales in FY 2018 (the previous survey rate of which is 47.2%). Breaking down the overseas sales, 40.3% of firms have used Cross-Border EC sales from Japan to overseas markets, an increase of 9.4% over the previous survey (Figure.3). Among 1,025 firms, the number of Large-scale ones is 187 and that of SMEs is 838. The Cross-Border EC utilization proportion of the Lage-scale firms is 27.8% and that of SMEs is 43.1%.

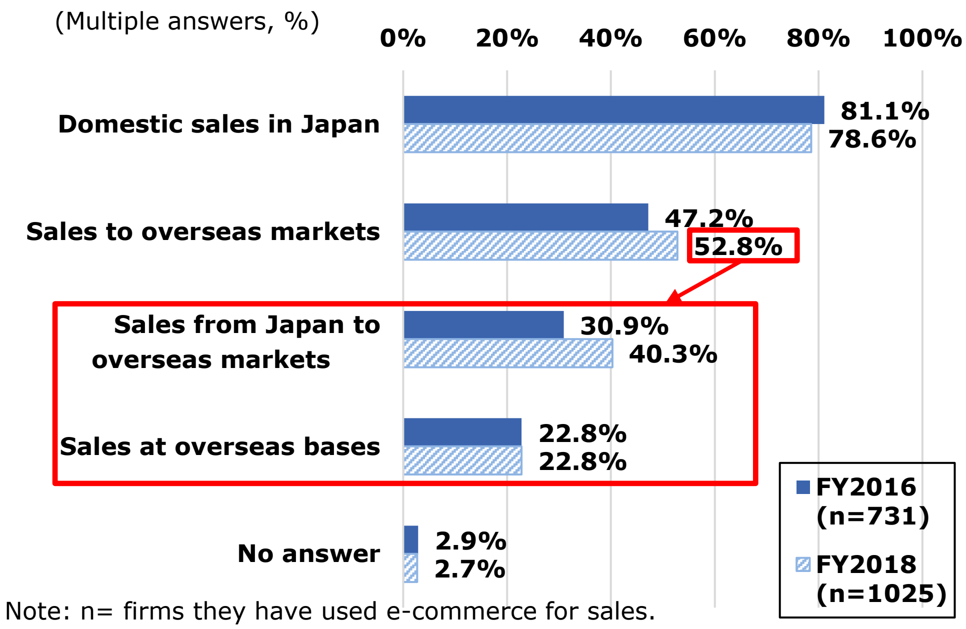

Figure.3 Status of EC utilization among Japanese Firms

Source: JETRO(2019)

Japan is not bigger Cross-Border EC consumer's market than China. However, Japan is one of the biggest suppliers because of selling to Chinese consumers. According to China (Hangzhou) Cross-Border E-Commerce Comprehensive Pilot Area(2018) and Baidu(2019), most Chinese respondents answered that they have purchased goods from Japan.

CHANGE OF CUSTOMS CLEARANCE SYSTEM

Cross-Border EC is one on of private import transactions. Thus, goods which are purchased by foreign consumers are taxable. In the case of Cross-Border EC toward China, goods were mainly transported to China by EMS (Express Mail Service). EMS inspection is not more rigorous than general cargo one. Consequently, there are a lot of tax dodges because of evading inspection. Moreover, in many cases, the parcel tax rate is lower than tariffs one. In addition, goods were imposed only the parcel tax instead of tariffs and not imposed Chinese domestic VAT (value added tax). These customs situations caused missing tax collection to Chinese government and unfair competition between Chinese domestic firms and foreign ones.

Because of these reasons, Chinese government released "Notice on Taxation Policies for Cross-Border EC Retail Imports" in April 2016. It shows that Chinese government basically restricted type of goods (only goods described in Positive List) and Cross-Border EC scheme toward China to official transaction (Bonded Area type and Consolidated Air type) which Chinse customs house can monitor imported goods and tax rates. However, there still exist Cross-Border EC by EMS because a lot of small retailers such as students studying in Japan sell goods through online shopping site or SNS (Social Networking Services).

That notice suggested that Chinese government applied to new tax policy "Cross-Border EC Comprehensive Tax Policy" and then, added some modifications in January 2019. Prior to April 2016, Cross-Border EC purchases in reasonable quantity for personal use would be treated as personal parcels subject to parcel tax at rate of 10 percent, 20 percent, 30 percent, and 50 percent, depending on the type of goods. The parcel tax was exempted if the payable tax amount was lower than RMB 50 (US$7.5). Comprehensive Tax Policy shows maximum purchase amount through Cross-Border EC is changed from 1,000 (approximately US$ 150) to 2,000 RMB (US$ 300) per single trade and set annual maximum purchase amount as 20,000 RMB (US$ 3,000). Maximum purchase amount was increased to 5,000 RMB (US$ 750) per single trade and annual maximum purchase amount was increased to 26,000 RMB (US$ 3,900). In addition, in that new policy, tax exemptions are no longer available (the parcel tax remined and added some modifications).

Table.1 Cross-Border EC Tax Policy

	Old Policy (before April 2016)	New Policy (After April 2016)
Maximum Purchase Amount	1,000 RMB (single trade)	2,000 RMB (single trade) (20,000 RMB per year) *From Jan 2019 5,000 RMB (single trade) (26,000 RMB per year)
Goods Available for Trade	All goods other than prohibited ones by government	Depending on Positive List
Tax Policy	Parcel Tax	Cross-Border EC Comprehensive Tax
Payable Tax Amount	Exemption (amount of tax is less than 50 RMB)	Nothing

Source: JETRO(2016)

In Comprehensive Tax Policy, imported goods are imposed VAT and luxury tax instead of the parcel tax. As of May 2019, tariffs are not imposed on (0%) and VAT and luxury tax rates are 70%. As a result, Comprehensive Tax Policy's tax rates are generally less than the parcel tax ones (Table.2).

Table.2 Cross-Border EC Tax Rates

Classification of goods	Price	Old Parcel Tax (~2016.3)	New Tax System (from April 2016)	
			New Parcel Tax (EMS)	Cross-Border EC Comprehensive Tax
Food, Baby	~500 RMB	Exemption	15% (Exemption if the amount of tax is less than RMB50)	VAT*13%× 0.7=9.1%
	501 RMB~	10%	15%	
Apparel, Home Electrical Appliance	~250 RMB	Exemption	30% (Exemption if the amount of tax is less than RMB50)	VAT13%× 0.7=9.1%
	251 RMB~	20%	30%	
Beauty	~100 RMB	Exemption	60% (Exemption if the amount of tax is less than RMB50)	(VAT13%+luxury tax30%) × 0.7=30.1%
	101 RMB~	50%	60%	

*: VAT in China is changed from 17% (before May 2018) to 16% (May 2018 ~ April 2019) and to 13% (After April 2019).

Source: China State Taxation Administration (2019), JETRO(2019)

LOGISTICS SUPPORT SERVICES FOR CROSS-BORDER EC

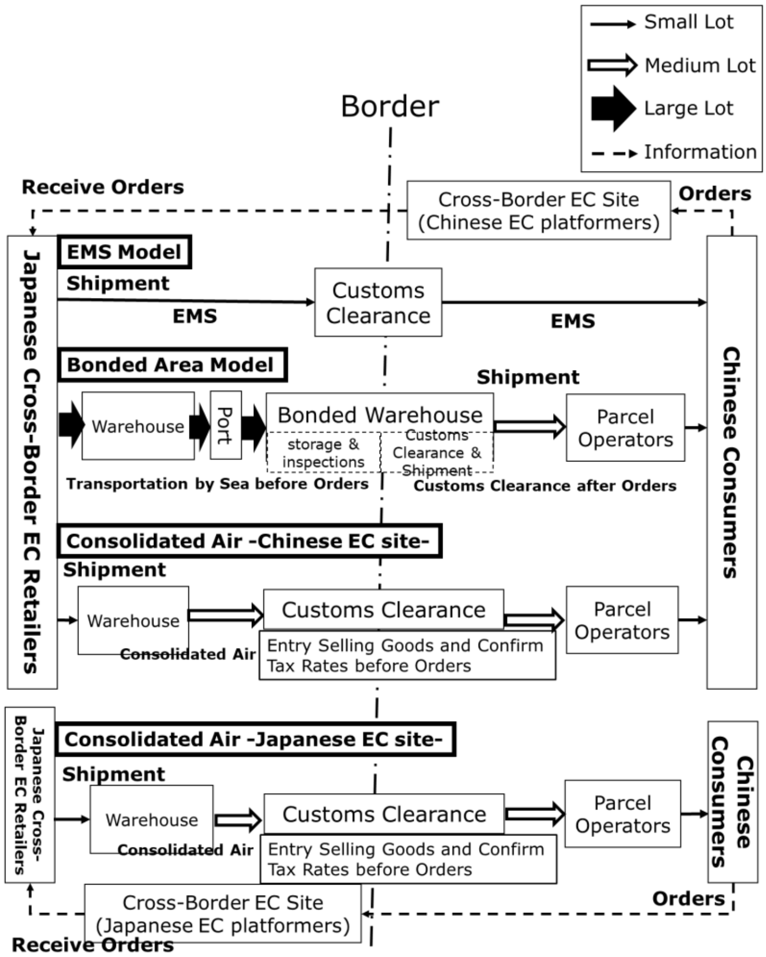

Figure.4 Classification of Cross-Border EC Logistics Support Model

Source: JETRO(2016)

There are some logistics problems including customs clearance system changes and international transportation for Japanese retailers in Cross-Border EC toward China. To solve these problems, some logistics operators provide logistics support services for Cross-Border EC.

In order to prevent tax dodges, scheme which Chinese customs house monitor imported goods is important in both cases of the new parcel tax and Cross-Border EC Comprehensive Tax. Thus, Japanese logistics operators provide Cross-Border EC logistics support services which they can consistently manage selling, shipment, cross border transportation, customs clearance and delivery to consumers in cooperation with Chinese customs house. We define 4 types of Cross-Border EC support models (EMS, Bonded Area, Consolidated Air -Chinese EC site- and Consolidated Air -Japanese EC site-) based on JETRO (2016) (Figure.4).

EMS Model

As mentioned previously, in Cross-Border EC market toward China, it is said that large part of it is EMS model. Total amount of EMS from Japan to China consistently increased until FY 2015 (from April 2015 to March 2016). However, in FY 2016, it fell by approximately 19.7% from the previous FY. The amount of EMS from Japan to China accounts for approximately 40% of total amount of EMS from Japan. Thus, this reduction may be caused by tax policy's changes in China. Some modifications of tax policy about Cross-Border EC made lost comparative advantage of the parcel tax rate.

Japanese Cross-Border EC retailers have gradually shifted from EMS model to other. It is difficult to check custom clearance of a lot of EMS. Therefore, Chinese customs house tries not to miss collecting taxes by promoting other 3 types of models. In the following sections, we focus on these models.

Bonded Area Model

Cross-Border EC retailers generally have their inventory in their own country. However, it takes a lot of time to deliver ordered goods to their foreign consumers because of distance and customs clearance. In addition, cross border transportation cost or time tends to be high because Japan is island country.

Bonded Area Model solves these Cross-Border EC logistics problems. China has a lot of Bonded Area and warehouse. In this model, Japanese retailers transport their goods by sea and storage in bonded warehouse. They send their goods from it after they receive orders from Chinese consumers. Retailers receive some benefits such as low cross border transportation cost and short lead-time (approximately 1-3 days). Moreover, big possibility to attract a lot of consumers. This is because Bonded Area is mainly used Chinese EC retailers such as Alibaba for Cross-Border EC.

On the other hand, the inventory cost of Bonded warehouse costs higher than general warehouse. Thus, there are higher risk of unsold inventory. In addition, it also takes higher cost to operate Cross-Border EC store on biggest Chinse EC platformers site.

Consolidated Air Model (Chinese and Japan EC site)

Unsold inventory cost is one of the biggest problems for Cross-Border EC retailers. Therefore, some retailers remain their inventory in Japan and transported their goods by air in consideration of trade-off between transported and inventory cost. The advantages of Consolidated Air are low inventory cost and risk of unsold inventory. On the other hand, the disadvantage of that are long lead-time, (approximately 2-5 days) high cross-border logistics cost.

In the case of Chinese EC site, big ability to attract consumers is also advantage and high management cost for EC site is also disadvantage. In the case of Japan site, management cost is low but small ability to attract consumers. Therefore, momentary trend items which has enough volume of sales to manage Chinese popular EC site are fit for Consolidated Air -Chinese EC site- model. In the case of Consolidated Air -Japanese EC site- model, niche items are suitable.

Features and Suitable Goods of Each Models

In this section, we organize the logistics and market features of 3 models.

The advantages of Bonded Area model are short lead-time, low cross-border logistics cost and big ability to attract consumers (This is because Bonded Area is mainly used Chinese E-Commerce retailers such as Alibaba for Cross-Border E-Commerce). On the other hand, the disadvantage of that are high inventory cost, risk of unsold inventory and management cost for EC site. Therefore, appropriate goods of this model are top selling and large volume (or heavy weight) such as paper diaper.

The advantages of Consolidated Air are low inventory cost and risk of unsold inventory. The disadvantage of that are long lead-time, high cross-border logistics cost. Therefore, appropriate goods of this model are goods whose sales volume is not so large. The management cost of Chinese EC platformer site tends to be higher than that of Japanese. So, that model is suitable for the goods whose sales volume is medium size such as fashionable goods like beauty. On the other hand, Consolidated Air Model -Japanese EC site- is suitable for niche goods.

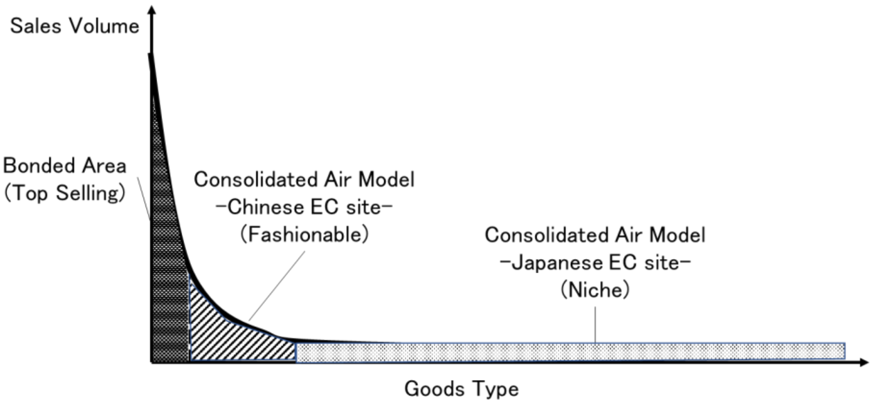

Figure.5 Sales Volume and Cross-Border EC Logistics Support Model

Table.3 Features and Suitable Goods of Each Models

	Bonded Area	Consolidated Air -Chinese EC site-	Consolidated Air -Japanese EC site-
Number of goods type for sale	▲	○	○
Lead-time	○	▲	▲
Cross border transportation cost	○	▲	▲
Inventory cost	▲	○	○
Risk of unsold inventory	▲	○	○
Abilities to attract consumers	○	○	▲
management cost of EC site	▲	▲	○
Appropriate goods	Top Selling (paper diaper)	Fashionable (beauty)	Niche (Japanese Magazine)

Note: ○=advantage ▲=disadvantage

CONCLUSION

This paper suggests international logistic model of Cross-Border EC for Japanese EC retailers and logistics service providers. Cross-Border EC market situation toward China is drastically changing.

Cross-Border EC is often used for purchasing rare goods which are seldom sold in consumers' country. However, some commodities such as paper diaper are purchased from Japan by Chinese consumers. This may be caused because of distrust of those goods sold at Chinese retailers. Current situations in Cross-Border EC between China and Japan helps Japanese retailers which sold those top selling commodities. On the other hand, it is not clear that how long the preferential treatment in Cross-Border EC Comprehensive Tax Policy such as 0% tariff or 70% VAT and luxury tax. If these treatments were abolished, Cross-Border EC market between China and Japan might be changed to small market. However, international standard trade framework of Cross-Border EC is being established such as World Customs Organization (WCO). Therefore, we hope this paper is valuable not for only current market participants but for potential ones.

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MANAGING BIG DATA IN GENERAL CARGO WAREHOUSES FOR INTERNET OF THINGS PROJECTS

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ABSTRACT
Purpose:
In general cargo warehouses, general cargo is handled manually by industrial trucks. This can give rise to errors in logistical processes, with costs being incurred in the subsequent elimination. Examples include incorrect stacking and storage or loading of packages onto the wrong truck. If digitization in general cargo warehouses were intensified, large volumes of unstructured data would be available that can be processed in real-time. The paper examines how various Big Data concepts and Internet-of-Things (IoT) can be used to detect and report logistical errors while the goods are still in the general cargo warehouses in order to save costs.

Design:
Applied research is chosen as the research methodology. Starting from the reference architecture of NIST for Big Data, the functional areas along the data flow are being examined. Here, special attention is paid to the different types of analysis with respect to use in a general cargo warehouse. Different existing frameworks for the realization of Big Data tasks are described in terms of their properties. Afterwards, a methodology for managing large amounts of data in general cargo warehouses in Internet-of-Things projects will be presented. A selected Big Data framework is evaluated. The results are documented and discussed.

Results:
The result of this study is the proposal of a methodology for the management of large amounts of data in general cargo warehouses in Internet-of-Things projects. Here, the use of a big data framework based on a time series-based database is proposed for the real-time monitoring of logistical processes in a general cargo warehouse.

Value:
Scientific literature has so far only contained general suggestions for the use of Big Data and IoT in logistics. What is new in this work are concrete suggestions for the use of Big Data and IoT, using the example of cargo handling in general cargo warehouses. These findings will help operators of general cargo warehouses save costs in their logistical processes.

1. INTRODUCTION

General cargo includes goods that are divided into courier, express, parcels and bulk goods based on weight and dimensions. General cargo is handled individually (ten Hompel and Heidenblut, 2011). The handling takes place in general cargo warehouses. The different characteristics of piece goods (dimensions, shape, weight and material (Klaus et al., 2012), (Martin, 2016) require them to be handled manually. Here, forklifts, electric pallet trucks and hand pallet trucks are used to transport general cargo in warehouses. Errors in logistical processes, for example due to monotony, can occur as a result of manual activities. Examples of possible error situations include incorrect loading, surplus loading, unauthorized loading, surplus deliveries, incorrect deliveries, partial shortages, incorrect stacking and storage (Rieger, 2012). These error situations cause costs for warehouse operators if the errors have to be rectified when the packages have already left the warehouses.

The data available in general cargo warehouses increases further as the number of connected devices rises. This study will examine whether technologies such as Big Data and IoT are suitable for the early detection and reporting of errors in logistical workflows so that errors can be remedied while the goods are still in the warehouses. This could save costs and it requires a real-time analysis of the situation in general cargo warehouses.

2. LITERATURE OVERVIEW

The data volumes generated in the world are growing continuously. The market research company IDC predicts that the amount of data generated will grow to 40 billion GB by 2020 (Gantz and Reinsel, 2012). This data comes from different data sources and is unstructured.

Acatech presented recommendations for implementing the future project Industry 4.0 in Germany (acatech, 2013), that also included general recommendations for logistics. However, the proposals do not include any options for implementing Big Data concepts and IoT projects in general cargo warehouses. Neither could any approach to managing Big Data in general cargo warehouses for IoT projects be found in scientific literature.

Starting from this research gap which has been identified, the following research questions arise for this study:

- RQ1: How can large quantities of unstructured logistics data be processed quickly in general cargo warehouses?
- RQ2: How can IoT projects detect and report error situations in logistical processes?

2.1 Big Data and IoT

The terms Big Data and IoT are not defined uniformly. Therefore the definitions for the terms are given first as they are used in this paper.

Big Data is defined as follows according to the NIST (NIST, 2018a):

> "Big Data consists of extensive datasets - primarily in the characteristics of volume, variety, velocity, and/or variability - that require a scalable architecture for efficient storage, manipulation, and analysis."

NIST has proposed a reference architecture for Big Data that is shown in Figure 1.
The definition of the IEEE Internet Initiative for small environmental scenarios is chosen in order to define IoT (Minerva et al., 2015):

> "An IoT is a network that connects uniquely identifiable "Things" to the Internet. The "Things" have sensing/actuation and potential programmability capabilities. Through the exploitation of unique identification and sensing, information about the "Thing" can be collected and the state of the "Thing" can be changed from anywhere, anytime, by anything."

The IoT "Things" are devices that transform data and states from the physical world into the Cyber World by means of their measuring capability. For example, they can report the loading status of the fork of a forklift truck or the opening status of a gate to another system, which then processes this information further. The IoT devices thus offer a good starting point for recording the situation in general cargo warehouses.

2.2 Big Data functional areas

In the NBDRA, data is forwarded from so-called data providers to the Collection, Preparation, and Analytics functional areas. The data consumers then receive the processed data from the Analytics, Visualization and Access functional areas. The tasks of the functional areas are described below.

2.2.1 Collection functional area

Data is collected from the different data providers. Here, structured and unstructured data is received and passed on to the Preparation functional area (NIST, 2018b).

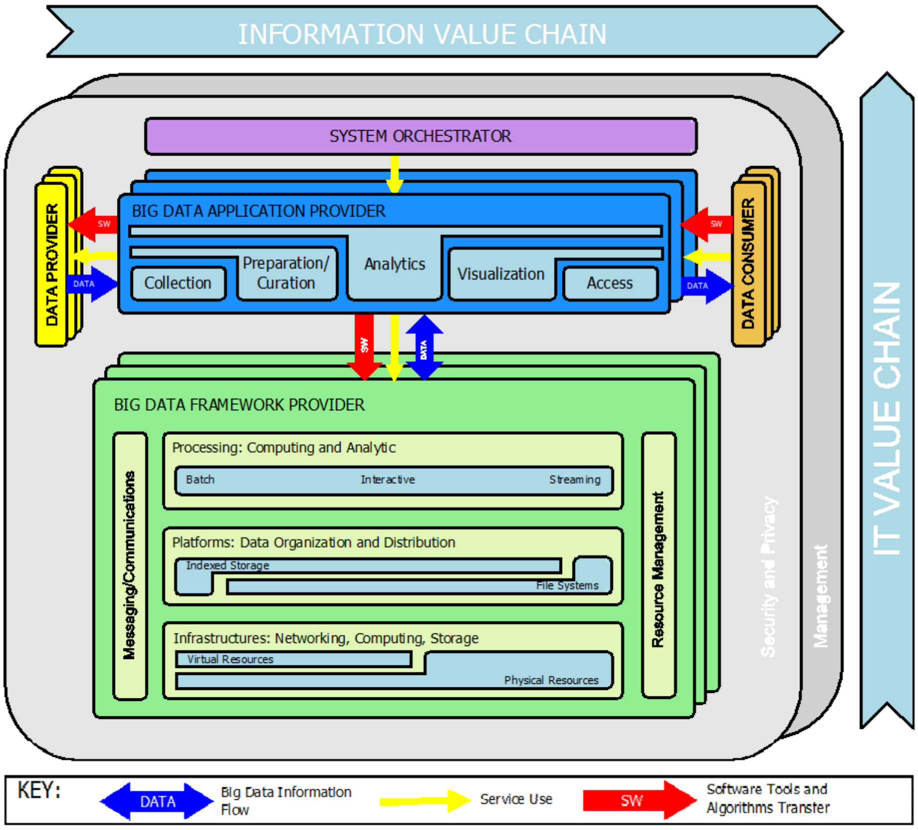

Figure 1: NIST Big Data Reference Architecture (NBDRA), (NIST, 2018b, p. 10)

2.2.2 Preparation functional area

Here, the data from the Collection functional area is prepared for subsequent analysis. This includes data verification, outlier handling and reformatting. In addition, data from different data sources is merged in order to obtain extended data sets. In addition to these functionalities, the data is also stored persistently (NIST, 2018b).

2.2.3 Analytics functional area

Techniques are provided to extract knowledge from the data based on the set requirements (NIST, 2018b).

Four types of analysis can be distinguished:

- Descriptive Analytics,
- Diagnostic Analytics,
- Predictive Analytics and
- Prescriptive Analytics.

Descriptive analytics

Descriptive analysis uses procedures and methods to analyse historical data. It is a retrospective of events that have occurred in the past. The analysis considers the question "What happened?" (Bakhshaliyeva et al., 2017). Descriptive models identify many different relationships, e.g. between customers or products. Simple summaries about the target group of the sample and the observations made are provided by descriptive analytics in the form of summary statistics or graphs (Strickland, 2015, p. 2).

Key Performance Indicators (KPIs) are defined that illustrate the efficiency and performance of the logistical processes in general cargo warehouses. These KPIs are suitably visualized to the warehouse clerks or dispatchers.

Diagnostic analytics
Diagnostic analytics investigates the question "Why did something happen?" As is the case with descriptive analysis, the past is considered here (Bakhshaliyeva et al., 2017). Diagnostic analytics could be used, for example, to analyze a sales campaign or a social media marketing campaign. The failure of a marketing campaign can then be explained by the use of analytical dashboards or widgets (Cody, 2016).

With regard to logistics in general cargo warehouses, different data sources are related to each other to identify the cause.

Predictive analytics
Events that are likely to occur in the future can be forecast by means of predictive analysis (Bakhshaliyeva et al., 2017). Statistical methods as well as machine learning algorithms and heuristics are used in predictive analytics (Strickland, 2015, p. 4). Predictive analysis looks at the past to predict the future (Cody, 2016). With the help of predictive analysis, classifications can be carried out or developments, e.g. of values, can be predicted. Statistical methods or methods from the field of machine learning are used for this purpose. An example of the application in relation to logistics is the forecasting of the availability of goods in a supermarket (Lehmann, 2017). In predictive analysis, a model is trained from historical data. New unknown data is then applied to this model to identify future events. Predictive analysis is suitable when the parameters which influence a process are unknown.

By using predictive analysis, any error situations in logistical processes arising in general cargo warehouses can be detected and reported in advance. If these logistical errors are detected with the aid of predictive analysis and corrected in general cargo warehouses, the operators of general cargo warehouses are able to save costs.

Prescriptive Analytics
In prescriptive analytics, methods are used to derive optimal decision-making strategies based on predictions (Bakhshaliyeva et al., 2017). Prescriptive analytics suggests decision options on how to take advantage of a future opportunity or mitigate a future risk and shows the implication of each decision option. (Strickland, 2015, p. 3).

In general cargo warehouses, suitable measures can then be proposed to the warehouse clerk or dispatcher for returning to normal operation if an error situation is detected. Appropriate rules are defined for this purpose.

2.2.4 Visualization functional area
In this functional area, the processed data and the analytical results are prepared for the data consumers. Data must be presented in an understandable form so that meaning and knowledge are conveyed in an optimum manner (NIST, 2018b).

2.2.5 Access functional area
The Access functional area represents the interface between the Analytics and Visualization functional areas and the Data Consumers (NIST, 2018b).

2.3 Frameworks for Big Data Analytics
Various frameworks for different purposes have been developed for Big Data Analytics. The frameworks enable us to collect data from different data sources, analyze the data and present the results. Table 1 shows a selection of frameworks. The frameworks offer analyses in batch operation and streaming method and differ in the way they are stored.

Since relational databases reach their limits if large amounts of data are to be stored, NoSQL databases were developed. Here are some examples:

- Key/value database (Redmond and Wilson, 2012),
- Column-oriented database (Redmond and Wilson, 2012),
- Document database (Redmond and Wilson, 2012),
- Graph database (Redmond and Wilson, 2012),
- In-memory database (IMDB) (Plattner, 2013) and
- Time series database (TSDB).

3. METHODOLOGY

For the management of large amounts of data in general cargo warehouses in Internet-of-Things projects, the project requirements must first be defined. The choice of processing method (batch, streaming) is then derived from these requirements. Once the processing method has been defined, a Big Data Framework must be selected. Subsequently, the data provider must be specified. Furthermore, the analytical methods must be selected and integrated into the Big Data Framework. Finally, the selected system must be evaluated to determine whether it can meet temporal requirements.

Table 1: Frameworks for Big Data Analytics

Tool	**Batch**	**Streaming**	**Database**
Data Torrent RTS	x	x	Files, Hbase (Spaltenorientiert)
Disco	x		DiscoDB
Google BigQuery	x	x	Data Warehouse
Hadoop	x		Files, Hbase (Spaltenorientiert)
Hydra		x	HydraDB
Spark		x	Resilient Distributed Dataset (RDD)
Storm		x	Integrates into any database
TICK Stack	x	x	TSDB

3.1 Definition of requirements

A real-time analysis of the situation in general cargo warehouses is required in order to detect logistical errors in the workflows in general cargo warehouses so that the errors can still be rectified in the warehouse.

3.2 Selection of processing methods

The available processing methods are batch processing, where the data is first collected and then processed as a whole, and the streaming method where data is processed immediately. If logistical errors are to be detected while goods are still in the warehouse, only the streaming method can be used in real-time operation, since the data is processed without delay in contrast to batch operation.

3.3 Selecting a Big Data Framework

Table 1 describes various frameworks. A framework is to be selected that offers the processing method selected in Chapter 3.2. The framework "TICK Stack" (InfluxData, 2019) is selected in this paper, which is offered by the company InfluxData as an open source variant. The framework was, on the one hand, selected because it offers the streaming method for the required real-time analysis and, on the other hand, because it provides an TSDB. For real-time analysis, data that changes over time must be processed. The sequence of the data in chronological order also plays an important role for modelling, in particular for predictive analysis. The TSDB meet these requirements very well in comparison to relational databases, since the TSDB already offer the necessary functions for this purpose, whereas the functions for relational databases must first be programmed which is a complex and time-consuming procedure.

Table 2: Components of the "TICK Stack" and their tasks

Component	Functional area	Task
Telegraf	Collection	Data collection
Telegraf	Preparation	Data preparation
InfluxDB	Preparation	Data storage
Kapacitor	Analytics	Identification of alerts through comparison with threshold values (threshold checks)
Chronograph	Visualization	Presentation of data and processes, Dashboard

The framework "TICK Stack" consists of the components Telegraf, InfluxDB, Chronograph and Kapacitor. The framework "TICK Stack" was developed for monitoring computers in a network. Table 2 shows the assignment of the components to the functional areas described in Chapter 2.2. Figure 2 shows the presented concept with the framework "TICK Stack".

3.4 Definition of data providers

For the integration of the system into the environment of the IT structure in general cargo warehouses, interfaces with the following systems are required:

- Warehouse management system,
- Dock/yard management,
- Forklift guidance system and
- Shipment tracking system within the general cargo warehouses.

These systems then represent data providers for the "TICK stack".

In order to obtain necessary data that is not provided by the systems, devices can be digitized in the form of IoT devices. IoT devices can then also act as data providers.

3.5 Selection of analytical methods

The four analytical methods described in chapters 2.2.3 can all help to detect errors in logistical processes. The data for descriptive and diagnostic analyses can be visualized in the Chronograph component.

The software for obtaining historical data for modelling, which is necessary for predictive analysis, can use the data interface with the InfluxDB component. The evaluation of new data by predictive analysis must then be done through an interface with the Kapacitor component or through a user-defined function (UDF) in the Kapacitor component. Suggestions for appropriate measures through prescriptive analysis can also be generated through an interface with the Kapacitor component or through a UDF in the Kapacitor component.

3.6 Evaluation

The selected system shall be evaluated with respect to its performance in data processing and the application of rules for creating alerts. In the process, the number of processable data per second is to be determined.

4. RESULTS

4.1 Test procedure

The "TICK Stack" is installed on a computer. An MQTT broker is installed on the same computer. The Telegraf component is configured in such a way that it logs on to the MQTT broker and subscribes to the topic "/sensors/temperature".

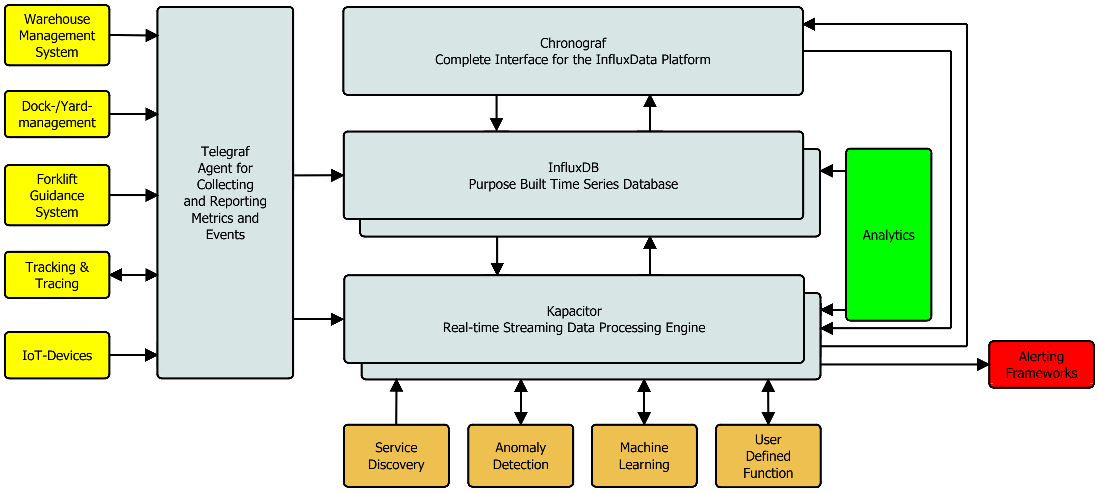

Figure 2: Concept based on the TICK stack (InfluxData, 2019)

A program was created in the programming language Go that logs on to the MQTT broker and publishes random temperature values between 20 and 30 degrees Celsius for the topic "/sensors/temperature". The program creates and publishes 30000 temperature values in the line-based Influx data format without a waiting period. The Chronograf component was used to graphically create a rule for excessively high temperatures for the Kapacitor component. If the temperature value is greater than or equal to 28 degrees Celsius, an alert should be generated. The alert is logged in a text file. After defining the monitoring rule, the program was started for data generation.

4.2 Hardware

The test was conducted on an Acer Aspire 7740G notebook.
Processor: Intel Core i3 330M, 2.13 GHz, 1066 MHz FSB
RAM: 4 GB HD: 500 GB

4.3 Software

Operating system: Pearl Linux 7 x64, based on Ubuntu 18.04 LTR
Telegraf: Version 1.10.3 InfluxDB: Version 1.7.6
Chronograf: Version 1.7.11 Kapacitor: Version 1.5.2
MQTT-Broker: mosquitto 1.6.2 Go: go1.12.4.
Go MQTT library: github.com/eclipse/paho.mqtt.golang

4.4 Results

4.4.1 Data Generation Program

The data generation program had a runtime of 886 ms.

4.4.2 Number of processable data per second

In order to write the 30000 data into the InfluxDB database, 5607 ms was required.
For the number of processable data per second, this yielded the following result:
30000 / 5607 = 5350.46

The number of processable data per second then amounts to 5350.

5. DISCUSSION

In order to answer the research question RQ1, the functional areas along the data flow were examined based on the reference architecture of NIST for Big Data. In order to answer the research question RQ2, special attention was paid to the different types of analysis with regard to their use in a general cargo warehouse. Different existing frameworks for the realization of Big Data tasks were described in terms of their

properties. In order to identify error situations in logistical processes, it is first necessary to enhance the transparency of the processes.
The selected Big Data framework was evaluated with regard to its efficiency and performance in processing data and the subsequent evaluation with regard to the triggering of alerts. The results are documented and discussed.
The difference between the runtime of the data generation program and the storage times in the InfluxDB database can be accounted for by the fact that the incoming data is first temporarily buffered in memory and then processed. If more powerful hardware (CPU, RAM) is used, the number of data to be processed per second is expected to increase.
The number of more than 5000 data per second determined in this paper is deemed more than sufficient, since far less data per second will be generated for the task of real-time monitoring of logistical processes.
The "TICK Stack" was developed for the monitoring of IT infrastructures. If the information about logistical processes is provided in exactly the same form as the information about the computers and networks, the "TICK Stack" will provide a good basis for the monitoring of logistical processes. In the "TICK Stack", the standard tools have so far been used for the generation of alerts with threshold checks. An alert generation based on predictive analysis is still to be realized and evaluated.
The findings regarding Big Data frameworks will help operators of general cargo warehouses to save costs in their logistical processes. To secure competitive advantages, companies see to it that their IT infrastructure ends at the company's boundaries. As a result, there is no connection to the Internet. However, the use of Internet protocols in an intranet is conceivable.

6. CONCLUSION

IoT devices and interfaces with the warehouse management system, dock/yard management, forklift control system and shipment tracking system lay the foundations in general cargo warehouses for increasing the transparency of logistical processes for operators. This is the prerequisite for identifying error situations in logistical workflows. The recognition of error situations, for example through the use of predictive analysis, is the subject of further research.

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TOWARDS POSITION-BASED TECHNOLOGIES FOR DIGITIZED PROCESS MANAGEMENT ON THE SHOP FLOOR

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Abstract Position-based technologies, e.g Ultrawideband (UWB), WiFi or Bluetooth, for indoor localisation purposes are already commercially available. With the highly increasing digitalization of industrial processes, the potential of these technologies comes into focus of process management research. This paper aims to structure position-based technologies according to their potential to support shop-floor process management. For this purpose, a framework with the following dimensions is developed: technical performance properties of the IPS, economical aspects, relevant use-case requirements, and appropriate data aggregation strategies. Following this, two representable use-cases show the implementation of an indoor-positioning-system and the data aggregation in order to derive relevant process data from position data.

INTRODUCTION

Location-based services are widespread in society. Navigation via smartphone apps or the localization of mobile phones are just two examples, which relate GPS position detection in outdoor environments to a service. For indoor environments, alternative technical solutions for position detection are available: WiFi, Ultra-Wide-Band, and Bluetooth, for instance, are already used or at least applicable in intralogistics and industrial production (Krzysztof and Hjelm, 2006, p. 6-8; Mautz, 2009). With the highly increasing digitalization of industrial processes, the potential of indoor positioning (IP) technologies comes into focus of process management research (Vossiek et al., 2003). Based on position information, a variety of services and key performance indicators are conceivable on the shop-floor. However, the degree of dissemination has to be classified as rather low, as a systematic selection method that relates IP technologies to application scenarios is still lacking. Furthermore, the algorithms for using position data in intralogistics and production processes have not yet been systematically prepared.

Hence, this paper aims at structuring position-based technologies according to their potential to support shop-floor process management for logistic and production issues. The next paragraph clusters, by means of a comparative analysis, the methods for indoor position determination and the available indoor positioning and tracking technologies. Their respective performance features such as accuracy, integration effort or range are evaluated and benchmarked. After this, a generalized framework is introduced, facilitating the selection and application of indoor positioning and tracking technologies for shop-floor processes. The framework also contains strategies to aggregate position data for process engineering, optimization, and mining. Finally, general key performance indicators derived from position data are presented and subsequently applied to a use case.

PRINCIPLES FOR POSITION DETERMINATION

Available indoor positioning systems (IPS) are based on different technologies, but the method of position determination is mostly founded on one of the following principles:

trilateration, triangulation, proximity detection and fingerprinting. The following paragraphs give a brief overview; details can be found in Koyuncu (2010) and Mautz (2012).

Trilateration and triangulation methods utilize the geometrical properties of triangles to determine the position of an object. **Trilateration** measures the distances to a minimum of three reference points (Shchekotov, 2014). Here, either the received signal strength (RSS) or the transit times of the signals between object and reference point (ToF) are measured. The distance is determined by multiplying signal transit time and signal speed. ToF methods can use different techniques: Time-of-Arrival (ToA), Time-Difference-of-Arrival (TDoA), or Roundtrip-Time-of-Flight (RToF). **Triangulation** is based on the same principle as trilateration, but uses the angle and distance of the reference points to determine the position of an object (Koyuncu, 2010). The Angle-of-Arrival (AoA) technique uses three angles and one distance to describe the position of an object.

Fingerprinting (FP) tries to minimize the inaccuracies of the direct position determination by the non-deterministic correlation between measurement result and object in an offline training phase. During the offline phase, position-specific data is collected, assuming that each position has its individual fingerprint of characteristics, e.g. signal strength. This data is used to create a map that evaluates each position by its specific characteristics. During the online phase, the measured data is compared with the data collected in the training phase in order to place an object within the map (Lin and Lin, 2005).

Proximity detection is mainly used in radio-based technologies. It examines the position of a tag in relation to a known area or position (anchor). Either it measures whether the tags are within a limited range of the anchor or the signal strength of the tags is determined and then – depending on the strongest signal – assigned to an anchor (Faragher and Harle, 2014). As a result, proximity detection does not indicate a position, but an area of possible localizations. The more anchors are in the vicinity, the smaller the resulting area becomes.

IP TECHNOLOGIES AND PROPERTIES

Currently, different technical solutions for indoor positioning are available deploying the principles of position determination described above. The following Figure 14 shows the assignment of technologies to the described principles.

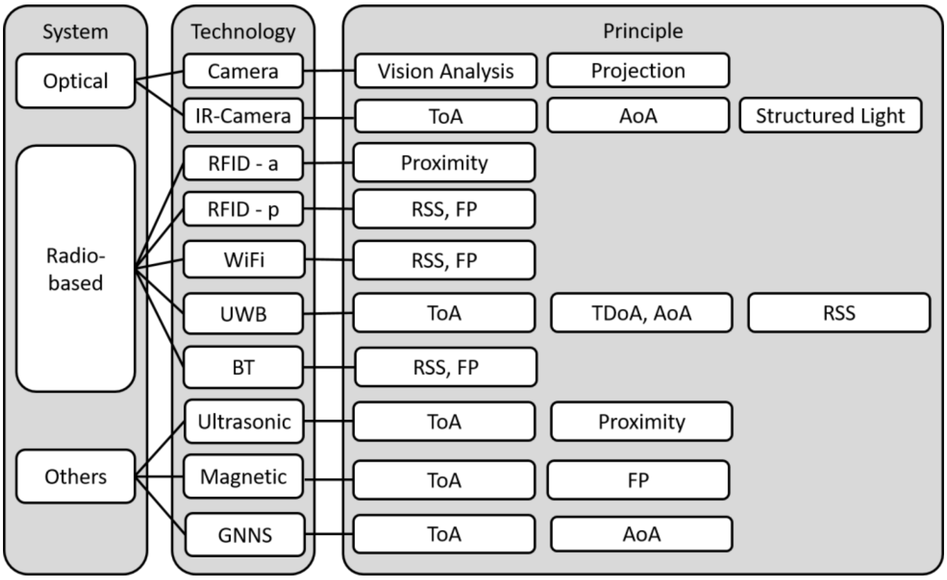

Figure 14: Overview of IPS, technologies and their underlying measurement principles for position determination

Optical IPS

The position of objects is determined by either using stationary cameras at defined points (**camera** = anchor) or a camera mounted at a moving object, where the camera captures known reference points in order to calculate the position of the object. As reflection is much more deterministic at short wavelengths compared to radio-based systems and RToF can provide an accurate length measurement, **IR** cameras are also utilized for indoor position capturing.

Radiofrequency-based Systems

High-frequency technologies have a high priority in IPS. Radio waves can penetrate walls and human bodies more easily than other technologies, which increases the range. Mostly triangulation, trilateration and fingerprinting techniques are used. For complicated interiors, the combination of location-based RSSI and fingerprinting evaluation is an effective method, as errors can be corrected by interference. The different radio-based technologies differ mainly in frequency.

RFID systems consists of RFID readers, tags and communication technology between these two. The RFID reader can acquire data from the tags, both active and passive. A passive RFID tag is a small and inexpensive receiver, but its range is also low. In contrast, an active tag is a transceiver that actively transmits its identification and data. This method is more expensive but has a much larger coverage area. The **WiFi** technology is popular for implementation in public buildings such as hospitals, railway stations, and universities, as existing infrastructure can be used. The routers work as anchors and small battery-powered modules as tags. The **Bluetooth** technology is similar to the WiFi localization principle in the 2.4 GHz frequency range but has a lower bit rate of about 1 Mbps. With the Bluetooth Low Energy 4.0 standard, devices within a range of about 10 meters can be connected to each other. The **Ultra-wideband Technology** (UWB) is a radio based IPS with a small coverage area and high bandwidth. As a result, UWB has a high permeability for many building materials, which is very advantageous for indoor positioning. The typical design consists of a stimulus radio-wave generator and receivers that capture the scattered waves.

Ultrasonic-based Systems

In ultrasonic-based systems, the propagation of sound waves in space is used for position determination. The noiseless sound waves in the ultrasonic range do not affect people and can be easily evaluated using trilateration methods with ToA and TDoA. Due to the reflection on walls and ceilings, the range is restricted to one room.

Magnetic-based Systems
In a magnetic system, electric coils regularly generate static magnetic fields. The tag, which has a magnetic field sensor installed, measures the field strength of at least three reference coils. These values are then used to locate the target object in space using either trilateration or fingerprinting. Unlike other technologies, magnetic systems do not require line-of-sight between the sensor and the source.

Global Navigation Satellite System (GNSS)
GNSS as a positioning method has two advantages: independence of a local infrastructure and worldwide coverage. However, the indoor reception of the satellite signals is limited because building materials reflect these signals. These difficulties in reception have triggered the development of some promising, highly sensitive GNSS receivers. The influence of reflections can be improved by pseudolites, strong transmitters transmitters with known positions resembling pseudo-satellites. As their implementation is rather complex and time-synchronization is challenging, the use of GNSS is not yet suitable to meet the requirements of an IPS due to both low accuracy and low update rate**.**

More detailed descriptions of the function principles of IPS can be found in Guo (2009) and Liu (2007).

GENERAL DATA AGGREGATION AND INDICATORS

Based on the technological implementation of the IT infrastructure, the generated data sets must be used appropriately to derive relevant logistics- or production-related KPIs. The available data is usually provided as a matrix D with

$$D = \begin{pmatrix} Index\ 1 & \mathrm{yyyy-mm-dd} & \mathrm{hh:mm:ss.ms} & \mathrm{tagID} & \mathrm{Xpos\ 1} & \mathrm{Ypos\ 1} & \mathrm{Zpos\ 1} \\ Index\ 2 & \mathrm{yyyy-mm-dd} & \mathrm{hh:mm:ss.ms} & \mathrm{tagID} & \mathrm{Xpos\ 2} & \mathrm{Ypos\ 2} & \mathrm{Zpos\ 2} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ Index\ n & \mathrm{yyyy-mm-dd} & \mathrm{hh:mm:ss.ms} & \mathrm{tagID} & \mathrm{Xpos\ n} & \mathrm{Ypos\ n} & \mathrm{Zpos\ n} \end{pmatrix}$$

where the rows display the indexed time series of the position data. The tagID references the tag for which Xpos, Ypos and Zpos represent the captured position in three spatial dimensions. Based on these raw data, information can be aggregated via appropriate algorithms and calculations.

As the aim of this paper is to develop a generalized framework to support the screening process for a suitable IPS and setting up the application more efficiently, the performance properties of the IPS, economical aspects, relevant use-case requirements, and appropriate data aggregation strategies are systematized below. MATLAB® is used as the computing environment to implement the algorithms to aggregate and visualize the position data.

GENERALIZED FRAMEWORK

The selection of an appropriate IPS technology is mainly based on the intended application. Companies which want to implement position-data controlled processes need a framework to define the intralogistics or production scenario on the shop-floor first. Fig. 2, adopted from (Štolfa et. al., 2015), presents a tool for describing processesin order to implement IPS for process management.

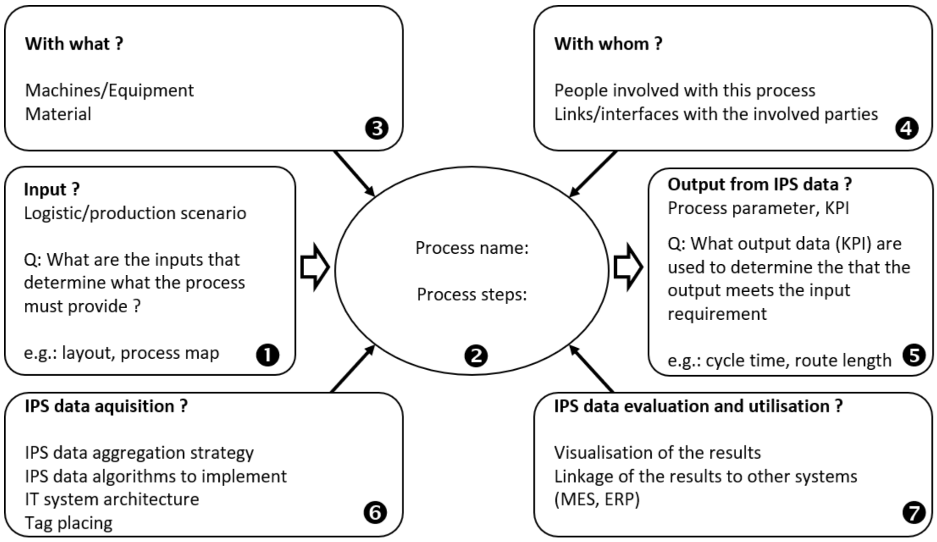

Figure 15: General process description scheme

First, the logistics and/or production scenario, e.g. the relevant layout or processes are used as an input (1). The processes need to be named, and process steps (2) as well as the used equipment, machinery and/or material specified (3). In addition, the involved personnel is needed for a complete process description (4), before the output can be defined in the sense of process parameters or KPIs which should be derived from the position data (5). Based on this information, the technical implementation is derived in (6) by defining the data aggregation strategy and the evaluation/utilization of the data for managing the process based on position information (7). The last two aspects can be found in the second part of the framework. Here, a selection strategy for an IPS is provided based on four dimensions:

1. Core technical properties of the IPS
2. Economic implications
3. Data aggregation aspects
4. Algorithmic considerations

The "core technical properties" of IPS are accuracy and range. The accuracy ranges between millimeters and meters, while the range is within a single-meter to a 100-meter span. In the "economical dimension", the initial infrastructure costs as well as the cost per client are taken into consideration. Fig. 3 shows the framework. The data for accuracy, range and costs aspects have been summarized from LaMarca and De Lara (2008), Gu et. al. (2009), Liu et. al. (2007) and Mautz (2012). The dimension "data aggregation aspects" indicates the utilization of the position data with respect to the purpose within the shop-floor process management. Based on this, the quadrant "algorithmic considerations" gives a first indication of data processing. The selection of an IPS can be done starting from economical and technical characteristics or the use-case requirements.

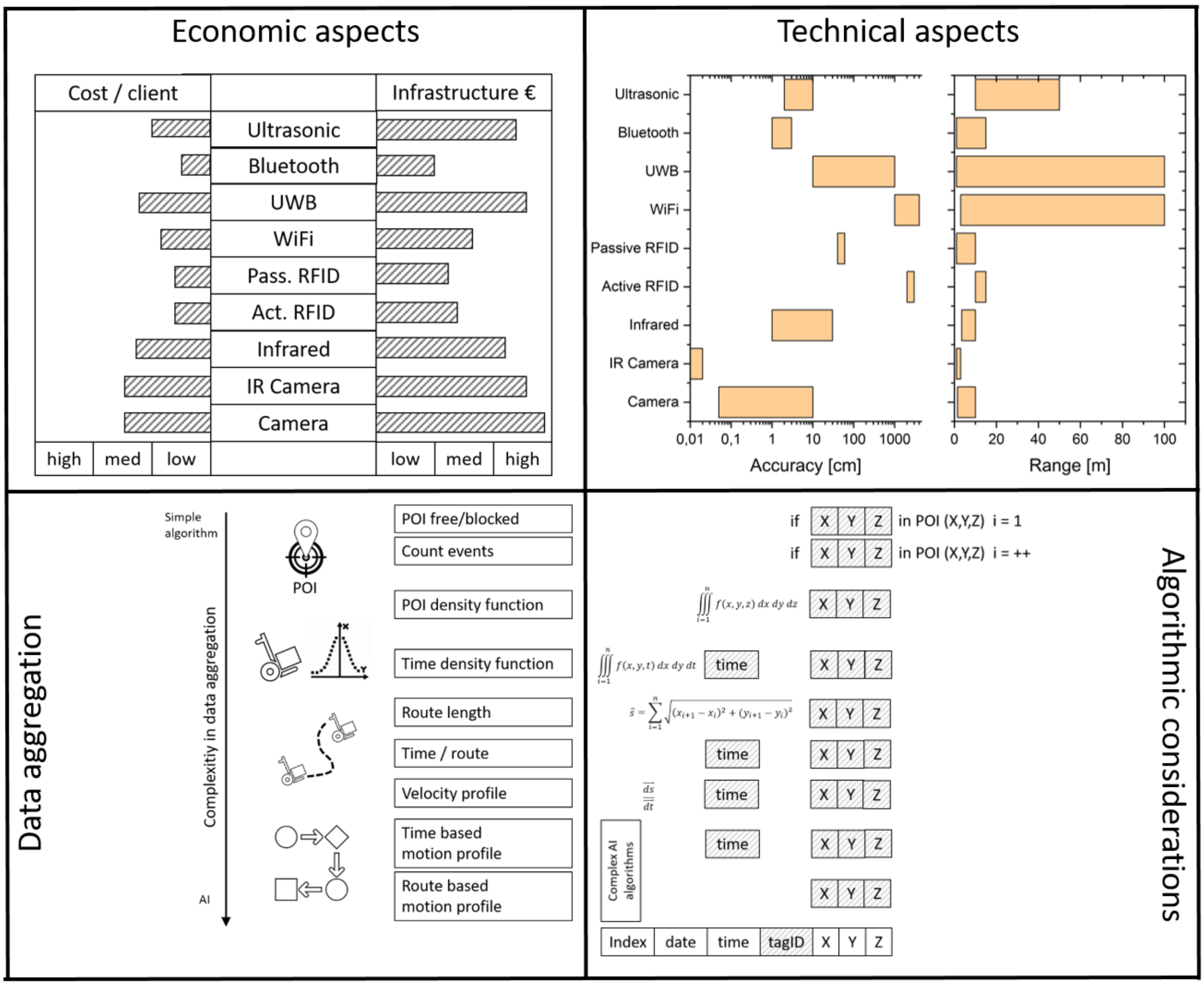

Figure 16: Framework for structuring IPS application

PROCESS MANAGEMENT BY POSITION DATA ANALYSIS: USE-CASE APPLICATION

The c-factory and its IT-Infrastructure for IPS

The approach of shop-floor management by position data is validated by implementing an UWB-based IPS in the c-factory at the University of Applied Sciences Würzburg-

Schweinfurt (FHWS) (see fig. 4). It features various industrial production machinery and logistics systems in a process chain, e.g. milling (2), injection molding, manual assembly (3), an automated guided vehicle system (AGV) as well as a small robot-feeded stock (1). Within the c-factory a customizable toy car is produced, assembled and tested (6/7) with holistic data transparency for customer orders: All process and product parameters derived from the CAD customization and the production steps are transferred to a cloud and made available to the customer via a website. The linkage to the product is a QR code printed (4) on the car.

The c-factory was equipped with an UWS IPS with four fixed anchors and a tag was placed on the AGV for use case 1 and the manufactured product for use case 2, respectively. The position of the tags was derived according to the functional principle of UWB IPS described above. The position data were sent via a local WiFi to the server to a database integrated in MATLAB® as the development environment for data aggregation and implementation of algorithms.

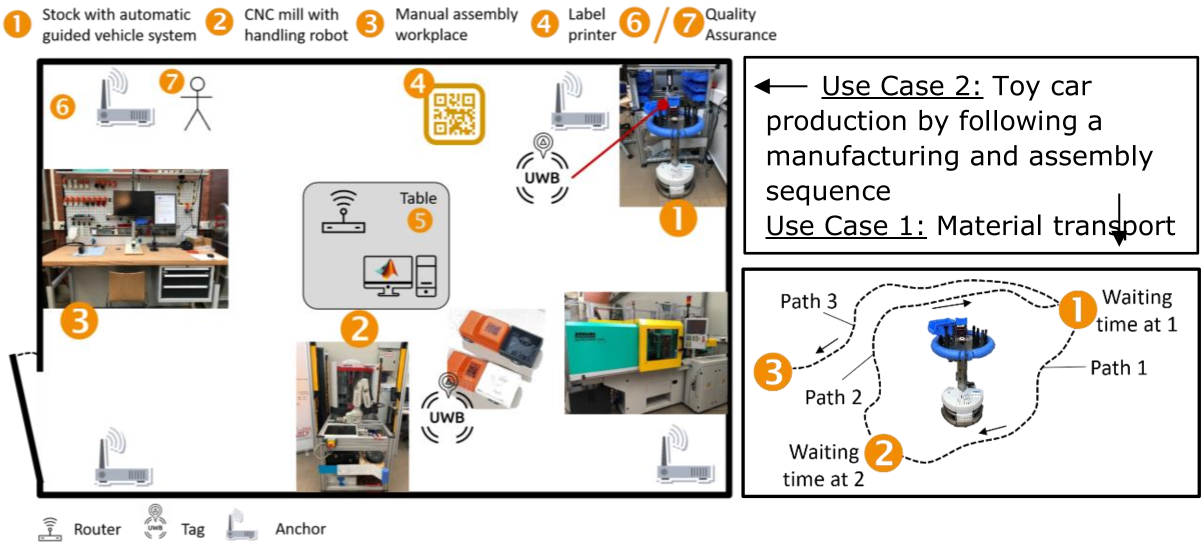

Figure 17: c-factory with workstations and installed UWB-WiFi IPS (left); logistics use case with the AGV (right)

The two use cases are described (table 1) following the scheme shown in fig. 2.

Table 3: Use-case description

	Use-Case 1	**Use-Case 2**
1 – Input	Logistics scenario with the AGV, path comparison and derivation of KPIs for material supply between stations 1 -> 2 | 2 -> 1 | 1 -> 3	Production scenario, manufacturing of a toy car in an assembly sequence 5 -> 2 -> 1 -> 4 -> 3 -> 6/7
2 – Name	AGV tracking	Assembly characterisation
3 – With what?	AGV, tag placed on the AGV	Named stations, tag is placed at or near the product
4 – With whom?	None – fully automated	Assembly worker
5 – Output	Route length, way time, absolute and relative	Abs./rel. cycle time for each production step
6 – IPS data agg.	(X,Y) and (X,Y, time aggregation)	(X,Y) map with POI identification
7 – IPS data vis.	Route (Time)	X,Y,POI

Use Case 1: Deriving Logistical KPIs for Process Management
In use case 1, the AGV is supplied with material from the stock. The goods are delivered by the AGV and a robot feeds the material to the CNC milling machine. The semi-finished part is then transported back to the warehouse. As the AGV is equipped with a tag, the position data are provided and aggregated to derive route length and travel time as KPIs.

Fig. 5 (left) shows the raw position data from the IPS as (x,y) coordinates in relation to a time stamp. These data are aggregated due to both the duration of the transport process and the route. Here, the strategy shown in fig. 3, quadrants 2 and 3, is used. Regarding the process KPIs travel time and route length, the route from the milling machine back to the stock is more time-efficient than vice versa.

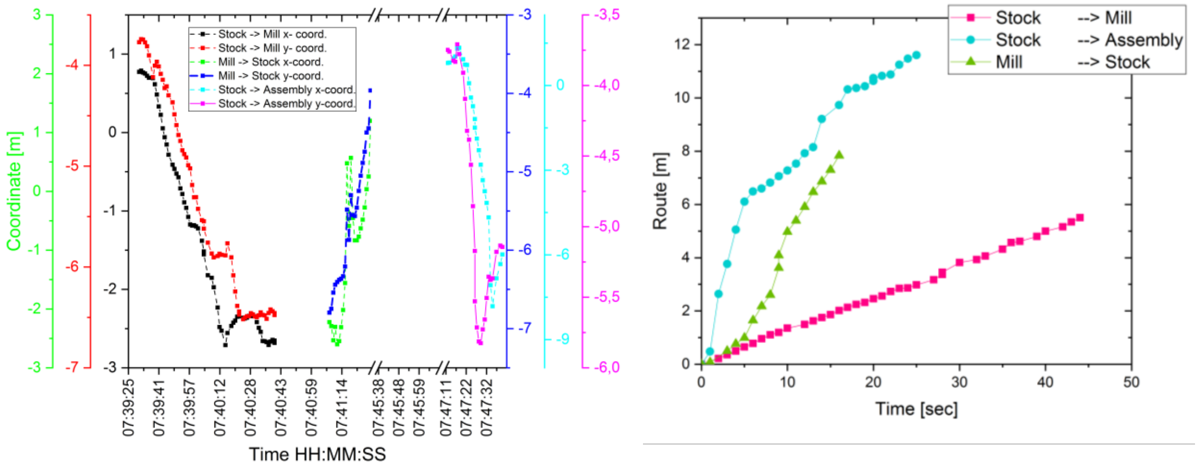

Figure 18: Raw position data (left) and aggregated data (right) for use case 1

Use case 2: Tracking Toy Car Production via IPS
In use case 2, a toy car is produced and equipped with a tag right from the start of production. The position data of an entire production process (configuration, production, warehousing, assembly, and testing – see table 2) are collected and analyzed with respect to the cycle time of each step. The raw data in fig. 6 (left) show the time-based position information. In order to filter for the respective manufacturing stations, POIs or regions of interest (ReOI) are defined based on their physical location in the c-factory. The implemented algorithm marks the data points – see fig. 6 (right) –which are inside an ReOI. This is matched with the time entering and leaving an ReOI in order to derive the cycle time for each manufacturing station.

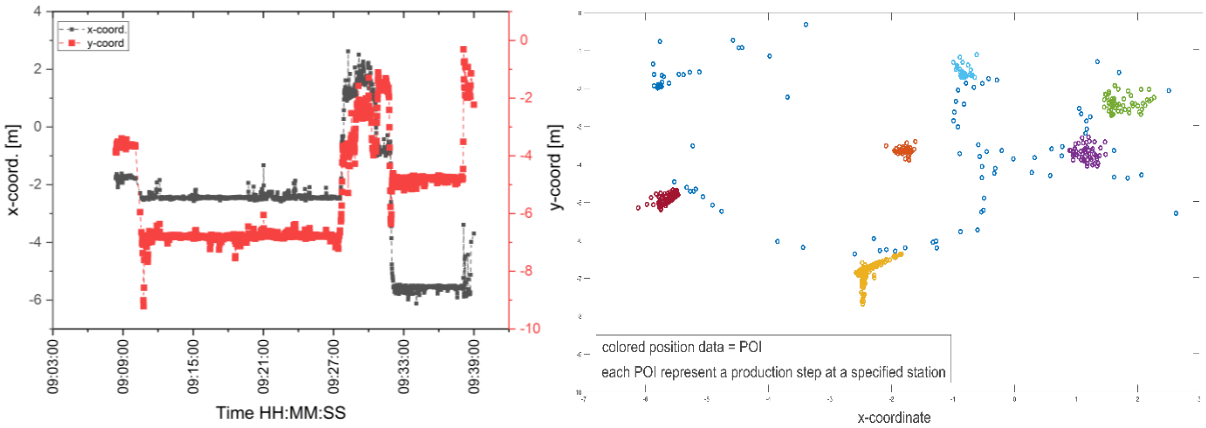

Figure 19: Raw position data (left) and aggregated data (right) for use case 2

The overall aim is to convert raw position data into aggregated data in order to increase the transparency of a process by means of deriving its key performance indicators. For use case 2, the evaluation of position data allows to derive the cycle time for each production step and the overall transportation time as well as the ratio of value-adding and non-value-adding processes. In table 2, the KPIs from use case 2 show that the milling process is the bottleneck of the production, constituting a line-balancing optimization potential for the entire process chain.

Table 4: Overview on cycle-times and value-add

Station	**Abs. cycle time [sec]**	**Rel. cycle time [%]**	**Value adding**
5 - Configuration	101	5,9	no
2 – Milling	1018	59,5	yes
1 – Warehousing	149	8,7	no
4 – Label printing	54	3,2	no
3 – Assembly	357	20,9	yes
6 / 7 – QA	31	1,8	no
Acc. transport time	58	-	-
Value adding ratio	1375	78	

CONCLUSION AND FURTHER RESEARCH

This paper presents technologies and systems for collecting indoor position data of objects. The principle determination methods (trilateration, triangulation, fingerprinting) are briefly described and related to IPS. On this basis, the paper presents a framework for a process-scenario-based selection of IPS and shows its application in two use cases. In either use case, the position data are recorded with an UWB system and aggregated with algorithms implemented in the MATLAB® environment to derive KPIs relevant for process management and continuous improvement.

The approach presented in this paper allows the automated evaluation of KPIs for different scenarios in both, the logistics and production field. One limitation is the data integrity and the accuracy in relation to the size of the ReOI. Depending on the factory environment the position data might not be not provided appropriately, which can affect the KPI evaluation. Furthermore, the accuracy restriction of the IPS has to be considered in the definition of the ReOI. Here, further research must be done to increase the robustness of the algorithms in terms of incomplete data sets. Additional work has to be done in combination with other relevant process management data sources such as ERP or machine data.

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THE ROLE OF COLLABORATIVE NETWORKS IN OVERCOMING ADOPTION CHALLENGES OF 3D PRINTING

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ABSTRACT

Purpose: Limited research explores the role of different types of collaborative networks, i.e., cluster-based, academia, or industry-led in addressing challenges and barriers in adopting 3D printing. The literature on the adoption of new technologies focuses on the intra-organisational enablers and to a limited extent on the role of external partners. Hence, this paper explores the role of collaborative networks in overcoming adoption challenges of 3D printing.

Design: The exploratory interview and case study approach employed here identifies companies' challenges in adopting 3D printing. The interview questionnaire caters to research gaps identified in the literature review and is used to conduct semi-structured interviews with firms adopting 3D printing. The research design includes interviews with three service providers and seven customer firms (three in Denmark and four in Germany) between January and May 2017.

The design also includes interviews with one Danish and two German 3D printing networks combined with public domain information (websites, etc.). Nexttech in Denmark is an industrial cluster, while 'mobility goes additive' in Germany is an industry-led consortium, with universities added as academic members. The University of Paderborn Direct Manufacturing Research Center (DMRC) is a university-led consortium that also has industry partners.

The research team recorded, analysed, and shared the interviews with the participants.

The theoretical lens in the paper includes co-opetition, technology dispersion and adoption theory, and ambidextrous network theory.

Findings: Networks provide solutions for challenges not addressed by individual service providers. The findings illustrate that networks serve as a platform to discuss and share best practice on challenges such as lack of 3D printing technology awareness in the procurement function, how to train strategic buyers on the technologies, and in developing a customised Total Cost of Ownership (TCO) analysis for 3D printing for their requirements. Networks also liaise with industry associations and regulatory agencies for creating industry-specific standards and addressing IPR-related issues. An academia-led network that allows industry partners to initiate research projects provides a balance of creativity network, transformation network and process network characteristics.

Value: This research clarifies the role and contributions of networks in overcoming challenges in the adoption of 3D printing from exploration to exploitation – an important issue largely neglected in the literature and highly relevant for industrial companies.

Practical implications: There is a clear need for organisations across the 3D printing spectrum to develop a collaborative platform to share challenges and develop solutions, which also facilitates the further development of the technologies. A group of companies

can drive these, including both users of the technology, raw material and equipment suppliers, service providers and also educational institutions (e.g. 'mobility goes additive'). Such networks can also be operated as an independent entity as an industrial cluster based organisation (e.g. Nexttech) or led by universities (e.g. the University of Paderborn DMRC), bringing in companies to test the latest developments and to train engineers and executives.

INTRODUCTION

Across industries, firms explore 3D printing for component manufacturing, tooling, and prototyping, and so on. 3D printing has room for further and rapid development and is at an early diffusion stage (Anusci, 2015). 3D printing technologies promise to transform manufacturing and boost new business models and printing services (Gallouj et al., 2015, Jiang et al. 2017). The perceived relative advantage of 3D printing and related performance expectations serve as strong adoption motivators (Schniederjans, 2017).
Nevertheless, depending on a firm's adoption cycle stage and adoption maturity level, implementation motivations and the willingness to scale additive manufacturing (AM) processes may differ. However, research on how to overcome 3D printing adoption challenges in industrial manufacturing companies is limited. 3D printing service providers, of course, play an important role in this (Chaudhuri et al., forthcoming 2019). However, collaborative networks are also important.
3D printing technology and related collaborative networks (that support adoption of 3D printing) are growing rapidly. Research has looked into the potential and growth of 3D printing (Berman, 2012, Mellor et al., 2014, Weller et al., 2015, Baumers et al., 2016, Birtchnell et al., 2017, Dwivedi et al., 2017), but not analysed the role of collaborative networks in addressing the challenges faced by manufacturers in adopting 3D printing. This research, therefore, studies challenges faced by Danish and German manufacturers in adopting 3D printing and the role of 3D printing collaborative networks in overcoming these challenges. The research outlines how collaborative networks can help in challenges associated with the adoption of 3D printing adoption in terms of solving problems and sharing capacity and knowledge.

LITERATURE REVIEW

The theoretical lens in the paper includes co-opetition, technology dispersion and adoption theory, and ambidextrous network theory.

3D printing Adoption Challenges

Limitations such as restricted choice of materials (Berman, 2012), rough surface finish (Petrovic et al., 2011), slow process speed (Merrill, 2014), poor dimensional accuracy compared to some conventional processes, and problems with process predictability and repeatability (Baumers et al., 2016) hinder widespread 3D printing adoption. Other 3D printing technology related implementation barriers include high material and maintenance costs, high energy intensity, high process costs, high capital investments, difficulties with material removal, and insufficient material properties (Mellor, 2014, Gilpin, 2014, Oettmeier and Hofmann, 2016). Companies also struggle with investing in the training concerning design, materials, infrastructure and specialised software (Holweg, 2015), as well as ethical concerns and intellectual property (Li et al., 2014). For non-experts, it is difficult to optimise product designs and obtain the necessary knowledge due to the lack of guidelines (Weller et al., 2015). For instance, knowledge about different costs, particularly concerning metal-based additive manufacturing processes is lacking (Mellor et al., 2014). One reason is that equipment vendors may fail to disclose costs related to maintenance and operations (Dwivedi et al., 2017) or technology weaknesses (Rahman and Bennett, 2009).

Role of networks in facilitating the adoption of new technologies

For superior business performance, firms often simultaneously pursue collaborative and collaborative strategies (Lado et al., 1997). 'Coopetition' entails knowledge sharing in intra-organizational networks consisting of both collaborative and competitive ties (Tsai, 2002). An industrial cluster is one such network that includes knowledge producing institutions, interdependent firms, technology-providing firms, bridging institutions and customers, linked in a value-creating production chain (Bititci et al., 2004).

In clusters, facilitators assist and encourage companies, educational institutions, consultants, vocational training providers and trade association to collaborate and create more value. The companies collaborate by sharing information and integrating similar activities (such as research, education, marketing and information technology (IT) to achieve competitive advantages for the members and to support the economic region (Bititci et al., 2004). Clusters can improve customer service through reduced delivery times, achieve better economies of scale (Carrie, 2000) and ensure stronger bargaining power in all respects, including suppliers, government (e.g., build infrastructure, tax incentives) and other relevant bodies (Scheel, 2002). Moreover, regional and local networks can be essential for small and medium enterprises (SMEs) (Marri et al., 2002).

Universities can be members of a local cluster or can create a network on their own. Universities, being at the centre of regional economies, remain close to local actors, e.g., non-governmental organisations, SMEs, multinational corporations, or councils (Birtchnell et al., 2017). Intermediaries can play a role in connecting SMEs and universities (Drilhon and Estime, 1993). In the context of the adoption of Computer Integrated Manufacturing (CIM), according to Marri et al. (2002) SMEs need to collaborate with universities for short-term employee training, seminars and workshops for factory managers and to use university facilities and equipment as a source of ideas. Organising a team of professors and industry executives working together can considerably speed up the adoption of CIM in SMEs (Marri et al., 2002). While the industry is making investments and playing a key role in the expansion of 3D printing beyond rapid prototyping, universities have a significant role to play in evolving the 3D printing ecosystem (Birtchnell et al., 2017) and more importantly enabling SME's adoption. Managers in adopting companies can promote compatibility of 3D printing with the existing 'traditional' technologies by investing in initiatives such as creating a makerspace environment or facilities conducive to the use of 3D printing (Schniederjans, 2017).

Networks can be cluster-based, academia or industry-led. However, one can also distinguish between creativity networks, transformation networks and process networks. Creativity networks with weak ties as primary sources of specialised knowledge focus on exploration. Process networks have strong ties between R&D-Marketing, ensuring alignment and focus on exploitation. Transformation networks bridge creativity networks and process networks (Harryson, 2006, Harryson et al. 2008, Harryson and Søberg, 2009).

In summary, while the literature discusses challenges and barriers in adopting 3D printing, there is limited research on exploring the role of different types of collaborative networks, i.e. cluster based, academia or industry led in addressing those challenges. The literature on the adoption of new technologies focuses on the intra-organisational enablers and to a limited extent on the role of external partners. Thus, it is necessary to identify the challenges faced by companies in adopting 3D printing and how collaborative networks can help address these challenges.

METHODS

The exploratory interview and case study analysis approach (Remenyi et al., 1998, Dubois and Gadde, 2002, Dubois and Gadde, 2014) employed here identifies to what extent the participating companies faced challenges in adopting 3D printing. The interview questionnaire caters to research gaps identified in the literature review and is used to conduct semi-structured interviews with firms adopting 3D printing. The research design includes interviews with three service providers and seven customer firms (three in Denmark and four in Germany) between January and May 2017.

The design also includes interviews with one Danish and two German 3D printing networks combined with public domain information (websites, etc.). Nexttech in Denmark is an industrial cluster, while 'mobility goes additive' in Germany is an industry-led consortium, with universities added as academic members. The University of Paderborn Direct Manufacturing Research Center (DMRC) is a university-led consortium that also has industrial partners. Apart from the semistructured interviews, unstructured interviews (Leonard-Barton, 1990) took place with the network managers. Collected public domain information (websites, etc.) constitutes a part of analysed data. Interview sessions were recorded, analysed and subsequently shared with the interview participants.

DESCRIPTION OF THE AM NETWORKS STUDIED

Nexttech is the only functional industrial cluster network organisation in Denmark dedicated to 3D printing technologies. Some of the customers and service providers we spoke to (including one customer in Denmark) are also members of the two networks in Germany and benefit from the network activities.

Nexttech is a networked organisation, located in Kolding, Denmark. It provides 3D printing equipment, which local companies can use. Thus, it creates a platform for manufacturing companies, knowledge institutions, suppliers of 3D printers, scanners, materials and other stakeholders to collaborate and produce, develop, research and educate professionals on the technical and business possibilities offered by 3D printing.

"**Mobility goes additive**" is a network with the main objectives of joint, competent development of innovative products, exploration of new international markets, and increasing the competitiveness of the members. Deutsche Bahn coordinates the network and brings together companies in the automotive, transportation and logistics industries, along with universities, equipment manufacturers, software service providers and consulting firms. This industry-focused platform seeks to facilitate closer collaboration between service providers, customers, equipment manufacturers and universities and to foster the development and adoption of additive manufacturing technologies.

The University of Paderborn's **Direct Manufacturing Research Center** (DMRC) has a large number of industrial collaborators consisting of user companies, raw material suppliers, equipment suppliers, modelling and software services providers and other interested parties. DMRC's projects receive funding from the State Government of North Rhine-Westphalia, from the industrial partners and public sources. Additionally, industry partners guide and control all projects. This co-funding model allows all partners to generate industry-relevant scientific output. DMRC focuses on five pillars: Laser Sintering, Laser Melting, Fused Deposition Modelling, Construction and Business. Thus, the network activities attend to the entire process from thinking ahead concerning the products of tomorrow to laying the foundations for their manufacturing. Thus, DMRC's work spans across both technology and business. From a research perspective, nine 'chairs' support the pillars. Each chair conducts research projects within one or more of these pillars, drawing on funding from both public and industrial sources.

ANALYSIS AND DISCUSSION

Role of collaborative networks in the adoption of AM

The analysis and discussion part of the paper discusses Table 1 that outlines the network name, network type and achieved AM adoption objectives of the three investigated networks.

Network and network type	Achieved AM Adoption Objective
Nexttech, Industrial Cluster, Transformation Network	Test ideas, Equipment Training
Mobility goes additive, Industry-led consortia, Transformation- and Process Network	Transfer of know-how, joint product development and training
DMRC, Academia-led, Creativity, Transformation, and Process Network	Provide Communication Platform, Define and carry out industrially relevant research

Table 1: Network name, network type and achieved AM adoption objectives

Networks, such as industrial clusters, academia or industry-led consortia, can play an important role in addressing 3D printing adoption challenges. A network of 3D printers available to firms is often a valuable complementary asset and be integrated fully into the firm's business model. Technological networks can provide the necessary resources to change the business model and increase competitiveness (Calia et al., 2007). Nexttech in Denmark is such an industrial cluster-based network. Through Nexttech, involved stakeholders collaborate and help smaller manufacturing companies to adopt 3D printing and improve their business potential. For example, service providers who are members of the network have the opportunity to understand customer needs, contribute to their adoption of the technologies and in supporting their business development. Nexttech's member companies are exploring opportunities to reduce the spare parts delivery lead-time and to increase their global business potential. These companies consider 3D printing as an attractive opportunity, but many of them are not in a position to make the investments or have the resources to conduct the necessary analysis. Nextech, with its 3D printing equipment and academic collaborators, can help these smaller companies in their journey towards adopting 3D printing. Such a cluster-based network can provide options to manufacturers to try various equipment, processing different materials. The network can thus help manufacturers experiment and hence, find the most appropriate material and equipment. It can also provide training on using the equipment.

An industry-focused network such as "mobility goes additive" facilitates closer collaboration between service providers, customers, equipment manufacturers and universities and fosters development and adoption of additive manufacturing technologies. It adds value to its members through the transfer of know-how, joint product development and training. Its partners collaborate closely on research projects, generate funds and drive application-oriented innovative projects. It organises regular workshops on its key areas of interest, i.e. education, digital supply chain, approvals and legal framework. The network involves a large number of players across the 3D printing value chain that discusses problems, shares best practices, and offers solutions. Such a network can share best practices in creating business cases and thus can address the challenges associated with the difficulty in creating business cases. It can organise working groups on design for 3D printing to address challenges associated with lack of knowledge on design for 3D printing. Companies discuss and share best practices to solve challenges such as conducting a Total Cost of Ownership (TCO) for 3D printing, lack of awareness in the procurement function, and how to train strategic buyers on the technologies. Developing a customised TCO approach for their requirements is one way to address the challenge. The network also plays a vital role in liaising with the industry associations and the regulatory agencies for creating industry-specific standards, addressing intellectual property rights related issues. An academia-led network such as DMRC allows industrial partners to initiate research projects with them. DMRC balances interests in the diverse field of additive manufacturing, as the projects are both publicly and privately funded. DMRC also acts as a communication platform for all its stakeholders. Thereby, it can quickly leverage contacts and initiate projects of mutual interest. At DMRC, industrial partners guide and control all projects. The guidance allows all partners to generate a large amount of output, especially regarding the development of 3D printing technology and in addressing common problems. DMRC also provides practical training and seminars for industry professionals on multiple aspects of 3D printing. Specialised services offered by DMRC in the areas of potential identification, selection of products and business planning attract companies who use those to make informed decisions about adopting 3D printing. Such an academia led network can also address challenges associated with the choice of different materials by conducting specific research projects on which materials to use for which applications, given the capabilities of the processes. Thus, it can also help in optimising the processes for specific parts. It can also organise training on design for 3D printing, operate, and use the equipment. If employees are knowledgeable regarding new technology, they are likely to be more capable of embracing technology adoption (Ghobakhloo and Tang, 2011). Indeed, technical expertise and availability of training are key elements of organisational learning capabilities, which can facilitate technology adoption (Migdadi et al., 2016). Collaborative networks can play a big role in improving employee knowledge of 3D printing technologies and thereby facilitate adoption. Hence, we can conclude that service providers, industry-led networks, cluster-based networks and

academia led networks can play a complementary role in addressing the challenges faced by the manufacturers in adopting 3D printing.
Nexttech resembles mostly of a transformation network that can take ideas from companies, helps to test them and make steps towards further exploitation of these ideas. “Mobility goes additive” has a strong exploitation focus that shares best practices of how the 3D printing technologies generate value for the companies. The network focus is less on exploring how they possible otherwise could do so. The DMRC network presents an interesting example of coexisting network characteristics. The network is academia-led which resonates strongly with the exploration focus of a creativity network but combined with the fact that industry partners guide every project introduces transformation network and even process network elements that likely benefit the outcomes for the participants.

CONCLUSIONS AND IMPLICATIONS

The study highlights the important role played by industrial cluster-based networks, industry-led and academia-led networks in overcoming challenges associated with 3D printing. The findings indicate more such networks may be necessary to facilitate the increased adoption of 3D printing amongst industrial customers.

Practical implications

There is a clear need for organisations across the 3D printing spectrum to develop a collaborative platform to share challenges and develop solutions, which also facilitates the further development of the technologies. A group of companies can drive some of these, include both users of the technology, raw material and equipment suppliers, service providers and also educational institutions (e.g. ‘mobility goes additive’). Such networks can also be operated as an independent entity as an industrial cluster based organisation (e.g. Nexttech) or led by universities (e.g. the University of Paderborn DMRC), bringing in companies to test the latest developments and to train engineers and executives (Marri et al., 2002).

LIMITATION AND FURTHER RESEARCH

Further research should investigate other AM networks as well as participant companies. How to evaluate network performance is a relevant issue for further research.
A challenge faced by the networks is how to balance on the one hand openness that nurtures knowledge identification good for exploration and on the other hand close collaboration with trusted, strong ties, that nurtures transfer and sharing of complicated knowledge good for exploitation. As networks grow, it becomes a challenge to strike a balance that invites newcomers to the table while not jeopardising the trust established between early network members. An issue that is not easy to resolve is who gets access to what shared knowledge in the network? Best practices in this context is a relevant concern for further research.

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NETWORK VALUE CREATION IN DIGITALIZED SUPPLY CHAIN PROCESSES

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Purpose
New technologies are changing the way traditional manufacturing businesses and supply chains operate. The implementation of new digital technological innovations has crucially impacted the interorganizational supply networks. Especially in the fields that are considered more traditional and rigid by nature (e.g. some parts in logistics, machining, energy) have experienced great difficulties in defining the overall change and its consequences to their supply network. The value creation in digital supply chain processes requires a holistic approach in order to understand the value of the new technology. This paper illustrates the value of digitalization in different processes in the supply chain.

Design/methodology/approach
This study aims to explore the value from digitalization in supply chain processes using both supply chain and value network theories to the new technology adoption in supply chain context. The empirical part of the study relies on analysing survey data from 101 companies which investigates the value from digital processes in supply chains. Numerous sources found from the literature are used to gain a holistic understanding of the attributes and impact digitalization change the value creation. Value network literature from the innovation and supply chain management perspectives are used to understand the linkages between organization and the adaptation of the integrated digital processes.

Findings
This study provides an important, yet sparsely addressed viewpoint to the supply chain management literature by illustrating how digitalization impacts supply chain performance and customer benefits. The findings of the paper suggest that digital technologies will impose drastic changes to the supply chain management where creating customer value will become increasingly integrated and networked process. The findings suggest that increased integration and information exchange in the network interactions between organizations can enable combining of the independent business models into a networked business model.

Value
This paper contributes to the both supply chain management and value management literature with insights into how networked digital solutions impact and transform the processes in the supply chain. Analysing the dynamics of the value creation can provide crucial information, thus enabling better value creation and more efficient and effective implementation of new digital technologies in the supply chain. The results illustrate the bottlenecks of implementing new digital technologies in supply networks, and give insights how to manage the changes in the network context.

Practical Contribution
The study helps to understand the nature and dynamics of value in the supply chain and how digitalization impacts the supply chain processes. The presented view offers insights

for utilizing new digital information exchange technologies and evaluating the benefits from investing into the digital technologies in the supply chain

INTRODUCTION

New technologies are changing the way traditional manufacturing businesses and supply chains operate. The implementation of new digital technological innovations has crucially impacted the interorganizational supply networks. Especially in the fields that are considered more traditional and rigid by nature (e.g. some parts in logistics, machining, energy) have experienced great difficulties in defining the overall change and its consequences to their supply network. The value creation in digital supply chain processes requires a holistic approach in order to understand the value of the new technology. This paper illustrates the value of digitalization in different processes in the supply chain.

Digitalization has proven to provide multitude of both opportunities and challenges in the supply chain and it can be argues to be the most important megatrend in improving supply chain value creation performance. In here, the information integration and electronic business processes play a significant role. The information exchange and manual processing of information form a major part of the administrative tasks involved in the business processes of supply chains. Digitalization can bring vast amount of opportunities of increasing performance of both the efficiency and accuracy of these operations. (Büyüközkan and Göçer, 2018; Singh and Teng, 2016)

Information exchange and integration play a vital role in supply chain performance and value creation (e.g. Kim and Chai, 2017; Gu et al. 2017). Information integration not only enables improvement of the information exchange and business process performance but also enables the use of analytics and modelling in a supply chain level and increases the availability of essential information. Indeed, for example Tesco has saved millions through using supply chain analytics in their retail chain (Information Age, 2013). The impact of digitalization has been calculated to be 2-5% of organizational turnover (Hameri and Lehtonen, 2001), the performance it can bring to the whole supply chain processes can be considered significant. Indeed, currently IT integration improvements are expected in 82% inside organizations and 77% in supply chain level (ATKearney, 2015), which demonstrates the scale of change in the supply chain processes.

The benefits caused by the introduction of new technologies rely on the fluent information exchange in the supply chain. Thus, the value from new technologies is dependent from integration between the network actors. Supply chain digitalization has transformed the value creation and can have eroding effect on the traditional, institutional value creation forms, when new digital-based forms of value creation take more control (Reinartz et al. 2019). It is important for the organizations to identify the new forms of value creation and how those impact on the whole supply chain. As the integration of supply chains is getting denser, the information has become more essential element which ensures uninterrupted co-creation of value towards the end customer. While many studies have focused on the benefits from value co-creation in supply chains (e.g. Vilko and Ritala, 2016; Aarikka-Stenroos and Jaakkola, 2012) the role of information integration in this is still less explored. Few studies have however proven how information integration can improve both the operational and financial performance of supply chains (e.g. Gu et al. 2017; Wong et al. 2011).

The impact of digitalization has received vast attention in both the academic and managerial literature, while the evidence of the real impact in organizations and supply chain has been scarce (Li and Found, 2017). Furthermore, less attention has been paid to the development of novel methods to analyse the value of external integration and the ability to scale the performance at the supply chain level or even the business ecosystem level (Hernandez and Pedersen, 2017). Hence, this paper studies the impact of information integration in supply chain processes value creation. More precisely, we will analyse the impact of digitalization in supply chain using Monte Carlo-simulation method, through the whole supply chain.

THEORETICAL BACKGROUND

Increasing pace of changes has contributed to a more complex business environment. Arguably, one of the most drastic changes over decades has been the development of digital technologies and information exchange in supply chains.

As supply chain are being digitalized the way information is exchanged in the supply chains is changing drastically. The old tangible paper documentation is changed with the digital one. The service nature of the digital processes can be more abstract by nature and thus it can be more complex to understand than traditional supply chains. In service supply chain management the process differentiation is of importance, which can be achieved through different types of relationships with customers as well as suppliers (Arlbjørn et al., 2011; Cho et al., 2012). Ellram et al. (2004), list seven theoretical processes of service supply chains, including: information flow; capacity and skills management; demand management; customer relationship management; supplier relationship management; service delivery management; and cash flow.

Supply chain management can be defined (Mentzer et al., 2001) as "a systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across business within supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole". In terms of SCM activities, the aim of supply chain management is organizational integration and coordination of flows of goods, information and funds, where ICT has a critical role (van Hoek, 2002). In doing this, the supply chain have to be built for meeting customer demands and expectations, and as such the organizational integration and flow coordination only come second following the guidelines of responsiveness and customer expectations.

ICT and electronic data interchange are widely identified and acknowledged as significant elements for inter-firm processes, productivity and performance in supply chain (e.g. Hazen and Byrd, 2012; Jeffers et al. 2008), there still occur obstacles for deeply automatized transactions between supply chain stakeholders. The main barriers to deploy ICT technologies in supply chains are high investment costs, incompatibility of software/hardware and lack of awareness of ICT benefits. (e.g. Evangelista and Kilpala, 2008; Ferguson et al. 1996). However, due to development of integration standards and technologies in supply chain information exchange it is expected that these models will become more popular in various industries.

Collaboration and information exchanging with the partners involved is the basis for supply chain existence. In order to be competitive and successful, supply chain operations and processes have to be organized in effective and reliable manner, that requires changing from managing individual functions to integrating activities into key supply chain processes. Information technology has been a crucial element for supporting process integration and development of supply chain management (Ordanini and Rubera, 2008; Gunasekaran and Ngai, 2003). In integrated processes, information gathering, sharing and exchanging among the participants is essential. Especially in supply chain, information flow must be exact and real-time. Information technology enables to process more information, more accurately and frequently, from more sources over the world (Neubert et al. 2018).

Value creation in supply chains

Customer value is a very complex phenomena and there is no broad-based definition available (Anderson et al., 2006). Customer value has been extensively studied in the last fifteen years (Lepak et al., 2007; Gummerus, 2013; Bourguignon, 2005; Ulaga and Chacour, 2001; Ford and McDowell, 1999). However, there still isn't consensus what customer value really is. To create value in todays networked business environment, companies need to find partners with whom to create superior value compared to that of other value creators and to deliver high performance in terms of the attributes that are important to the customer. Companies should also be able to manage these partnerships in a way that allows value to be transported and added along the supply chain actors. The uninterrupted and constant flow and production of value requires high visibility and integration where information exchange plays a crucial role.

To gain insight into the distinctive features of customer value in supply chain management, we refer to categorization introduced by Rintamäki et al. (2007). They divide customer value to four categories: 1) economical, 2) functional, 3) emotional and 4) symbolic. Each value proposition pursues to create value to the customer in one or several of these areas. Economic value refers to the financial benefits that can be offered to the customer. Functional value is the actual service, which helps to solve a concrete problem, e.g. moving products to one place to another. Emotional value refers to the feelings such as convenience, entertainment or feeling of safety. Finally, symbolic value refers to social status, respect and identity.

In service supply chains, the value creation process becomes more complex when compared to dyad-level analysis between provider and customer. While the functional and economical value creation has been seen as very difficult issue to handle in complicated, multiparty logistics services, the issue is even more pronounced when it comes to emotional and symbolic value.

METHODOLOGY

An explorative research design was employed to establish an understanding of value perception, risk management and different stakeholder groups' contribution to risk management process. Case study approach was employed to study a contemporary phenomenon in its operational contextand was considered appropriate the serve the explanatory nature of the research (Yin 1994).

Empirical data was collected by means of semi-structured interviews and stakeholder analyses. Interviews were mainly conducted with the entrepreneurs or managerial level personnel who are in charge of daily business as they were evaluated to be suitable informants being experts of their business and having insights on the industry. Identification of different stakeholders begun by utilizing value mapping tool by Bocken et al. (2013) which contributed to establish an understanding of different stakeholders in networks and their proximity to the firm. Next, the same stakeholders were further examined and categorized with stakeholder analysis tool, which was prepared according to the procedure by Eden and Ackermann (1998) by assorting stakeholders on a commitment versus influence grid, a two-by-two matrix. In combination, these tools established an overall understanding of the stakeholder networks and their roles.

Cases were selected on information-oriented selection in order to maximize the empirical data (Flyvberg 2011). The selected cases reflected a variety of different SMEs operating in different sectors. Detailed respondent information can be found from Table 2.

The interviews were personal face-to-face interviews with open-ended questions. The interviews were conducted during spring 2018 and the average length of the interviews was 75 minutes. Participants were asked to reflect on the impacts of

ANALYSES AND RESULTS

The empirical study is based on the survey-based data from industry. The sample consists of manufacturing and service companies in Finland. The respondents presents supply chain and IT development in large and medium-sized industrial companies. More than 500 companies were first contacted by telephone to identify the most suitable informant in relation to digitalization and supply chain management. From those companies outreached, 348 respondents agreed to participate in the survey, and a weblink to the questionnaire was emailed to them. A total of 101 answers were received (101/348).

Survey Instrument

The measurement reliability of the constructs was assessed using construct reliability ('CR') and the variance captured by latent construct by average variance extracted ('AVE') (see e.g. Fornell and Larcker, 1981). According to Kine (2011) the CR coefficient should exceed .50 to indicate acceptable if the model validity otherwise is good. The measurement reliabilities are reported in the Table x. The project margin variable uses standardized measures. It can be stated that all of the latent variables had acceptable reliability for further analyses.

	Loading	p-value	Mean	SD	AVE	CR
SCM Integration success					**0.622**	**0.868**
Integ1 *DigiIntegSuccess_eConnectCustom*	0.829	****	3.267	1.004		
Integ2 *DigiIntegSuccess_AllureCustomer*	0.779	****	3.089	0.924		
Integ3 *DigiIntegSuccess_EnableSuppliers*	0.834	****	2.921	0.961		
E-logistics					**0.675**	**0.912**
E-logistics1 *eOrder*	0.861	****	3.050	1.594		
E-logistics2 *eTracking*	0.838	****	2.842	1.633		
E-logistics3 *eInventorystatus*	0.882	****	2.465	1.738		
E-logistics4 eReceipt	0.813	****	2.465	1.698		
E-Order-to-pay					**0.710**	**0.907**
Ordertopay1 *eOrder*	0.899	****	3.050	1.594		
Ordertopay2 *eOrderverification*	0.886	****	3.198	1.623		
Ordertopay3 *eOrderchange*	0.863	****	2.584	1.606		
Ordertopay4 *eBilling*	0.708	****	3.762	1.510		
SCM Performance					**0.673**	**0.911**
SCMperf1 *Sustainability*	0.777	****	3.050	0.894		
SCMperf2 *Flexibility*	0.815	****	3.248	0.938		
SCMperf3 *Costs*	0.813	****	3.129	0.875		
SCMperf4 *Deliverytimes*	0.872	****	3.248	0.979		
SCMperf5 *Reliability*	0.823	****	3.218	0.863		
Customer benefits					**0.596**	**0.911**
BenefForCust_ResponsivenessProduction	0.802	****	3.396	0.845		
BenefForCust_ProductImprovement	0.813	****	3.416	0.847		
BenefForCust_NewProductsForCustomer	0.690	****	3.327	0.986		
BenefForCust_ProductQual	0.808	****	3.535	0.839		
BenefForCust_ReduceProductCosts	0.816	****	3.347	0.861		
BenefForCust_ProductAccuracy	0.807	****	3.366	0.887		

n) not significant, *) Statistically significant at $p<0.1$, **) Statistically significant at $p<0.05$, ***) Statistically significant at $p<0.01$, ****) Statistically significant at $p<0.001$

PLS Path Model

We analyzed main effects in the model which are defined in the Figure x2. The path model presents only significant relationships. Other direct relationships were also tested, however, they were not defined significant. Mediation of the indirect effects were also assessed. The resampling of the data was repeated 5000 times with traditional Bootstrapping method analysis which is adequate for estimation of parameters in the model (Kline, 2011). We tested and validated quality of the structural model through the following steps; (1) collinearity issues and overall fit, (3) explanatory power, (4) path significances.

The collinearity and the model fit to the data was assessed in order to validate the structural model. The latent constructs did not indicate collinearity issues where the values remain clearly below critical value of 5. Root mean square residual covariance (RMStheta, critical value >.12) was also assessed to specify to assess the overall fit of the structural model (see Hair et al., 2016). Here, model fit by RMStheta= .185 indicates that serious misspecification of the structural model does not occur.

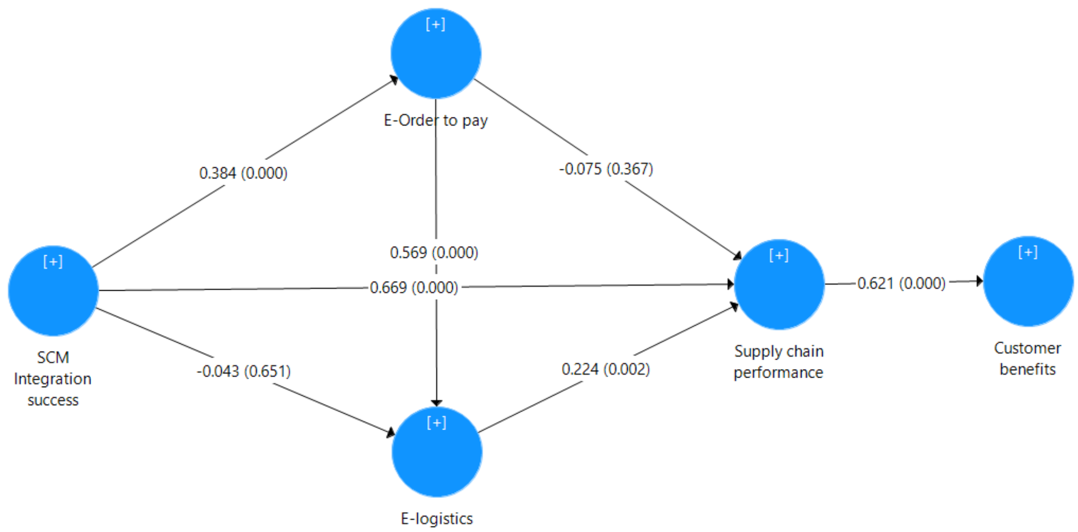

Figure 2 Path model of PLS analysis with t-values and (p-values)

The r-squared for the latent variables in the path model were; "Customer benefits" 0.39 "Supply chain performance " = .50, "E-logistics" = 0.31 and "E-Order to pay" = 0.15. The default model (see Figure x2) shows that the "SCM integration" has positive influence on the "E-Order to pay" and t; "Supply chain performance ". However, it showed no direct influence on "E-logistics" processes. The analysis shows that "SCM integration" has indirect significant influence on E-logistics processes via "E-order to pay" processes indicating the mediation role of ""E-order to pay" processes in the model. Furthermore, "E logistics" processes have direct influence on the "SCM performance". "E logistics" also mediates the relationship between "E order to pay" and "Supply chain performance" in the model. Finally, the model show that "Supply chain performance" has both direct and mediation effect to the "Customer benefits" by following the showed paths.

CONCLUSIONS
Digitalization of operations is changing drastically the way information is exchanged in the supply chains. Digitalization of information exchange offers a lot of opportunities to improve the performance and providing customer benefits. The value from digitalization in a complex supply chain system is not obvious and the value identification requires focus on information amount and quality and discovering how firms utilize the information. The full network potential may not be utilized as networks have potential to provide an access to resources, technologies and markets as well (Gulati et al. 2000). This study provides insights in how the supply chain information exchange impacts the business performance. In doing this, the mechanism thru which the customers benefits are received is illustrated.

According to the study results, the information management processes are handled mostly within organizational actors, which can limit the control capability and overall visibility in the supply chain. Digitalization can enable visibility by enabling information availability in the supply chain and as such enables integration between the supply chain partners. As the focus of information management process is on value creation, organizational resources are seen most suitable which may reflect on the responsibility entrepreneurs' sense and tend to favour stakeholders closely proximate to the firm.

The study results help better to understand the beneftis of digitalization in information process management and how networks are utilized in change-related value management. For example, instead of benefiting every organization, some firms seemed to benefit less from focusing on digital solutions with their network partners. By utilizing more holistic perspective and analyses in digitalization investments, supply chains may be able to increase the variety of actions to manage value. Taken into consideration the versatile networks case companies possess, the full network potential is not been utilized to the full by the current models. Overall, the investments made in to digitalization can be better grounded and focused by increased understanding in which type of operations can impact the performance and customer benefits the most. The single process improvements of digitalization seemed to have poor direct impact on the supply chain performance, rather the benefits were received via increased integration.

The research follows a mixed methods research approach with a limited number of companies on a limited geographical area, which limits the generalizability of the results. Further research should be focused on the different types of benefits and the factors the improve the customer benefits and value in the supply chain.

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RISKS OF INDUSTRY 4.0 FOR LOGISTICS – A SYSTEMATIC LITERATURE REVIEW

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Purpose
The prospective digitized industrial value creation, also called Industry 4.0, leads to numerous advantages in the logistics sector, through applications such as tracking of products and automatic re-ordering (Kagermann, Wahlster & Helbig, 2013). Despite these advantages, studies have revealed downsides of Industry 4.0, such as excessive data traffic or gaps in the IT security (Barreto, Amaral & Pereira, 2017). However, risks affect different areas of a company while their impact differs among the companies. So far, the literature lacks a holistic overview and framework to describe Industry 4.0 risks (Schneider, 2018). Thus, our study analyses which risks emerge from Industry 4.0 for logistics. The aim of this paper is to detect and classify the risks of Industry 4.0 into corresponding dimensions, to highlight the challenges of these risks for logistics, and to indicate measures to cope with them.

Design/methodology/approach
In order to achieve this research goal, we conducted a systematic literature analysis/review. This method is an adequate and transparent method to analyze and present the current state of research of this defined field. Following common research practice, the following steps were taken during the analysis: definition of the research period, selection of databases, selection of publication types, selection of relevant papers and categorization of papers.

Findings
By analyzing the existing literature, 69 relevant papers from academic databases were identified. Five risk dimensions of Industry 4.0 could be derived from these publications having a direct impact on logistics: human factor, IT security, organization and implementation, data analysis and legal issues and standards. Furthermore, our study exposes characteristics of these dimensions as well as challenges for logistics.

Value
To the best of the authors' knowledge, this is the first paper to provide a holistic overview of the risk dimensions of Industry 4.0 in the context of logistics. In addition, the study provides measures how companies can cope with the risks.

Research limitations/implications
Our study contributes to the academic discussion in this research field and helps to understand the risks of Industry 4.0. Future research can shed light on the interdependencies between the risk dimensions and their impact on future value creation.

Practical Contribution
Firstly, the identified risk dimensions and their characteristics within the framework are a guideline for practitioners to be able to understand and classify the risks of Industry 4.0. Secondly, risk management departments in corporate practice can use the findings as a basis for their risk assessment. Thirdly, the logistics departments of companies can use this paper to adjust their logistics processes and accordingly take measure to protect them.

PURPOSE OF THE PAPER

The omnipresent changes caused by digitization and interconnection are finding their way into any company worldwide, not only large companies, but also small and medium-sized enterprises. Companies expect this so-called fourth industrial revolution or Industry 4.0 to provide them with far-reaching opportunities and potentials to be prepared for current industrial trends (Bauernhansl, 2014). The implementation of Industry 4.0 key technologies like Big Data or Cloud Computing does not only take place within the boundaries of a company, but across several horizontally connected value creation stages (Kempermann & Lichtblau, 2014). In addition to opportunities, Industry 4.0 also brings a wide range of challenges and risks that need to be examined in equal degree. This is of fundamental importance for the successful implementation of Industry 4.0. The question how to establish new technologies poses complex tasks for both researchers and practitioners alike. Many different perspectives on Industry 4.0 are reflected in the numerous definitions that can be found in literature (Bauer et al., 2014). The difficulties outlined so far are mostly of a technological and company-related nature. However, Industry 4.0 also affects entire ecosystems and companies across value chains. The previous discussion of Industry 4.0 in the literature, requires further economic consideration and categorization of the challenges of Industry 4.0. Based on this, the following research question will be answered in this study:
What challenges and risks does Industry 4.0 expose and how can the scientific literature be categorized to meet these challenges?
The objective of this study is to present and analyze the state of research as for challenges and risks of Industry 4.0 using a systematic literature analysis. Within the framework of the categorization of challenges, economic, legal and human implications of the topic are considered and discussed in addition to technical aspects, such as IT security. On the basis of the results, space for further research and implications for corporate practice are provided.

THEORETICAL BACKGROUND

About the current fourth industrial revolution, better known in German-speaking countries under the synonym.

Definition of Industry 4.0

Industry 4.0, internationally also known as the Industrial Internet of Things (IIoT), refers back to a forcasted fourth industrial revolution (Bauer et al., 2014). The term Industry 4.0 was established in January 2011 by the Forschungsunion Wirtschaft-Wissenschaft. Industry 4.0 combines current trends in information and communication technology (ICT) with industrial production systems (Ramsauer, 2013). Along with a further development of information and communication technologies, powerful and cost-effective measuring and drive elements are available in production-related applications (Spath et al., 2013). Industry 4.0 leads to progressive and comprehensive transformation processes, especially in the industrial production area, but also in further parts of the value creation chain such as logistics. Human-machine interactions change the way of work in production areas and creates a cooperative environment characterized by virtual collaboration (Kagermann, Wahlster & Helbig, 2013). The optimization of production based on a comprehensive integration of people, e.g. employees, and technologies makes production and logistic processes more flexible. This flexibility eases value creation processes and allows to create new data-driven and platform-based business models (Spath et al., 2013).
This study uses the definition of Bauer et al. (2014) stating that Industry 4.0 focuses on real-time, intelligent, horizontal and vertical connectivity of people, machines, objects and ICT systems for the dynamic management of complex systems.

Categorizations of Industry 4.0 challenges in literature

According to Rose, Eldridge and Chapin (2015), five challenges arise in connection with the industrial application of Industry 4.0. These include security, data protection, interoperability and standards, and legal and regulatory issues. Security concerns in connection with information technology are not new, but technological changes lead to new unique security requirements. Due to the constantly growing number of connected devices, possibilities to attack increases with the amount of heterogeneous data (Rose et

al., 2015). Potential concerns about the security of data can impede the implementation of technologies (Rose et al., 2015). A lack of standardization and interoperability between different systems reduce the end-user value. Standards and reference models for the implementation can reduce complexity in general, and in addition prevent strong dependence on individual technology providers. Rapidly changing technologies create new legal issues and challenges, such as protection of intellectual property andliability issues. The cross-company exchange of data poses risks in terms of data protection. Further, problems arise in case of data breakdowns (Rose et al., 2015).
Thoben, Wiesner and Wuest (2017) define three main categories of Industry 4.0 challenges. The authors subdivide challenges into technical and methodological problems and business challenges. The technical problems include norms and standards that become necessary due to different systems. The standards ensure interoperability of technologies, since several companies cooperate being interconnected in the value chain. In addition to data security, the quality of the heterogeneous data collected by sensors is crucial.The methodology includes necessary reference models for the description of different complex application models for the implementation. Companies need a structured requirements management and common definitions in order to successfully implement digitization projects in the areas of production and logistics. The business challenges of Industry 4.0, the third category, are divided into data protection problems, investment risks, and service-based business models. In addition to data protection, information security describes the technical possibility of protecting sensitive data (Thoben et al., 2017).

METHODOLOGY

A systematic literature review is chosen to analyze the existing literature as for challenges and risks of Industry 4.0. The chosen methodology allows a comprehensive presentation, synthesis, and analysis of the state of research (Tranfield, Denyer & Smart, 2003). The five individual steps of the systematic literature review described in the following sections are based on the study of Kiel (2017).

Selection of the period

The start of the period was set for January 2010, as this covered the literature that already deals with corresponding topics before Industry 4.0 was defined. In order to present the most recent state of knowledge on the challenges of Industry 4.0, November 2018 was chosen as an end point. Thus, the literature review includes publications published during eight years.

Selection of scientific databases

As is common in research practice, selected databases to search for literature include Scopus, Web of Science Core Collection, EBSCO Business Source Complete and ABI/Inform. These have been selected in order to identify specific and current literature on the challenges of Industry 4.0.

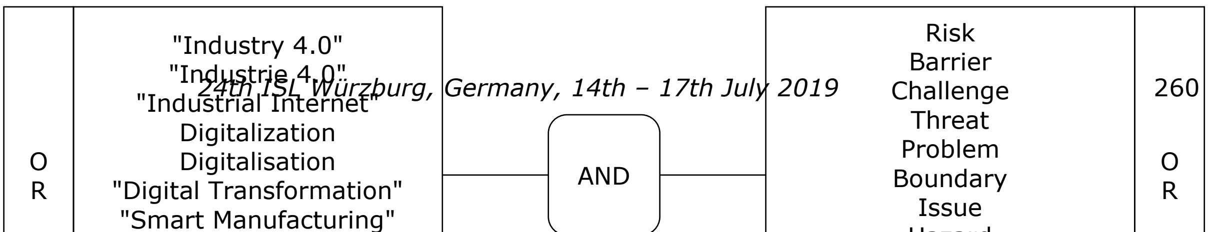
Selection of the relevant publication types

Publications in scientific journals and specialist journals, book chapters in anthologies and conference contributions were considered as relevant forms of publication (Kiel, 2017). As far as scientific journals and specialist journals are concerned, only peer reviewed publications were included in this study. This ensures high academic quality publications and improves the results.

Selection of articles

As a first step, thematically relevant keywords for systematically searching in the scientific databases were defined. Figure 1 present selected keywords that are based on trends and the state of the art in research on Industry 4.0. These were linked with various synonyms of challenge and risk to form a search string. This allows to identify publications that are relevant in content. With the exception of the German term "Industrie 4.0", English terms were exclusively chosen as keywords.

Figure 1: Combination of keywords in a search string

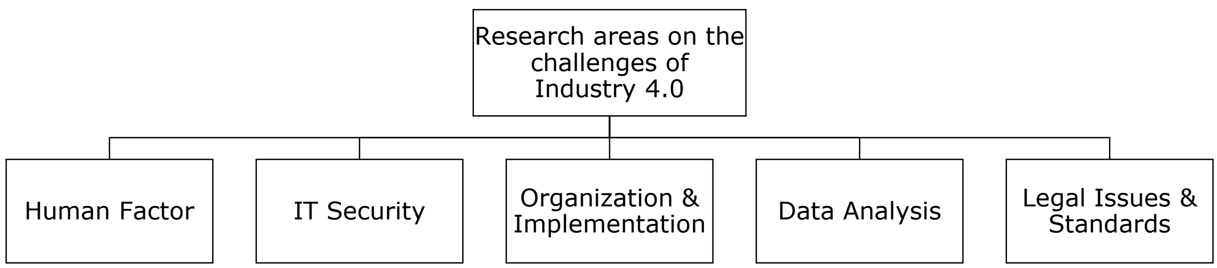


The left column contains keywords related to Industry 4.0 and similar designations. The right column contains terms related to the word categories risk and challenge. The OR and AND search operators link the two components. Thus, the final sample included only publications that contain both one of the Industry 4.0 terms and a synonym for risk or challenge, e.g., "Smart Factory" and "Challenge". After the pre-selection, articles are further excluded, for instance, if they are not relevant for the topic or if they had less than five pages. A total of 69 relevant articles could be identified by the systematic search.

Categorization and analysis of articles

Hereafter, individual publications were classified into categories for further analysis and discussion. The articles can be aggregated into the categories human factor, IT security, organization and implementation, data analysis, and legal issues and standards (compare Figure 2). The categories reflect similarities in scope and content of the individual articles.

Figure 2: Categorization of relevant publications



Source: own illustration

FINDINGS

The challenges are compared with each other and discussed contents and concepts are shown in the following.

Category 1: human factor

The progress made by Industry 4.0 and the vision of fully automated production systems do not only change production technologies and processes within the value creation chain, but also place people in a new context. For instance, this does not only create new requirements for employees in the production environment, but also poses far-reaching challenges as for the transformation of competencies and has the potential to reshape entire labour markets (Johansson et al., 2017). The English term "operator 4.0" summarizes changes in the manufacturing and logistics environment that affect humans. It describes a new generation of well-trained, rationally acting skilled workers who cooperate with machines in the context of Industry 4.0 (Garrido-Hidalgo et al., 2018).
These changes in the framework conditions result in new challenges for the qualification of employees. Above all, a technical understanding is required, but qualifications should not be limited to this aspect. Modern work requires interdisciplinary skills and the ability to integrate oneself into production and logistic processes (Simons, Abé & Neser, 2017).

The way people and machines work together within and across organizations, e.g., in cloud environments, blurres boundaries of separate processes. An awareness of the opportunities and safety of Industry 4.0 must be created to enable people to work efficiently with each other and collaborate with machines, and to increase the acceptance of new technologies (Robla-Gomez et al., 2017). These developments require new, comprehensive approaches to further develop employees and qualify them for Industry 4.0 (Chen, Chen & Hsu, 2014). Amladi (2017) describes that companies experience problems meeting the need for skilled workers and retain existing skilled workers. According to the author, this shortage will continue to increase in the future.

Eichhorst et al. (2017) list the increasing polarization of labour markets in industrialized nations as the first effect of the risk of automation. The number of jobs requiring medium qualifications is declining, whereas the number of jobs for highly qualified skilled workers and low-skilled assistants is increasing. In addition, the increasing flexibilization of the value chain also flexibalize labour markets, e.g., through fixed-term employment, temporary employment, and freelance work.

Category 2: IT security

Interconnection and digitization enable systems to control decisions and processes in real time, which results in enormous amounts of data that have to be managed properly. An increasing complexity and connectivity require a higher need for security. In turn, this implies requirements for the confidentiality, integrity and availability of data, and the security of systems (Mozzaquatro, Agostinho, Goncalves, Martins & Jardim-Goncalves, 2018). According to Engels (2017), companies are reluctant to implement cloud applications due to uncertainty about data security and increasing cyber crime.

To minimize cyber risks, companies are asked to implement and use an effective and comprehensive IT security management system (Tuptuk & Hailes, 2018). According to Barreto, Amaral and Pereira (2017), companies tend to implement new technologies without considering security vulnerabilities if technologies provide sufficient benefits in spite of being potentially insecure. The responsibilities ans tasks of IT security management systems change from protecting large computer systems to protecting entire production systems and value creation networks. Following Tuptuk and Hailes (2018), companies are not aware of major differences, such as high number of heterogeneous objects or the durability of the systems, which often create vulnerabilities in the system. Organizations lack knowledge in how to securely design value creation processes in Industry 4.0. Therefore, awareness should be expanded within the company and knowledge has to be built up to protect property assets (Mozzaquatro et al., 2018). Due variety of available protective measures and control mechanisms, it is important to balance costs and benefits in order to find an individual security solution (Häckel, Hänsch, Hertel & Übelhör, 2018). The importance of IT security is emphasized by the fact that digitalization and interconnection pave the way for large value creation systems that can be destabilized by inadequate security (Healey, 2016).

Category 3: organization and implementation

As for the organization and implementation of Industry 4.0, the literature divides challenges into the following three areas: technological obstacles for implementation, changes in the organizational structure or business processes of companies, and economic challenges.

Both vertical and horizontal integration pose major problems for companies in terms of technical implementation. The vertical integration of different companys and corporate functions does only succeed if data is available throughout the entire system, as this represents the only way to ensure real-time flexibility and transparency in production and logistic processes (Müller, Kiel & Voigt, 2018). An additional horizontal interconnection and integration of the upstream and downstream stages of the value chain reinforce this effect. However, companies are becoming more and more dependent on the respective hubs of connectivity. An unplanned breakdown or unscheduled maintenance of key technologies thus has the potential to harm the entire value chain’s efficiency (Fernandez-Carames & Fraga-Lamas, 2018).

The implementation of technologies and the transformation towards smart factories, result in considerable costs. A further problem is that employees do not share a homogeneous vision for the concepts due to different ideas and definitions. However, a uniform vision is of fundamental importance for a successful implementation (Sjödin, Parida, Leksell, & Petrovic, 2018).
The implementation of Industry 4.0 is associated with high uncertainty. This is especially true, as not only the overall complexity of value creation and technologies increases, but also the economic complexity (Magruk, 2016). In addition to the investment, there are further follow-up costs, such as the qualification of employees or IT security (Engels, 2017). The planned return on investment should advice to introduce new technologies, whereby analytical consideration of the requirements and opportunities in addition to investment risks form the basis for the calculation (Illa & Padhi, 2018).

Category 4: data analysis
In addition to real-time availability, Ji et al. (2016) emphasize difficulties steeming from the characteristics of the data masses generated by different objects and systems. Different systems generate different data types, which in turn leads to strong data heterogeneity. Aside from new, digitized applications, there are also older applications and structures in the company that generate data. Thus, heterogeneous data from different sources must be managed within the data analysis (Ji et al., 2016). Data should be selected by relevance and quality to provide accurate and high-quality data for reliable cloud based analysis (Jiang, Yin & Kaynak, 2018).
An automated analysis results in different application areas for the interpreted data. For example, it is possible that decisions can be made autonomously or processes can be controlled on the basis of these data. Wang et al. (2016) illustrate the importance of production-related application, because data generated during the production process can comprehensively be analyzed using cloud technologies. The vulnerability of processes due to inadequate analyses can be reduced when developing adaptive and learning control systems (Jiang et al., 2018). Especially with the support of artificial intelligence, e.g., by using machine learning, processes can be stabilized. However, it is difficult to implement artificial intelligence for analysis purposes and to interpret results accordingly (Wuest et al., 2016).

Category 5: legal issues and standards
Popescul and Georgescu (2013) address the importance of data protection for society and consumers in terms of business ethics. As a solution to the data protection problem, the authors propose regulations for technical solutions. Further aspects include economic policy or social approaches such as certifications and improved consumer (Popescul & Georgescu, 2013). The cooperation of different companies in a value creation chain creates new challenges with regard to contractual framework conditions. These include the cooperation itself, but also the responsibilities for data protection and liability issues. The same does also apply to international cooperation and cross-border data traffic (Hornung, 2017). Based on these new fundamentals, trust can be created between companies and thus previous cooperation obstacles can be reduced (Saniuk & Saniuk, 2018). In summary, Bonilla, Silva, Terra da Silva, Franco Gonçalves and Sacomano (2018) state that the long-term implications of Industry 4.0 are influenced by social reactions, legal framework conditions and political decisions. In order to implement Industry 4.0 globally and sustainably, technologies should be homogeneously distributed internationally in order to avoid inequalities between companies and economies (Bonilla et al., 2018).

CONCLUSION AND VALUE

Technological progress and the transformation of industrial value creation in the context of Industry 4.0 reshape companies and economies. New possibilities through interconnection within a value creation chain bring promising opportunities and potentials. However, associated challenges and risks must also be examined as well. The aim of the present study was to present and analyze the current state of research based on a systematic literature review. In the course of the study, 69 articles from the period 2010 to 2018 were identified. Following the study's results, challenges and risks of Industry 4.0

can be divided into five categories: Human factor, IT security, organization and implementation, data analysis and legal issues and standards.
The human factor is discussed by 17 articles representing the most important aspect. Literature emphasizes that the human factor and the work environment evolve just like technologies. The qualification of people focuses on interdisciplinary and creative ways of thinking and competences. Companies need new approaches to qualify employees and strengthen the acceptance of changes. In the field of IT security (n=15), the authors indicate that companies increasingly become a potential target of cyber crime. In addition, the demands on IT security also increase due to extensive interconnectivity and cloud applications. According to the literature, characteristics such as confidentiality, availability and integrity of data and systems must be considered decisive factors in implementation and security management. For the category organization and implementation (n=14), the results are subdivided into technological, structural, process-related, and economic challenges. Thus, the selection of hardware and software, a fusion of the virtual and real worlds, and vertical and horizontal integration lead to challenges from a technical point of view. Successful implementation requires adjustments as for processes and organizational structure. With regard to the economic aspects of Industry 4.0, the literature highlights the difficulty of changing business models in addition to investment decisions under uncertainty. In data analysis (n=12), companies face the challenge of using heterogeneous data from different sources for real-time-based evaluation and finally for the automated optimization of processes. Literature describes that data analysis must be organizationally anchored in a company to optimize information-driven decisions based on relevant and high-quality data. Integrating data analyses into existing business practices and processes represents a critical success factor in the future. In the last category, legal issues and standards (n=11), the literature concludes that a smooth integration and thus system implementation is hampered by a lack of internationally valid norms and standards. The authors describe that through international cooperation and uniform reference models the complexity of the systems can be controlled. In addition, technological progress calls to act and further develop legal framework conditions for system security and data protection. Companies need new contractual bases that enable international cooperation in the value creation chain.

Research and practical implications

This study contributes to research determining the state of research on the challenges of Industry 4.0 and further categorizing the challenges. The results add value for the academic discussion as for opportunities and challenges of Industry 4.0. The discussion can be continued assigning and further examining emerging problems. The approach of the present study can be used as a starting point for future, in-depth qualitative and quantitative research studies.
Companies and practitioners benefit from the results, as challenges are highlighted in the context of Industry 4.0 that may also be referenced to individual companies in corporate practice. Using the comprehensive illustration of challenges, companies can understand them at an early stage and address those applying several measures. This allows cost potentials to be realized during implementation.

Limitations and further research

Due to the requirement that articles relevant to the study can be accessed free of charge via the university licenses, it remains unanswered whether publications that are relevant but not accessible via the licenses could also have contributed to the results of the present study. It should also be noted that in order to increase the number of analysed articles, further databases could be used. Furthermore, it must be admitted that the article selection and the classification is based on a certain subjective assessment.
In order to determine the need for further research on the challenges of industry 4.0 and their implications for businesses, the results of the study provide a basis for future investigations. Thus, within the framework of the systematic literature review, further specific investigations of the individual categories are suggested. Expert interviews or surveys of enterprises may be a next step to further analyse to what extent enterprises

already recognize challenges of Industry 4.0. Based on further research, best practices can be developed for the successful implementation and management of Industry 4.0.

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AN INSTANT RESPONSE MOTORCYCLE PICK-UP SERVICE MODEL FOR PHYSICAL RETAILING STORE COMBINED E-COMMERCE ON BUSINESS AREAS

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Abstract
Purpose of this paper
This study is a manpower assignment and route planning problem. It can be regarded as an extension of the vehicle route problem under the consideration of capacity limitation. The purpose is to assign the personnel to pick up the goods in the business district to arrive at the store for immediate response. Pick-up service to speed up the pick-up efficiency of goods in the first mile. The motorcycles are used as agents to shared manpower to shorten the time from store pick up to the collection center. This study establishes a logistic system for local retail store in the business district improve their business using e-commerce business model.

Design/methodology/approach
Through the first mile pick-up system in a business circle, the quick reaction motorcycle pick-up service model of the retail store in the business district is combined with e-commerce function. Under the limitation of the motorcycle loading capacity, the minimum total pick-up route cost is pursued. aims. The combination optimization problem in the model is solved by Genetic Algorithms (GA).

Findings
In this paper, through the evolution of the Genetic algorithm for 5000 rounds, the algorithm can reach the approximate optimal solution of the minimum total pick-up route cost. This study shows that this model would be an effective solution to the pick-up in the business circle route planning for cargo problems.

Value
The logistics business model proposed provides independent operation of agents a tool to assign the picking work of shared manpower, to plan the route of picking up the goods. The logistics industry can use this model to assign multiple motorcycle pick-up service to deal with instant responses to achieve the minimum total cost. The business district manager can apply the model to reduce the cost for retail stores as well as to improve the pick-up service.

Introduction

In addition to the fierce price competition and low gross profit, the most important factor in the current retail business is labor costs. The use of manpower must be more compact, especially for physical retail stores in the business district. The consumption pattern of the business district tends to be multi-item, multi-frequency, small-volume product characteristics, and the customer's expectation of the delivery speed of the goods. When the store has the demand for real-time pick-up, it is impossible to hire a full-time job due to the cost. The cargo clerk and the vehicles entering the small business district are likely to cause inconveniences to the traffic and the parking. If the business is handed over to a professional pick-up staff, the manpower burden and the shortage of manpower can be saved. According to the statistics report of the Ministry of Economic Affairs (2019), the operating income of the retail industry has increased yearly. With the rapid growth of the online shopping market in recent years, the growth of the non-storefront retail industry in the retail industry has been increasing yearly, and has been growing for 10 consecutive years. The main force is the 70% electronic shopping industry, with an average annual growth of 7.4. %. Therefore, it is possible to combine the purchase method of e-commerce (hereinafter referred to as e-commerce) with the operation mode of the physical store. It can not only increase the income of the physical store to reduce the operating cost, but also reduce the distrust caused by the customer's usual purchase of goods through the e-commerce.

At the dawn of new retail, it is no longer just e-commerce, but further contact with customers to provide more appropriate service and convenient shopping experience. In response to the shift in consumption habits, real-time logistics that solves the needs of the public for dining, shopping, etc. is booming. The new retail era brings opportunities for real-time logistics development, combining online and offline delivery for one hour or even shorter delivery. Instant logistics services are also indispensable. The initial real-time logistics distribution service came from food and beverage take-out. When customers demanded more and more distribution in their lives, the service began to extend from take-away to fresh-skinned fruits and vegetables, drugs, or daily necessities.

At present, under the competition of various retail industries, real-time logistics has become a trend of current operation, and it is also in response to customers' new forms of consumer demand, in order to achieve customers' expectations and needs in the new retail era. Instant logistics has the characteristics of short distance, high frequency and high aging requirements. If it is delivered by truck, it cannot meet the immediate distribution demand. In order to increase the loading space of goods, logistics operators usually use trucks for distribution. Since trucks are difficult to park in the business district and traffic jams are easy to enter and exit, trucks cannot achieve immediate service when the distribution demand is made, and the time and cost are required. Also higher. In order to save time and increase the immediacy and multi-frequency of picking up at the store, the use of highly mobile motorcycles is relatively economical for transportation.

Literature Review

At present, in the process of new retail development, the real-time logistics service provided to meet the needs of customers uses the tools that can be successfully delivered. The rise of e-commerce and changes in customer habits have led to changes in the demand for instant delivery, which accounts for 2.5% of all shipments in major European cities to provide personal delivery within two hours (Morganti, Arvidsson, Woxenius, Browne & Saidi, 2017). Joerss, Schröder, Neuhaus, Klink and Mann (2016) indicate that 25% of customers are willing to pay a high fee for the day or instant delivery service. In addition, Morganti et al. (2017) show that bicycles and motorcycles are more suitable for distribution services in the city, and their cargo capacity is relatively small but more mobile. Due to the different traffic environment in Taiwan and the narrow roadway in some urban areas, in response to this problem, logistics operators use motorcycles with high mobility but small cargo capacity to distribute, making motorcycle distribution of small commodities more economical (He, 2007; Li, 2016)

However, the solution to the urban logistics problem is to use the city's integrated center to reduce the number of freight vehicles circulating in the city. The last shipment is usually

carried out by small and environmentally friendly vehicles (Letnik, Farina, Mencinger, Lupi & Božičnik, 2018). Urban distribution is mainly dependent on the manpower of the dispatcher. The design of the distribution route is not considered, and there are repeated intersections, resulting in long time-consuming distribution and waste of resources, which affects the efficiency of the final distribution (Baofeng, 2018). The short-distance distribution service in the physical store has gradually developed into an independent professional industry, which achieves a large distribution scale by common distribution, and at the same time improves vehicle utilization and effectively alleviates urban traffic congestion (Yu, Xing, Qiao, Xiong, Zhao Cong, 2017).
The physical retail store in the commercial circle proposed in this study combines the real-time response motorcycle pick-up model of e-commerce for manpower assignment and route planning. Considering the relevant limitations of motorcycle capacity, it is also called Vehicle Routing Problem (Vehicle Routing Problem, VRP). According to the characteristics of the problem of this study, it is considered to be an extension of the problem of the vehicle, which belongs to the NP-hard problem. Therefore, the heuristic algorithm is used to solve the problem to reduce the calculation time. There are many heuristic algorithms for solving VRP, and heuristic algorithms can be divided into traditional heuristic algorithms and universal heuristic algorithms.

Research Methodology

This study provides a service that meets the needs of customers by using the real-time reaction motorcycle pick-up service mode of the physical retail store in the business district. The agent uses the motorcycle as a substitute for the logistics provider to go to the store for immediate response. The goods service, and then the goods are sent to the collection center, which can effectively solve the problem of the first mile in the business circle. When picking up a service in a specific business district, the pick-up range is fixed, providing a short-time, small-volume pick-up service, showing the shipping characteristics for immediate response. The main problems that must be encountered and must be overcome during the picking process include:

1. the use of shared manpower, so the location of each picker is different from the store location;
2. the number of pick-ups for each store is more than the number of pick-ups assigned to the store;
3. the picking process must consider both the capacity limit of the motorcycle and whether it can be placed in different sizes;
4. each picker can receive multiple goods without exceeding the capacity limit;
5. each pick-up person goes to a number of stores to pick up the route planning.

After the above-mentioned integration, the study is a manpower assignment and route planning problem. The combination of the pick-up route increases as the number of pick-ups increases, which makes the difficulty of picking up the goods more difficult and the solution time is relatively long. It is a combination optimization problem. In order to meet the accuracy requirements in the calculation process, the genetic algorithm in the heuristic solution method is used to overcome the above difficulties in the picking process, thereby providing an effective pick-up route to reduce the cost of picking up.

c_{ij} : the unit distance cost for arc (i,j)

x_{ijklm} : if picker k is assigned to (i,j) to pick m goods of type, then this variable is 1, otherwise, 0.

a_k : the pick-up amount of picker k

$\bar{a}_k$: the capacity of picker k

ρ_l : the equivalent of capacity for type l goods.

Q_i : the total capacity at node i

QC : the sum of all capacities

L : set of goods type

M : set of goods

K : set of pickers

N : set of nodes

S : the collection center

The following is a mathematical formula：

$$\min Z = \sum_{i \in N} \sum_{j \in N} \sum_{k \in X} \sum_{l \in L} \sum_{m \in M} c_{ij} \cdot x_{ijklm} \tag{1}$$

Equation (1) is the goal of pursuing the minimum total path cost

s.t. $$\sum_{i \in N} x_{ijklm} \leq 1 \qquad \forall j \in N, \ \forall k \in K, \ \forall l \in L, \ \forall m \in M \tag{3.2}$$

Equation (2) shows the assignment for each picker will not be double assigned.

$$\sum_{k \in K} x_{ijklm} \leq K \qquad \forall i, j \in N, \ \forall l \in L, \ \forall m \in M \tag{3.3}$$

Equation (3) shows the total pickers assigned should be less than the total available pickers.

$$\sum_{j \in N} x_{ijklm} - \sum_{i \in N} x_{ijklm} = \begin{cases} 1 \\ 0 \\ -1 \end{cases} \qquad \forall k \in K, \ \forall l \in L, \ \forall m \in M \tag{3.4}$$

Equation (4) present the flow conservation constraints for pick-up node, transhipment nodes, and the collection center.

$$\sum_{i \in N} \sum_{l \in L} \sum_{m \in M} \rho_l \cdot x_{ijklm} = Q_i \qquad \forall j \in N, \ \forall k \in K \tag{3.5}$$

Equation (5) presents the total capacity constraint at node i。

$$\sum_{l \in L} \sum_{m \in M} \rho_l \cdot x_{ijklm} = QC \qquad \forall i, j \in N, \ \forall k \in K \tag{3.6}$$

Equation (6) is to ensure that the total goods to pick-up equals to total amount.

$$\sum_{j\in N}\sum_{l\in L}\rho_l \cdot x_{ijklm} - \sum_{i\in N}\sum_{l\in L}\rho_l \cdot x_{ijklm} = a_k \qquad \forall k\in K,\ \ \forall m\in M \tag{3.7}$$

Equation (7) presents the number of goods pick up by picker k.

$$a_k \le \bar{a}_k \tag{3.8}$$

Equation (8) presents the pick-up capacity for picker k.

$$\sum_{j\in N} x_{ijklm} = k \qquad j\in S,\ \ \forall i\in N,\ \ \forall k\in K,\ \ \forall m\in M,\ \ \forall l\in L \tag{3.9}$$

Equation (9) to ensure all the pickers will end up to the collection center.

$$\forall x_{ijklm} \in \{0,1\} \tag{3.10}$$

Equation (10) is to set x_{ijklm} as binary variables.

After the model is established, the gene algorithm is used to solve the route planning problem of the pick-up staff picking up the goods in the physical retail store in the commercial circle, and the best pick-up route is planned in the case where the shop without demand does not need to go to pick up the goods' order. The algorithm first converts the possible solution of the problem into a genotype by means of coding, and then uses the fitness function to evaluate the pros and cons of the chromosomes in the population, and determines the adaptation value for reproduction, crossover and mutation. The three main operators are repeated to perform the operation until the termination condition is met, and the operation is stopped to find the best solution to the problem. According to the characteristics of the problem of this study, the permutation coding is firstly used to solve the problem, which is most effective for the combination optimization problem. The most important thing to solve the combination optimization problem is to find the optimal permutation or combination that satisfies the constraint conditions. Such problems are the most effective method (Xuan and Cheng, 2004).

Results

Based on the characteristics of the pick-up problem in the business district, the physical retail store in the business district of Ximen Town, Taipei City was selected as the test case. The street distance between two points in Google Maps was used to mark the business district in Ximending. This study assumed that here are 50 physical retail stores, 100 available manpower around the business circle, and one collection center. Therefore, there are 151 nodes and 7601 round-trip routes.

Through the travel distance from the pick-up to the store, between the store and the store, and from the store to the collection center, as the test data of this study, the instant response motorcycle pick-up service for the physical retail store in the business district combined with e-commerce is setup. The model is tested numerically, analysed, and compared according to the test results.

In this study, at most 1-3 goods at each pick-up point need to be sent to the collection center. The cargo capacity is different, and can be divided into three types: large, medium and small, of which 25 are large goods and 30 are medium goods. There are 45 small-sized goods, and a total of 100 goods are distributed in retail stores in the Ximending business district. Note that, by sharing the manpower and considering that before the pick-up route planning, it is impossible to pre-locate the pick-up person and predict where and how many of goods should be picked up.

The result of the minimum total pick-up route cost calculated by the model and the pick-up route of the pick-up personnel respectively, only 56 pickers fully apply their own motorcycle loading capacity, and meet the load capacity of 1. Under the restriction of the conditions, 100 items of goods in the store with pick-up requirements are sent to the collection center. After 5000 rounds of computing the gene evolution generation algebra, the shortest pick-up distance for the route planning can be found to be 103.21 kilometres to complete the work of picking up the goods from the store to the collection center. Figure 1 shows the results of the evolutionary generation of the genetic algorithm, the shortest total pickup distance is 103.21 km in the evolutionary generation of the genetic evolution to the 3039th round, which is the best in the 5000 rounds of the evolutionary generation. The results of the 5000 rounds of the genetic evolution generation are analysed and compared as shown in Table 1 and Figure 2.

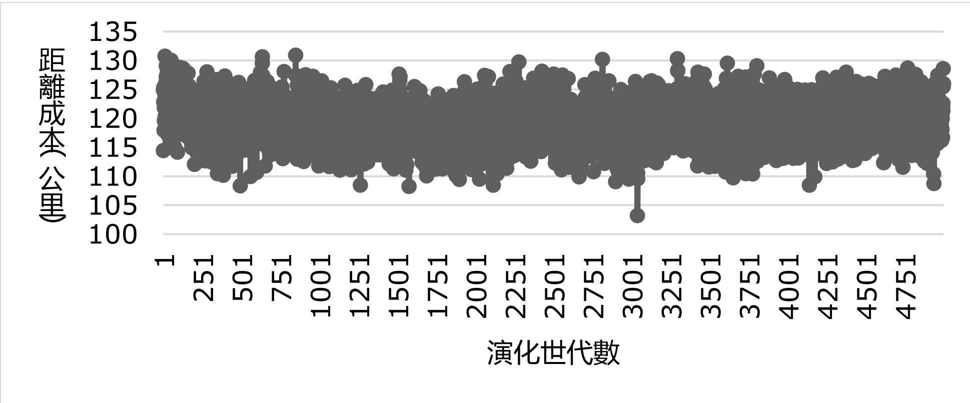

Fig. 1 The results of the 5000 rounds of the genetic evolution generation

Table 1. Ten rounds of results of the 5000 rounds of the genetic evolution generation

Rounds	Max route cost(km)	Min route cost(km)	The different rates of min route cost(%)	Computing time (sec)
1	132.19	107.40	0.42	183.46
2	132.47	107.10	0.70	173.53
3	134.60	106.78	1.00	166.89
4	134.76	106.38	1.38	171.07
5	133.75	107.85	0.00	173.85
6	132.94	106.95	0.84	173.35
7	130.26	105.94	1.80	172.06
8	129.28	105.38	2.34	174.01
9	130.89	103.21	4.50	137.85
10	131.57	105.56	2.17	174.65

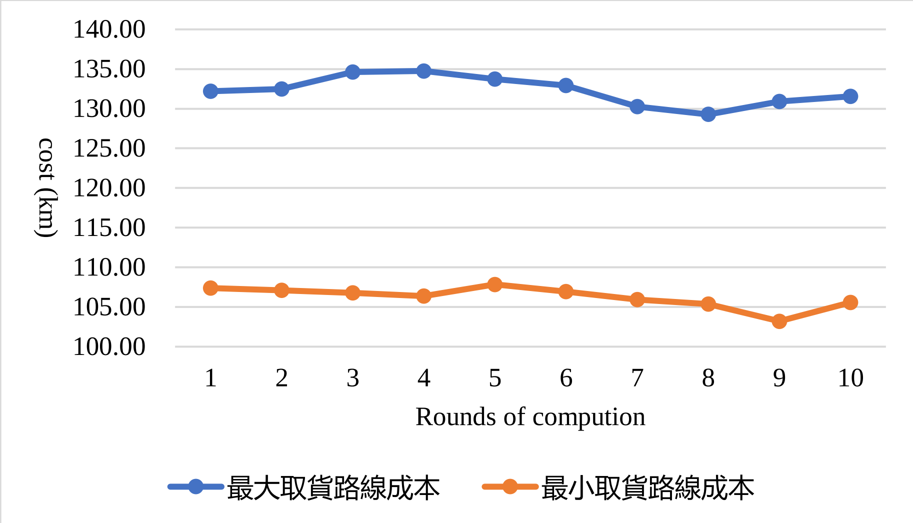

Fig. 2 Cost Comparison for Ten rounds of results

Finally, in order to verify the test results of the algorithm for the study, it can be seen from Table 1 that the model of this study is calculated for 10 rounds of 10 genetic evolution generations, and the model solution time is between 137 and 188 seconds to obtain the minimum total pick-up route cost. The minimum total pick-up route cost is between 103.21 km and 107.85 km, and the ratio of the minimum cost of the smallest total pick-up route through the calculation of 10 times, and the ratio of the cost of each other minimum pick-up route is 0% to 4.5% range. In Figure 2, in the 5000 rounds of calculation of 10 genetic evolution generations, the total cost of the retrieved route is reduced, and the minimum total pick-up route cost falls into the approximate optimal solution area. In the results of the 5000 rounds of the generation, the total cost of the shortest total pick-up route was 103.21 kilometres to complete the work of picking up the goods to the collection center. It shows the reliability of the gene algorithm in each calculation and through multiple gene iterations. The operation can effectively solve the approximate optimal solution to prove the accuracy and stability of the algorithm.

Discussion and Conclusions

The main purpose of this study is to explore the current operating environment and difficulties of physical retail stores in the business district, and to combine the trends led by the future retail industry in a timely manner, in line with the additional restrictions of the pick-up staff's use of motorcycle capacity limits. Based on the development and establishment of the model, the real-time reaction motorcycle pick-up service model of the e-commerce in the commercial circle under the loading capacity limitation of motorcycles is analysed, and the corresponding algorithm is developed and tested by numerical examples. To verify the correctness of the model solution and to demonstrate its characteristics. This study can draw the following conclusions on the results of the model:

1. This study is aimed at the operational mode of the physical retail store in the business district. In order to demonstrate the practical needs, it solves the priority order of the pick-ups to choose to go to the store to pick up the goods, and also reflects that the pick-up staff must go to the pick-up demand. The store picks up the goods.
2. Through the numerical analysis of the test data used in this study, by planning the route planning of multiple pick-ups to pick up the goods, it is shown that each pick-up can meet the capacity limit that the motorcycle can carry and take The size of the cargo capacity.
3. The study of the pick-up route planning and the size of the cargo capacity, with the relevant pick-up requirements personnel or agents and other managers in the planning of the use of the potential of the route, the route planning for picking.
4. The contribution of this study is to consider the impact of new retail sales in the

business circle while facing reforms. Proposing appropriate business models for physical retail stores in the business circle will help improve the development of physical retail stores. For the operation mode of the physical retail store in the business district, a pick-up service model is established, and the motorcycle is used as a transport tool to solve the problem and demand of the business circle.

In addition to the above research conclusions, based on the discussion of the motorcycle pick-up service model of the pick-up capacity limit, there is still much room for development pending further research. In the future, it is possible to consider the conditions such as the time limit of the store that has the pick-up demand, so as to appropriately describe the actual pick-up situation and include the time window limit for arriving at the store pick-up time.

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IMPLEMENTATION CHALLENGES OF BLOCKCHAIN IN SUPPLY CHAINS IN THE CONTEXT OF INDIAN

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Purpose
Blockchain is considered as a disruptive technology that has the potential to revolutionise the future businesses. It offers end-to-end transparency benefits by protecting digital record from deletion, tampering, and revision along the supply chain. It is expected that the world-wide spending on blockchain solutions to reach US$11.7billion by 2022 from US$0.95billion in 2017 (Statista, 2018). Although it appears the application of this technology is gaining momentum, organisations, however, are facing challenges in implementing the blockchain technology. Developing prior knowledge on challenges will facilitate the successful implementation of blockchain. The aim of the research is to identify and prioritise the implementation challenges of blockchain in supply chains.

Design/methodology/approach
Through literature review this study develops a conceptual framework by extending TOE (technology, organisational-context, and external environment) framework with the addition of inter-organisational relationships as a challenge-category of implementing blockchain technology in supply chains. A total of sixteen challenges are identified from the literature which is grouped under four challenge-categories. To prioritise critical implementation challenges, analytical hierarchy process (AHP) method is employed in this study. A two-part questionnaire with organisation and respondent demographic questions in one part and AHP comparison scale on challenges and challenge-categories in the second part is used to conduct interview with technology provider, consulting firm, and industry partner. Expert choice® software is used to calculate the priority weights of challenges and challenge-categories of blockchain technology implementation in supply chains.

Findings
Results indicate that organisational-context challenge-category is identified as the most critical challenge-category, followed by technology challenge-category in implementing blockchain technology in supply chains. On the other hand, external environment and inter-organisational relationships challenge-category are less critical in blockchain technology implementation. At challenge level complexity, financial resources, and top management support are considered as the top critical challenges.

Value
This research is an initial attempt to identify and develop a framework on the challenges in the implementation of blockchain technology in supply chains. By empirically examining the developed challenge framework in the Indian context, this research provides an explanation on how the framework can be used in future studies.

Research limitations/implications
This study investigates the blockchain implementation challenges in Indian context, so the results may not be generalised to other nations.

Practical Contribution
Insights into challenges and their criticality help organisations to develop strategies to assist in addressing the challenges and facilitates in their decision-making of the implementation of blockchain technology in supply chain

1.0 Introduction

The blockchain technology is considered as a disruptive technology that can revolutionise the businesses. Since its introduction in 2009, the technology has slowly build-up over the past several years and came to public notice in 2015. Since then several firms have started to experiment with the technology by creating proofs of concept while others have started using the technology (Marketline, 2018). As firms started using blockchain the market for the technology has been growing steadily and is expected to grow to US$ 11.7 billion by 2022 from US$ 0.95 billion in 2017 (Statista, 2018).

Despite the predicted increase in blockchain technology usage, its implementation is considered as an ambitious challenge. At this stage, the technology is still far from maturity with many challenges to overcome before it can achieve main stream adoption in all industries (Delloit, 2018). Developing prior knowledge on the challenges will facilitate the successful implementation of this technology. Although, many consulting firms such as KPMG, PWC, Deloitte, and IBM have identified various implementation challenges of blockchain technology, however, no one have attempted to prioritise these challenges. Furthermore, there is no prior academic research that have investigated the challenges comprehensively by using empirical data. Therefore, the aim of the research is to identify and prioritise the implementation challenges of blockchain technology in supply chains.

The rest of the paper is organised as follows. Following the introduction in section 1, background about blockchain technology and its application in Indian context is presented in section 2. Through literature review on technology implementation in supply chains, a conceptual framework is proposed in section 3. Section 4 presents research methodology adopted in this study to identify critical challenges. Results and analysis and discussion from the results is provided in section 5 and 6 respectively. Finally, section 7 concludes the paper with implications and future research area.

2.0 Background

2.1 Blockchain technology

Blockchain is a disruptive technology that revolutionised the way the transactions are recorded and stored on a decentralised network than a traditional centralised network. As Blockchain store information in multiple locations, it has obvious benefits such as public access (Kamble et al., 2019). Decentralised network of blockchain is a secured system that protects the identity of its users and the stored transactions. Moreover, blockchain brings highest degree of accountability with no more human or machine errors and missed transactions (Saberi et al., 2019). In addition, it also used as a validation mechanism by recording transaction in system of registers. Recorded transactions are secured by providing public-key cryptography. Once an element is recorded in the blockchain, it cannot be altered turning blockchain into an immutable record of past activity.

Blockchain focuses to incorporate decentralised applications with the use of cryptographic tokens to connect peer-to-peer network of users and providers directly. Connections provided through blockchain creates value by decreasing transaction costs with the removal of central authority (Yuan et al., 2019). Particularly the use of smart contracts of blockchain technology requires parties in the contract to follow the rules and trust each other even when they are not well known to each other. Blockchain ability to track the recorded transactions along with the tracking technologies such as RFID, NFC tags, and IOT can be used in tracking the products in supply chains (Tian, 2016).

Blockchain adoption depends on novelty of the application which refers to the degree to which the application is new to the world. The more novel it is, the more effort will be required to ensure that all the users understand what problems it solves. The second dimension is the complexity in which the number of diverse parties need to work together to produce a value with the technology. As the scale and the impact of the application increases, the adoption will require significant changes (Kamble et al., 2019).

2.2 Blockchain In India

India has the second largest pool of blockchain developers next to US. A large number of blockchain developers in the country would mean that India may get an edge over other countries when it comes to developing applications based on Blockchain or improving applications through the technology (Sharma, 2019). Not only developing applications, Indian government and private companies in India are increasingly exploring the use of blockchain technology for improved governance and transparency. One such initiative is Andhra Pradesh's government pilot project in recording land titles on blockchain that would help in reducing fraud and lessen the administrative hassle of land registration and titles. It is noticed that the over 66 percent of civil cases in India are related to property-related disputes (Bloomberg, 2019). Thus, recording land-titles on blockchain would boost the economic growth. Another initiative, Government of Kerala has invested in blockchain technology to streamline milk, vegetables, and fish distribution (Nasdaq, 2019). In addition, Banks in India (example: Yes Bank, Kotak Mahindra Bank, and Reserve Bank of India) are increasingly using blockchain technology to reduce the cycle time of bill discounting and to eliminate fraud in the process (CNC, 2019).

As India is recognised as the provider of Blockchain skilled developers, educational institutes in India such as Indian Institute of Technology institutes are delivering blockchain based courses. In addition, governments are planning to establish educational institutes to teachblockchain technology. For example: Andhra Pradesh government in collaboration with Malaysian and New York-based institutions is establishing educational institute to teachblockchain technology (Bloomberg, 2019). Further, developing blockchain skills among the India's huge number of IT professionals would assist India to retain its position as the leading IT service provider. Given the significance of blockchain technology to the Indian government in governance and the economic growth through the talented work force, India provides a best research context to examine the blockchain technology adoption.

3.0 Blockchain adoption challenges- Conceptual framework

Tornatzky and Fleischer (1990) proposed technological, organisational, and environmental (TOE) as the three elements of a firm that influences the process of adopting and implementing innovations. The technological context refers to technological attributes relevant to the innovation in question. The organizational context refers to characteristics of the firm that influences the adoption decision. The environmental context refers to the arena in which a firm conducts its business (Tornatzky & Fleischer, 1990). This framework serves as an important theoretical perspective to study the contextual factors of innovation adoption at organisational-level. Number of researchers in IS domain have extensively used the TOE framework to empirically identify the determinants impacting technology adoption and their impact on the firm performance (Thiesse et al. 2011; Tsai et al. 2010). In the context of supply chain, TOE has been applied to study adoption of various internet-based supply chain management (SCM) technologies such as e-business, e-commerce, ICT, ERP, EDI, RFID, and cloud computing (Low et al., 2011; Chan et al. 2012).

Based on the type of technology under examination, researchers have used specific measures within the three factors of TOE framework (Chong & Chan, 2012). Traditional TOE models are focused at organisational level and have excluded inter-organisational relationship aspects (Chan et al. 2012). Chong & Ooi (2008) have identified the inter-organisational relationship is an important factor in supply chains and should be considered as the factor that influence technology adoption between organisations. This study extends TOE framework by incorporating inter-organisational as a factor to the existing technological, organisational, and environmental factors of technology adoption.

3.1 Technological Factors

Technological context refers to the adopter's perceptions of technological attributes. In research, there has been considerable discussion on a broad range of technological factors affecting the adoption of technological innovation. In particular, diffusion of innovation theory is used to provide theoretical explanation of technological factors. Rogers (1995) diffusion of innovations literature labelled compatibility, complexity, relative advantage, trialability and observability as the factors impacting adoption patterns. Researchers have extensively used compatibility, complexity, and relative advantage factors in IT adoption literature (Thiesse et al. 2011; Tsai et al. 2010; Wang et al. 2010). Observability and trialability factors do not appear to be considered in the literature due to most technologies being readily observable and pilot studies and trials may not be applicable. Blockchain technology is an emerging technology and its adoption is still infancy, so observability and trailability are also considered as the technological factors in this study.

3.2 Organisational Context

Organization context describes several descriptive characteristics and resources of an organization. Common organizational characteristics: firm size; the centralization, formalization, and complexity of its managerial structure; the quality of its human resources; the amount of slack resources available internally; and the communication process. All these organizational characteristics facilitate the adoption and implementation of technological innovations in several ways. This study uses top management support, financial resources, firm size, and technical expertise as the organisational factors.

3.3 External environment

The environmental context refers to the environment in which an organization conducts its business. They are factors external to an organization that can present constraints and opportunities for technological innovations. This includes the industry and dealings with competitors and government. In particular, external environment factor is able to demonstrate intra-firm innovation technology adoption. In the context of blockchain, security is a major concern with miner capability to attack the system. Therefore, security, along with government regulations and industry characteristics are considered as the external environment factors.

3.4 Inter-organisational Relationships

Relationship between an organisation and its partners is important in adopting inter-organisational system such as EDI, ERP and RFID. Adoption of blockchain technology in supply chain requires cooperation between the organisations. Inter-organisational relationship is a complex construct with many dimensions such as power, information sharing, and trust. In addition, decentralised network system of blockchain technology may add complexity of privacy issues during the implementation. Information sharing, partner's power, trust, and privacy are considered as the inter-organisational relationship elements.

Based on the extensive literature review a hierarchical conceptual framework of implementation challenges of blockchain technology is proposed with four challenge-categories and sixteen challenges (refer to Figure 1). Methodology to identify the critical challenges are discussed in the following section.

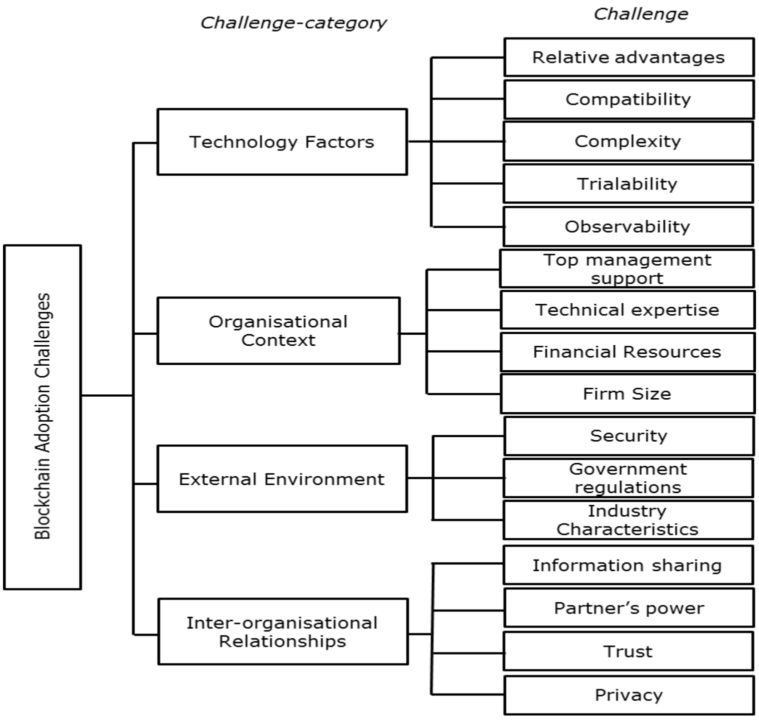

Figure 1: Conceptual framework of blockchain technology implementation challenges

4.0 Research Methodology

4.1 Analytic Hierarchy Process – a brief overview

To identify the critical challenges from the proposed framework, decision makers need to assign subjective priority weights for judgments. Analytic hierarchy process (AHP) is considered as a robust tool for decision making when both the quantitative and qualitative criteria are involved (Rahman et al., 2017). In the context of technology adoption, previously AHP is used to select technology providers (Yang & Huang, 2000), understanding factors influencing decision making of technology adoption (Bigdeli et al., 2013; Yan et al., 2019), and investigating market success and failure factors (Park et al., 2017). Hence this study adopts AHP and modelling process of AHP involves following the steps:

1. identification of critical challenges and AHP structuring,
2. structuring the problem as a hierarchy using challenges and challenge-categories to build the AHP model, and
3. collection and compilation of experts' opinions and application of the prioritisation procedure to determine normalised weights for each challenge and challenge-category.

The overall weights of the challenges are determined by aggregating the weights throughout the hierarchy. Expert Choice® software is used to calculate the priority weights of challenges and challenge categories.

AHP also provides a direct measure of consistency of judgment elicited by the managers. The consistency ratio (CR) refers to the degree to which decision-makers adhere to the rank order specified and measures the extent to which an established preference is kept. A CR ≤ 0.1 is recommended as acceptable (Saaty and Vargas, 2012). If CR > 0.1, it is suggested that the managers re-evaluate their judgments.

4.2 Case study

Case ABC is one of the largest Indian IT service, consulting and business solutions company. It provides solutions to a broad range of industries such as consumer packaged goods, retail, manufacturing, travel, transportation and hospitality, telecom, banking, financial services, insurance, life sciences, energy, and many others. Since its beginning in 1968, Case ABC has always offered services to address the business needs for innovative and advanced technology. Since last few years, Case ABC is developing blockchain platforms that include, digital identity, track and trace, assets in common, asset monetization, and tokenization. The role of Case ABC in developing blockchain solutions for Indian companies demonstrate the importance of the company in the study context.

Case XYZ is a financial and advisory service consultancy company. It is a coordinating entity for a global network of independent firms providing audit, tax and advisory services. Case XYZ services in India include financial and business advisory, tax and regulatory services, and risk advisory services. Case XYZ in India also provides advisory services such as management consulting, risk consulting, deal advisory and strategic alliances. The company serves healthcare, education, financial services, media, life sciences, building and construction, private equity, technology, energy, defence, and transport industries, among others. As a part of consulting, Case XYZ have been actively involved in implementing blockchain technology among the India's largest financial institution.

Established in 1907, Case αβγ is the Asia's first integrated private steel company. It is a leading global steel company with diversified operations. It is one of the few steel operations that are fully integrated – from mining to the manufacturing and marketing of finished products. As a vertically integrated organisation which is environmentally conscious, Case αβγ is implementing blockchain technology in tracing the life cycle of a steel bar in supply chain. In collaboration with SAP, IBM and Arup, Case αβγ have formed a Construction Smart Contract Committee to create a transparent chain of all resources in construction industry including steel construction materials.

4.3 Respondent

We adopt the case study design suggested by Yin (2003) and employed AHP methodology to provide insight into the criticality of challenges in implementation of blockchain technology in supply chains. A senior executive of an organisation who is responsible for blockchain implementation and senior technical staff member who oversee the implementation of blockchain technology in client organisations were chosen for interview. A two-part questionnaire was employed for data collection. Part A contained questions (in AHP format) designed to capture respondent's opinions on the relative importance of the criteria and factors, whereas, Part B contained general questions about the company and respondent's background. As the respondent was not familiar with AHP data collection procedure, the following steps were considered:

1. The meanings of the integer scores of the 1-9 scale used was explained.
2. How the scores need to be considered while making the pairwise comparisons between any two criteria of factors was explained.

These two steps were critical to ensure the accuracy of data and consistency of judgements discussed earlier.

5.0 Results & Analysis

Numeric analysis was conducted to determine the weights of challenge-category and challenges of blockchain implementation in supply chain. These weights identify the degree of importance of each challenge as a percentage of total importance. The results are summarised in Table 1 and Figure 2.

Challenge categories	**Relative Weight**				**Challenges**	**Relative Weight**			
	Case ABC	Case XYZ	Case αβγ	Overall		Case ABC	Case XYZ	Case αβγ	Overall
Technology	0.227	0.270	0.361	0.404	Relative advantages	0.055	0.188	0.080	0.098
					Compatibility	0.261	0.072	0.329	0.197
					Complexity	0.535	0.600	0.461	0.540
					Trialability	0.100	0.116	0.084	0.106
					Observability	0.049	0.064	0.044	0.057
Organisational	0.629	0.594	0.508	0.455	Top management support	0.238	0.620	0.282	0.304
					Technical expertise	0.052	0.109	0.112	0.157
					Financial resources	0.614	0.220	0.416	0.438
					Firm size	0.095	0.052	0.189	0.098
External environment	0.102	0.051	0.047	0.073	Security	0.113	0.731	0.614	0.250
					Government regulations	0.189	0.081	0.117	0.250
					Industry characteristics	0.709	0.188	0.268	0.500
Inter-organisational relationship	0.042	0.084	0.082	0.065	Information sharing	0.228	0.321	0.275	0.294
					Partner's power	0.063	0.074	0.141	0.088
					Trust	0.599	0.321	0.482	0.462
					Privacy	0.111	0.285	0.100	0.156

Table 1: Relative weights of challenge- categories and challenges

From overall weights of all the respondents (refer to Table 1), it is evident that challenges related to organisational aspects (weight = 0.455) has a major impact on the implementation of blockchain technology. Particularly, lack of financial resources (weight = 438) under organisational context challenge-category is the most critical challenge. Next to organisational context, characteristics of technology (weight = 0.404) poses a critical challenge for the blockchain implementation with complexity (weight = 0.540) as the critical challenge and compatibility (weight = 0.197) as the other challenge. External environment (weight = 0.073) and inter-organisational relationships (weight = 0.065) are the least critical challenges of blockchain implementation. Industry characteristics (weight = 0.500) of external environment plays a crucial role in the implementation. Among inter-organisational challenges, trust (weight = 0.462) between the supply chain members is critical in the blockchain implementation.

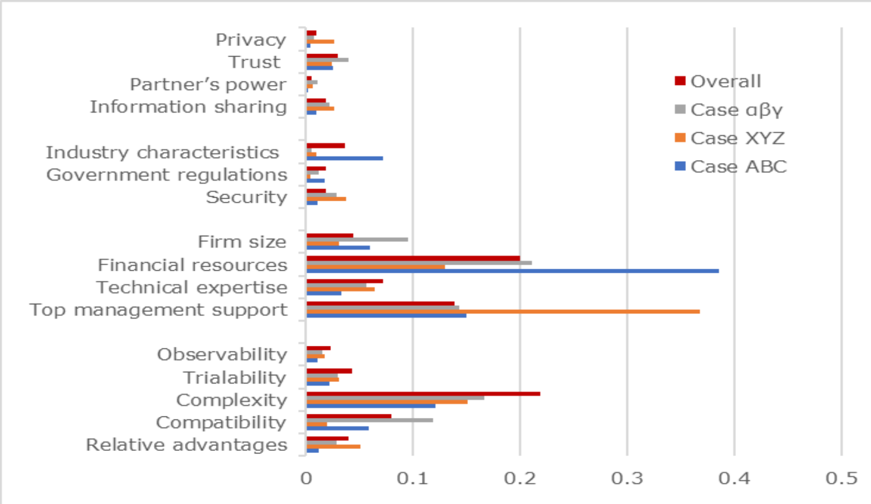

Figure 2: Overall priority weights of challenges

The global values of challenges demonstrate that complexity (weight = 0.219), financial resources (weight = 0.200), and Top management support (weight = 0.139) are considered as the moderately important challenges (refer to Figure 2). Other thirteen challenges are considered as the least-critical challenges for the blockchain technology implementation. Among the least-critical challenges, compatibility (weight = 0.080) from technology factors and technical expertise (weight = 0.072) from organisational context are the top critical challenges (refer to Figure 2). In comparison to the challenges of technology and organisational challenge-categories, challenges under external environment and inter-organisational are less critical in implementing blockchain technology in supply chains.

6.0 Discussion

Results indicate that all the challenges under organisational context received a higher weightage among the implementation challenges. Respondents believe that being a new technological innovation it is costly to acquire blockchain technology, and it requires expensive hardware for successful implementation. In addition, top management considers the perceived benefits of the technology are not fully known, so it is a challenge to support the initiative. India being the largest pool of technology developers after the US, still it is not easy to find the people with required skills for the blockchain implementation. People with the right skills are costly to hire. Generally, size of the organisation determines the firm's resources in investing in new technologies. Large organisations have more resources to invest, however some smaller innovative organisations strive to invest in new technologies. In the case of blockchain technology implementation in supply chains, size of the organisations is not a critical challenge.

Technology is the second critical challenge-category with complexity and compatibility as the top critical challenges. Currently, there is no clear understanding or protocol on blockchain adoption which complicates the process. In addition, most of the organisations where the respondents have implemented the technology have a very complex structure. On the other hand, based on the organisation's current technology compatibility is an issue. If the organisation has already adopted legacy system, then the compatibility is not an issue which resulted in lower ranking. Lack of existing proof of concepts in blockchain technology implementation contributes to the priority weights of the trialability challenge. Under external environment category, industry characteristics plays an important role in blockchain implementation. Since its introduction, blockchain technology is applied only finance industry. More recently, blockchain technology is applied in several industries and their supply chains. So, industry characteristics have received greater priority in external environment challenge-category. Among inter-organisational challenge-category, building trust is considered as the critical challenge. Trust is considered as the fundamental aspects which assists in information sharing and provides privacy among the supply chain partners. Particularly the use of smart contracts of blockchain technology requires parties in the contract to follow the rules and trust each other even when they are not well known to each other.

7.0 Conclusions

Implementation of blockchain in supply chains offers end-to-end transparency benefits by protecting digital record from deletion, tampering, and revision. However, organisations are facing several challenges in implementing the blockchain technology in supply chains. Developing prior knowledge on challenges will facilitate the successful implementation of blockchain technology. This study identifies and prioritises the implementation challenges of blockchain technology in supply chains. Based on the extensive literature review, TOE framework is extended by the addition of inter-organisational relationships to develop a framework of blockchain technology implementation challenges in supply chains. Results indicate that organisational-context challenge-category is the most critical followed by technology challenge-category. At challenge level complexity, financial resources, and top management support are considered as the top critical challenges. By looking into critical challenges, organisations can develop strategies to assist in addressing the challenges and facilitates in their decision-making of the blockchain implementation in supply chains. This study investigates the blockchain implementation challenges in Indian context, so the results may not be generalised to other nations.

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Session 3: Transport and Distribution

SMART MOBILITY: CHALLENGING ISSUES AND NEW OPPORTUNITIES IN A SUSTAINABLE SMART CITIES

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Abstract
Purpose
The self-driving technology brings to the development of smart city new opportunities and positive impacts, at the same time new challenging issue like negative social effects such as distance among social status of the people, moral and ethical issues, job loss or human behaviour make process of general adoption of autonomous vehicles (AVs). The paper addresses these critical issues and has an aim to provide the insights into a new mobility level that can contribute to a more sustainable city change.

Design/methodology/approach
The methodology includes a systematic review of the existing literature to understand capability and impact of the challenging issues associated with autonomous vehicles. Special focus is to investigate their effect on sustainability by the PESTEL analysis in the framework of the smart city.

Findings
This paper provides a PESTEL analysis for political, economic, social, technological, ecological and legal domains of the city environment in order to identify the most challenging barriers and advantages for the adoption of the autonomous vehicles in the smart city environment. The analysis takes into consideration public acceptance and cooperation aspects.

Value
The most important barriers for the effective adoption of the AVs have been identified on the macro-level of decision-makers, i.e. global standards for AVs, job market changes, waste management, effective resources and energy utilization. From another side there are a number of positive effects that can be realized from the adoption of AVs, in particular in greater flexibility and mobility for all members of the society. However, the speed of AVs technology implementation depends on and is strongly determined by the existing level of acceptance for the smart mobility concepts in the society.

Research limitations/implications
The finalised results of this research are not reached at this moment, but the preliminary outcomes show the potential of the topic and will be used as a fundament for the further investigations.

Practical Contribution
The results of this research have a conceptual nature.

INTRODUCTION

Globalisation and the preference of 55% of the world's population to live in urban areas – which is also around 7% in the largest mega-cities – is expected to have an increasing trend to 66% by 2050 (UN DESA, 2018). This tendency also means the exponential increase in the number of cars on the roads, requiring not only new infrastructure and service, but also new concepts for city planning and organization. The first ideas for creating the "intelligent city" in Singapore in 1993 (Heng and Low, 1993) have since been incorporated in the global concept of SMART CITY. There are various components such as smart home, smart health and care, smart energy, smart infrastructure or smart transportation that bring the resources and functionality of cities to the most effective operational level, creating the smartness of a city. The smart mobility concept is a component of the smart city, which is directly linked to the field of sustainable thinking based on numerous research studies (Noy and Givoni, 2018; Mangiaracina et al., 2012; Papa and Lauwers, 2015). Smart technologies in urban transport create new challenging opportunities for building safe, reliable and cost-effective transport systems. One of the United Nations' Sustainable Development Goals is to provide "… accessible and sustainable transport systems for all …" (UN SDGs, 2018) by 2030. To achieve this important goal, the vision of conventional transportat should be changed. If goods or passengers are transported from the starting point to the desired destination in the traditional transport process, the mobility concept has a much broader meaning. Smart mobility includes not only the trip itself, but also the quality of travelling taking into account various sustainability parameters of the city. The integration of city sustainability dimensions such as social, economic and ecological into the conventional city transport system and their combination with the emerging concept of smart mobility transport take the development of cities to a new level. Autonomous vehicles (AVs) as part of the smart mobility concept have great potential to contribute to the development of such smart sustainable cities. There are different levels of automation that can be applied in the smart city environment. The most promising technology is that of fully autonomous self-driving vehicles that could improve a city's logistics efficiency and ensure a high quality of travel experience (Hörold et al., 2015; Chamoso et al., 2018). At the same time, the perspectives of diverse stakeholders in the implementation of AVs in the city infrastructure could be fundamentally different. Smart mobility will have significant positive and negative impacts, particularly in the social and economic dimensions.

To address these issues, this study carried out a critical analysis of the key-parameters of sustainability related to the configuration of the smart city from the perspective of city residents.

LITERATURE REVIEW

"Smartainability" of technologies can contribute to enhancing resource efficiency and sustainability in the city (Girardi, 2017). The smart mobility concept for cities is developing in parallel with the concept of "autonomous" driving, in which the vehicle system can perform all driving functions automatically (Faisal et al., 2019). From the automation concept perspective, there are five levels of automation introduced by the Society of Automotive Engineers International (SAE). This differentiation in the automation levels has become an industry standard. At the first and second automation levels, the driver has the possibility to influence the operational functionality of the vehicle. At levels 3 to 5, the driving system in the vehicle can operate fully autonomous, but the level of autonomous control can vary (DoT, 2016). The main barriers for implementing AVs refer to legal issues as well as to social and behavioural questions (Hörl et al., 2016). The emerging field of AVs is of great interest to researchers. Many studies deal with AV operations on roads, AV capabilities, amd the software and hardware required for operation; another part of studies deals with the contributions of AVs to influence traffic congestion and reduce traffic accidents (Faisal et al., 2019; Hörl et al., 2016; Smolnicki, 2016). Infrastructure investments and the rational use of parking spaces for AVs are also a limiting factor for the application of AVs. An important direction in research topics is the sustainability component in autonomous driving of cars. The reduction of CO_2 emissions could be achieved directly with electrically powered AVs on the roads. Similarly, with AVs, the reduction of noise and light emissions is possible. The increased number of electrically powered AVs can lead to the side effect of increasing the demand for electrical energy.

The focus of current research is on the exploration of technological aspects of AVs and their impact on traffic flows; however, there is a lack of research on the social and economic effects of AVs on the environment (Milakis et al., 2017). Mobility on-demand services could potentially reduce the number of cars between 31 and 95 percent (Pakusch et al., 2018), which will have a positive impact on the sustainability of cities. Nevertheless, there are still a number of negative concerns from AVs such as empty runs, increased travel demand or the shift from public transport to AVs (Pakusch et al., 2018). The problem of positive social effects such as saving time, comfort, prestige, improving lifestyle and negative social effects such as distance in the social status of people, moral and ethical issues, job loss or human behaviour has already been partly addressed by some authors (Hussain et al., 2018; Holstein, 2018). There is still a need for research on public acceptance of the adoption of autonomous vehicles. Some factors that influence user confidence in AVs cannot be explained by reliability and safety aspects of operation alone. The problem of the acceptance of AVs in the sustainable society has been partly examined by empirical studies: how do respondents understand the term autonomous driving (Cho and Jung, 2019); how does user acceptance depend on the different levels of autonomy of the vehicle (Helgath et al., 2018). The Autonomous Vehicle Acceptance Model has been proposed to analyse the public acceptance of AVs (Hewitt et al., 2019). The investigation of the relationship between transparent driving systems and building trust in this system as well as confidence in AVs is still in its infancy (Cysneiros et al., 2018).

Therefore, the aim of this paper is to evaluate the correlation between a sustainable smart city and the implementation of AVs in urban transport systems; to identify the main challenges for the sustainable adoption of AVs in the city environment and to present the emerging benefits for potential users of smart vehicles in the smart city location.

The analysis in this article has an explorative character, based on our own considerations and supported by literature. It serves as an introduction to the topic and does not claim to be exhaustive.

PESTEL ANALYSIS: AVs IMPACTS ON SUSTAINABILITY

The purpose of this study is to identify factors that may facilitate or hinder the use of AVs in cities and to give an overview of potential impacts of smart mobility and AVs on a society with a special focus on sustainability issues.

One of the most widely used definitions in the context of sustainability is the one drawn up in the Brundtland Report. According to this, sustainability is the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). The further development of this approach considers three dimensions of sustainability - also referred to as the Triple Bottom Line (TBL) - according to which social, ecological and economic aspects of sustainability must be considered equally (Elkington, 1994). Alternatively, the term "people, planet, profit" is used, which emphasizes the operational implementation in companies.

The economic dimension focuses on aspects like generating profits, innovation and technology, economic growth, cost saving, investment in infrastructure, job creation, paying tax responsible, no bribery or corruption and contribution to local economy. The ecological dimension includes land use, use of natural resources, waste management and recycling as well as effects on climate, pollution prevention, protection of biodiversity, use of environmentally sound materials and energy, minimization of waste and emissions, minimization of hazardous substances and using energy and resources efficiently. The social dimension encompasses good and safe working conditions, where employees have a chance to prosper and develop their skills, a company's activity in community work, ensuring product safety, respect for human rights, good community relations, compliance with the law and fair treatment of suppliers (OECD, 2011; van Weele, 2014).

The main difference compared to the TBL-Approach is the differentiation of the social dimension into politics and culture, which creates a more balanced picture. In addition, Law and Justice as well as Technology and Infrastructure are listed as one of seven subdomains in each of the domains politics and economics respectively. However, this is not sufficient for a comprehensive analysis of AVs in the context of sustainability, so that the PESTEL analysis can be helpful in this case.

The PESTEL analysis is a strategic management tool typically used by companies to obtain an overall picture of the macroeconomic environment in which the company operates. PESTEL stands for the factors political, economic, social, technological, ecological and legal. The purpose of this framework is to provide valuable insights into specific market conditions and the development of an industry in the six areas mentioned in order to make informed decisions and develop strategies (Theobald, 2016, p. 3).
The PESTEL methodology has also been used to study the macro-environment of specific technologies and, in particular, to identify critical factors that support, hinder or challenge the adoption and success of this technology (Song et al., 2017; Issa et al., 2010). In our case, we differentiate between local (city), national (country/EU) and global levels for a more differentiated picture, since the necessary framework conditions, effects and challenges at these three levels can be very different.

Political
The first category of the PESTEL analysis covers political aspects. On the local level, permission to drive in a city is a key driver for the use of AVs in city logistics. Implementation also requires consideration of different modes and car-sharing concepts that may affect diffusion, as well as the interaction with public transport. Due to the already existing infrastructure in city logistics, specific challenges arise in the integration of AVs in cities (Stark et al., 2019). The different size and potential development of different cities also play a major role, as this results in different requirements.
From a country perspective, it should be noted that autonomous driving creates new rules for drivers that should be centrally determined. Furthermore, highly efficient and stable power and communication networks (such as 5G) are essential for the implementation of autonomous driving and vehicle-to-vehicle communication. Corresponding politically promoted investments and the enforcement of standards are therefore indispensable. The establishment of funding and investment programs to promote research and development in the Smart City context is another building block that needs to be strengthened at the country or EU level. Still unclear are questions of responsibility and liability (for example in the case of accidents), which can be classified into the political-legal area. In addition, the issues of waste management (including batteries) and safety standards (for companies, transport systems and infrastructure) in handling data will pose challenges for countries.
In the global context, the focus is primarily on issues of resource acquisition needed for the production of autonomous vehicles, recycling and waste management regarding end-of-life management of AVs as well as climate policy (e.g. CO_2 agreements).
Furthermore, there is a global cyber-security risk, such as hacker attacks on networks and autonomous vehicles, which can jeopardize the entire system and endanger passengers as well as other road users. Appropriate measures for protection and cooperation must be implemented across borders.

Economic
From an economic perspective, an optimized traffic system without congestions and accidents can be realized with the help of connected autonomous vehicles. This enables efficient last-mile transport as well as time-efficient passenger transports. If travel time can be used as working time, this leads to an increase in productivity and cost reduction. Critical factors that determine the feasibility are the number of autonomous vehicles required as well as the costs associated with purchase and maintaining AVs. Another challenge is the serious impact of self-driving transport systems on the labor market and a possible increase in unemployment. While a large number of jobs will become superfluous (e.g. truck drivers, taxi drivers, parcel deliverers), existing business models will change (e.g. insurance companies, rental cars, financing of car purchases or in a car-sharing context). However, the biggest restructuring will be in the automotive industry itself, as the focus is likely to be less on the production of automobiles themselves, but on the management of platforms, while at the same time the digitization of the industry requires new technologies and skills.
Thus, new job profiles are evolving and the demand for qualified employees with skills in software development, programming, data processing, artificial intelligence etc. increases.

At the same time, new opportunities are opening up for business models and start-ups dedicated, for example, to car-sharing or sustainable autonomous transport, as well as through the embedding of smart mobility in smart cities (Stocker and Shaheen, 2017).
In terms of dependencies and requirements for companies, the transport system and infrastructure, energy consumption and the level of security must be mentioned.
At the country level, long-transit transports can be ensured without accidents and delays. In addition, access to alternative energies must be promoted and waste disposal (batteries) coordinated. The development of new business models opens opportunities both nationwide and globally. Overall, efficient and sustainable transport systems can be implemented globally.

Social

Among the socio-cultural influencing factors, the social environment can be examined, inter alia, by considering the population structure (age, gender, social class) or cultural particularities (norms, values, attitudes, role understanding) (Theobald, 2016, p. 3).
In addition to greater flexibility and mobility, there are further positive developments for society that are reflected in access to mobility and thus in social participation and independence, for population groups that are not (or no longer) allowed to drive their own vehicle or are financially restricted (young, old, disabled people, no driver's license). This applies both to private autonomous vehicles and to sharing concepts.
While this supports the freedom of the individual, a loss of individuality and autonomy among the individual members of society can be criticized at the same time, if limited freedom of choice through pre-determined routes and complete autonomy of the vehicle as well as possibly limited ownership of private autonomous vehicles are placed at the center of the discussion.
Despite further benefits from fewer accidents, more safety (no inattention, early detection of technical defects), less noise, less stress, less congestion, which have a positive impact on public health, the use and acceptance of society remains an important driver or obstacle in the implementation of concepts for autonomous driving.
It remains to be clarified how the acceptance can be increased and which role the factors of cyber security, requirements for vehicles (comfort, equipment), personal lifestyle and the preference for renting or buying autonomous vehicles play.
It is also unclear and unpredictable how time, which will be available through less time lost due to an optimized transport and traffic network will be used in the future (more versus less driving, more free time versus more working time) and how this will affect the overall use of autonomous vehicles. The potential of using travel time as working time might maintain a better work-life-balance for employees, must be taken into account in the employment contract and agreed with the works council. However, if this results in disadvantages for employees, this can have a negative impact on the acceptance of AVs.
It is advisable to address implications on the labor market and working behavior (changed working hours due to more time) at the country level. This also applies to issues of privacy and security of persons (Lim and Taeihagh, 2018). Since large amounts of data are collected and needed for functionality in an IoT-context, regulations for the protection of persons are required that apply across countries or throughout the EU.
Globally, there will be an increase and enhancement in overall mobility in society. Nevertheless, the production of autonomous vehicles and associated technologies requires the global sourcing of raw materials and global value chains, which means that working conditions in the respective countries must not be neglected.

Technological

From a technological point of view, implementing and integrating AVs into the city infrastructure poses the greatest challenge. In a city, therefore, all the necessary prerequisites must be created, including the availability of new technologies such as high performance batteries and charging stations as well as the implementation of IoT. For countries, it will be relevant to provide the necessary new and stable infrastructure (internet connection, 5G, GPS, communication, power grid). Programs to promote new business start-ups with a focus on technology and sustainability are another prerequisite for the realization of autonomous driving and smart cities. The topics of end-of-life management and recycling must already be taken into account in product design and R&D. At the global level, support for technological developments and R&D-projects with a sustainability focus can be identified as a key driver.

Environmental

The environmental effects to be expected depend not only on the energy efficiency of autonomous vehicles, but also on the number of AVs used in a city. Assuming optimized transport and transportation networks, a better degree of utilization of autonomous vehicles and thus a reduction in vehicles demand can be achieved.

Less road capacity leads to less congestions and stop-and-go situations, which at the same time influences fuel efficiency and emissions. Less emissions then leads to an improvement in air quality. Other benefits include noise reduction and the reduced need for sealed surfaces for parking lots and roads. This opens up new potential for the planning and greening of cities and supports the strategy of turning cities into safe, healthy and green places.

However, the so-called rebound effect (Umweltbundesamt, 2014) has to be considered, according to which - despite increasing energy efficiency and the resulting cost reductions of autonomous vehicles - there is no reduction in the total energy requirements and emissions. This is due to the fact that more autonomous vehicles can be used with decreasing costs and increased energy efficiency. The potential development of individuals using autonomous vehicles more often due to the freed-up time and traveling more distances may also result in more vehicles being needed and the overall environmental impact being far less positive. The topics of climate, resource efficiency, land use and air pollution are important both at national and global level. In addition, the environmental impacts of resource extraction must be considered globally. In the long term, depending on the efficiency and number of AVs, there may be positive effects on the climate (ozone layer) and good or improved air quality.

Legal

New rules are needed for the new concepts and have to be implemented at the city level. In addition, new laws have to be enacted and changes must be made that are adapted to changing conditions and the dynamic environment and govern the handling of data such as data management, storage and protection as well as privacy issues (Lim and Taeihagh, 2018).

The topic of cyber security is to be addressed and updates of the Highway Code are to be made. As business models and the work environment change, new rules regarding employee rights, working hours, privacy, and customer safety are also required. All of these rules and laws are to be updated and developed taking into account the current state laws at the country level. In addition, cooperation is required to implement and introduce new concepts worldwide. Depending on the legal framework and developments, efforts to promote digital progress and technological innovations with regard to autonomous driving and smart mobility can be encouraged or slowed down.

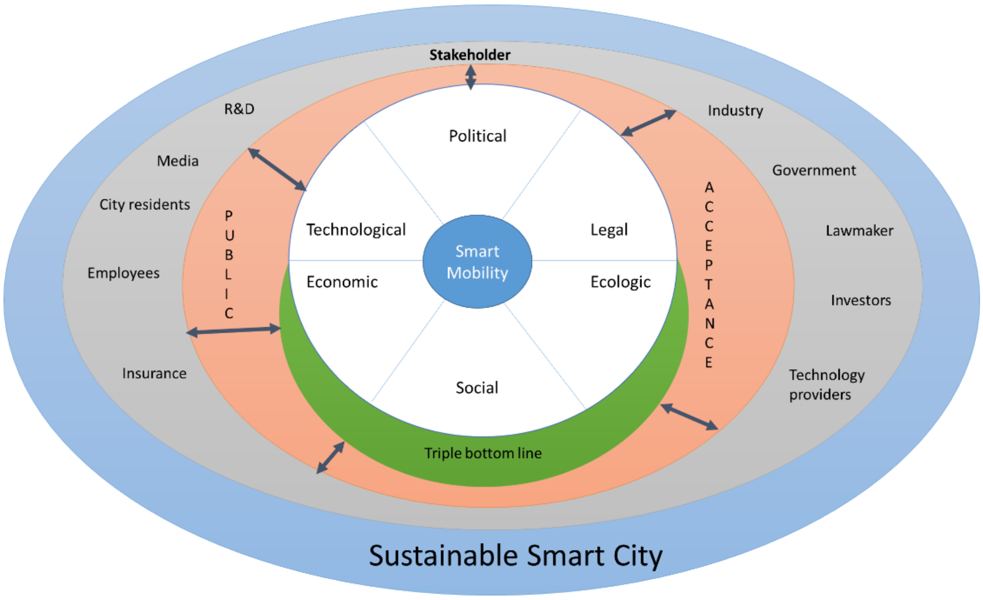

Figure 1. Main dimensions of the sustainable smart city

Hence, in the dimensions of the PESTEL framework smart vehicles have both positive and negative impacts on the sustainable development of the city. Main actors in the smart city system include not only technology providers, research and development institutions (R&D), politicians or city planners; on the other hand, there are always the potential users of the smart city product – the city residents. This means that the sustainable model of the smart mobility, i.e. the adoption of autonomous vehicles, can only be reached in the case of conscious and responsible cooperation between residents and city planners, including industry, lawmakers or technology. The cooperation process between the key stakeholders regarding the adoption of AVs represented as a public acceptance parameter (Figure 1). Therefore, the necessary level of acceptance can be reached if complex aspects such as trust and belief in the technology, societal change, different socio-cultural factors, mobility needs and behavior, as well as attitudes should be considered in the context of the existing infrastructure and sustainable city development.

CONCLUSION

This paper has presented an analysis based on the PESTEL method and identified the greatest areas of challenging parameters for the implementation of autonomous vehicles in the smart city environment. The most important barriers to the effective adoption of AVs are at the macro-level of decision-makers, i.e. global standards for AVs, labour market changes, waste management, effective resources and energy utilization. On the other hand, there are a number of positive effects that can be achieved through the adoption of AVs, in particular greater flexibility and mobility for all members of society. However, the speed technology implementation of AVs depends on and is strongly determined by the existing level of acceptance for smart mobility concepts by the members of the society.

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LOCATING THE REGIONAL LOGISTICS CENTRE: AN EMPIRICAL STUDY

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Abstract

Purpose

The purpose of this research is to propose multi stage process to locate logistics center given independent and partially conflicting criteria. Complex multi stage ranking framework is introduced to select the most desirable location of the regional logistics centers based on multiple criteria evaluation.

Design/methodology/approach

Location selection process is conducted at two phases. The first phase of selection process is applied following macro analysis criteria to select the most appropriate cities in each region. At the second phase, specific locations within each governorate are evaluated to select the best location following micro level analysis; where specific stakeholders, objectives, descriptor and perceptive are considered. At the macro phase, complex multi stage ranking process following three level hierarchical problem was established to rank cities in the region from the best to the worst in terms of their suitability for locating the logistics center. At the first level, distance matrix was constructed to measure the average distance between each city and other cities in the region. After excluding cities with distance longer than the average distance; production as a proxy of supply and population of each city as a proxy of demand were measured to choose cities with highest demand and supply. Finally, trade capacity for each city was considered in order to select the most appropriate cities in each region to establish regional logistics centers.

Findings

An empirical study on Egypt was conducted in order to select the best cities to locate the regional logistics centres. 27 governorates were classified in three regions (Delta region, Middle Egypt and Upper Egypt). The analysis revealed four governorates out of thirteen to serve as regional logistics centers for Delta region. Two governorates out of six can serve as regional logistics centers in Upper Egypt, while two governorates out of eight can serve as regional logistics centers in Middle Egypt.

Value

A multi stage process is introduced to locate logistics center at macro and micro levels while dealing with multi-criteria conflict. The research proposed a framework based on a set of macro criteria (distance, population, production and trade capacity) reflecting both the supply side and demand side to select the most desirable locations of the regional logistics centers.

Research limitations/implications

The paper conducted macro analysis to locate the regional logistics center at a city to serve the whole region, while further research - following the proposed multi stage process- should focus on micro level analysis to determine the most appropriate specific location within the city to establish the logistics center.

Practical Contribution

The proposed procedure can help both investors and governments to locate the regional logistics centers taking into consideration macro-economic variables in order to increase their efficiency in terms of improving their logistics performance,

increasing their sustainability and ultimately allocating fund to the most desirable location.

INTRODUCTION

According to Lee (2014), 70% of the population will live in cities by 2050 which will lead to many problems such as traffic congestion, environment pollution and safety risks. This can highlight the need to investigate transport issues and urban logistics with the aim of optimizing the logistics and transport activities in urban areas (Ndhaief et al., 2017). Creating logistics centres to improve urban logistics and minimize negative impacts through the consolidation of goods flows appears to be a good solution to meet the new objectives of the policy makers in terms of efficiency of goods flow inside the city, reducing pollution, increase citizens' quality of life and improve economic competitiveness (Moutaoukil et al., 2015).
The need for logistics centres has recently increased as a key element for freight transportation systems and the city planning both on an intra-urban and regional scale to reorganize life areas in the cities (Uyanik et al., 2018). Accordingly, the selection of logistics centres locations affects the functioning, efficiency and costs for urban logistics, and makes cities more sustainable (Rao et al., 2015). The proper location is a crucial factor for potential economic growth since it has direct and indirect impact on different stakeholders including investors, policy makers, infrastructure providers, hub operators, hub users and the community itself (Thai and Grewal, 2005; Kayikci, 2010; Alam, 2013). Inappropriate location may lead to bottlenecks and increase cost of providing transport solutions. Therefore, criteria and technique of location selection have critical importance to locate logistics centres properly (Europlatforms EEIG, 2004).
Locating regional logistics centres while considering different stakeholders with conflicting objectives may lead to poor and misleading decisions. Previous frameworks discussed in different urban freight reviews did not consider multi-actors perspective or define clear cut factors involved in logistics centre location problem. They rather concentrated on specific stakeholders, objectives, or perspectives (Anand et al., 2012). The purpose of this research is to propose multi stage process to locate logistics centre given independent and partially conflicting criteria. Complex multi stage ranking framework is introduced to select the most desirable location of the regional logistics centres based on multiple criteria evaluation.
The paper starts with review of previous studies to show different techniques and criteria used to locate logistics centres. Section three illustrates the methodology used in this research to locate regional logistics centres. An empirical study on the Egyptian regions was conducted and illustrated in section four. Finally, section five concludes the paper and draws agenda for future research.

LITERATURE REVIEW

The EUROPLATFORMS, an association of approximately 80 Transport & Logistics Centres all over Europe, defined logistics centre as "a centre in a defined area within which all activities relating to transport, logistics and the distribution of goods – both for national and international transit, are carried out by various operators on a commercial basis. The operators can either be owners or tenants of buildings and facilities (warehouses, distribution centres, storage areas, offices, truck services, etc.), which have been built here." (EUROPLATFORMS, 2015).
As illustrated in figure 1, logistics centre concentrates all logistics activities in one area (transportation, forwarding, material handling, warehousing, inventory management, storage, packaging, labeling, cross- docking, physical distribution) to be carried on a commercial base in order to handle the movement of goods from one location to another in a way allows the most efficient accessibility to multimodal transport modes (Rushton et al., 2006; Alam, 2013; Żak and Węgliński, 2014).

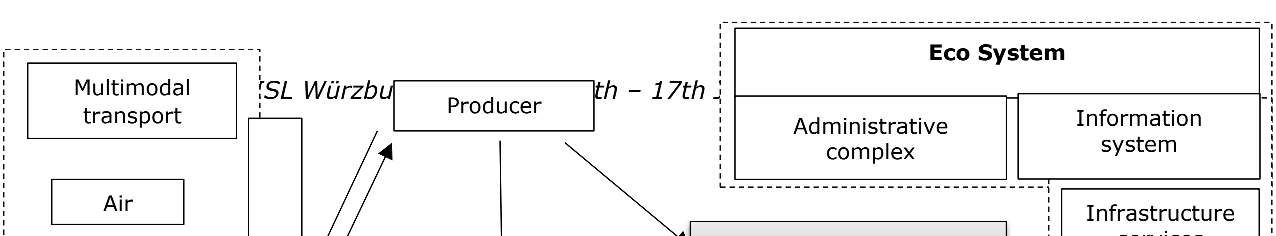


Figure 1: an ideal logistic centre and its surrounding
(Derived from: Skowron-Grabowska, 2008)

Skowron- Grabowska (2008) identified four levels of logistics centres: International logistics centre which is built on the highest degree of organizational and functional development in order to function on the global range. Regional logistics centre works as intermediary hub of regional and big-city distribution network. Local distribution centre serves local/city distribution network. Industry distribution centre serves only one particular industry or single large company with specialized production range of products. Farahani et al. (2010) highlighted the applied approach and the evaluation criteria as the most important factors when considering the location selection problem for a logistics centre.

Anand et al., (2012) conducted a review of city logistics modelling. The review concluded with a framework takes into account the diversity and complexity of location selection by considering the different aspects in the modelling selection process; stakeholders' involvement, objective of modelling, the descriptor for modelling and the perceptive. Stakeholders can be divided into public sector stakeholders that include traffic authorities, infrastructure authorities, municipalities, railway terminal/port authorities along with road users and residents; while private sector stakeholders include producers, suppliers, shippers, freight forwarders, trucking firms, truck drivers, shopkeeper and receivers. Different stakeholders might aim at different objectives while selecting the logistics centre location (economic objectives, efficiency, road-safety, environmental objectives, infrastructure & management, or/and urban structure). Also, different objectives are linked to different descriptors (indicators) that should be observed and measured while analysing urban goods movement. The review revealed that many modelling approaches consider traffic flow descriptor or/and commodity flow descriptor. Moreover, planner's perspective might vary leading to different priorities in the location selection decision such as infrastructure and services, technology, behaviour, or introducing policy measures as rules, regulation or initiatives.

The review revealed that the location of logistic centers is a strategic decision made based on multi-criteria analysis that can be independent or partially conflicting (Essaadi et al., 2016). The main contribution of this paper is to take into account multi-criteria conflict while dealing with location selection problem through conducting the selection process at two phases. At the first phase, the choice of a location can be done at macro level by choosing a region/city in the country based on hierarchical assessment considering common, objective and vital criteria to all different aspects in the modelling selection process (i.e. stakeholders' involvement, objective of modelling, the descriptor for modelling and the perceptive). At the second phase, the decision makers choose directly a specific location within the region/city among a set of areas based on a simultaneous assessment resulting in less biases. In this phase, specific criteria to choose should be identified (stakeholders' involvement, objective of modelling, the descriptor for modelling and the perceptive).

METHODOLOGY

A detailed literature survey has been conducted by Uyanik et al. (2018) on 35 studies containing the location selection problem for a logistics centre. The review classified the applied approaches into Multi-criteria decision making techniques (MCDM) and mathematical models and proper solution techniques. The majority of studies relied on Multi-criteria decision making techniques to choose the appropriate location of logistics centres particularly the Analytic Hierarchy Process (AHP), which has been reported as the most preferred method implemented to choose the appropriate location. Although mathematical models and proper solution techniques were not widely applied like MCDM techniques, they have been used in an integrated manner with Fuzzy Logic and MCDM techniques. The review also identified the evaluation criteria based on four main categories: Cost, Cargo Capacity/Economic Reflections, Environment, Location and Social Factors.

In the research, complex multi stage ranking framework is proposed to evaluate the suitability of cities to locate logistics centres based on macro criteria boundaries.

Logistics centre location problem is solved at two phases. At the first phase, macro criteria boundaries are considered to evaluate the suitability of cities to locate logistics centres, while at the second phase, the focus should be on micro level analysis to determine the most appropriate specific location within the previously selected city at the first phase (Daganzo, 1996; Żak and Węgliński, 2014). This research focuses on the first phase of problem solving by conducting the macro analysis following a complex multi stage ranking process.

Complex multi stage ranking process based on three level hierarchical problem was established to rank cities in the region from the best to the worst in terms of their suitability for locating the logistics centre. At the first level, distance matrix was constructed to measure the average distance between each city and other cities in the region. After excluding cities with distance longer than the average distance; production as a proxy of supply and population of each city as a proxy of demand were measured to choose cities with highest demand and supply. Finally, trade capacity for each city in terms of number of wholesale and retail institutions were considered along with trade values in order to select the most appropriate cities in each region to establish regional logistics centre which can serve as a hub to the whole region.

Figure 2 illustrates complex multi stage ranking framework comprising 9 criteria representing different aspects of evaluation. At level 1, Distance matrix (C1) measures the distance to select the cities with minimum average distance to other cities in the region. Level 2 measures the demand in terms of Population (C2) and the supply in terms of production (C3) in order to consider the cities with maximum demand and supply. At level 3, the maximum trade capacity is measured based on wholesale value (C4), whole purchase value (C5), No of wholesale institutions (C6), retail sale value (C7), retail purchase value (C8), No of retail institutions (C9).

An empirical study on Egypt was conducted in order to select the best cities to locate the regional logistics centres following the complex multi stage ranking process illustrated above. The Egyptian 27 governorates were classified in three regions (Delta region, Middle Egypt and Upper Egypt).

For each governorate, data in 2017 was collected as follows: Population, Total Production of 26 Harvest of three seasons (summer –winter - indigo), Wholesale and retail data was collected from the Egyptian Central Agency for Public Mobilization and Statistics (CAPMAS). Global prices of crops in US dollar were collected from Food and Agriculture Organization of the United Nations (FAO).

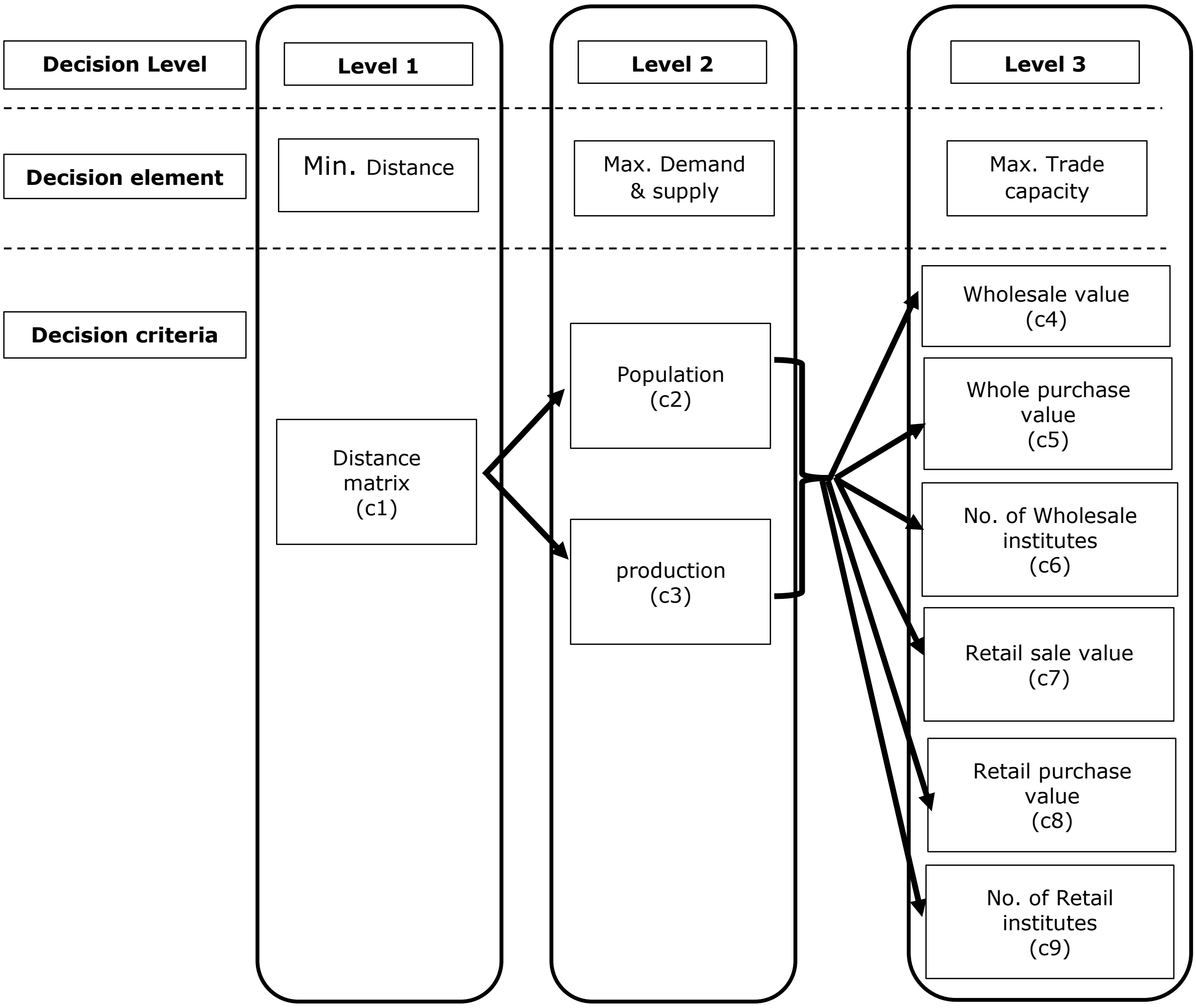


Figure 2: Complex multi stage ranking framework

EMPIRICAL STUDY

As illustrated in tables 1, 2 and 3, each region has been evaluated following the proposed complex multi stage ranking framwork. At level 1, for each governorate, distance (C1) to other governorates in the region was measured in km to select governorates with minimum average distance. At level 2, the demand for each governorate in terms of population (C2) and the supply in terms of production value (harvest quantities of three seasons multiplied by their average prices)(C3) were measured in order to consider the governorates with maximum demand and supply. At level 3, the maximum trade capacity was measured based on wholesale value (C4), whole purchase value (C5), No of wholesale institutions (C6), retail sale value (C7), retail purchase value (C8), No of retail institutions (C9).

After considering the 9 macro analysis criteria, the analysis revealed 4 governorates out of 13 to serve as regional logistics centres for Delta region. 2 governorates out of 6 can serve as regional logistics centres in Upper Egypt, while 2 governorates out of 8 can serve as regional logistics centres in Middle Egypt.

Governorate	Level 1	Level 2		Level 3					
	Min. Distance	Max. Demand & Supply		Max. Trade Capacity					
				Wholesale trade capacity			Retail trade capcity		
	C1	C2	C3	C4	C5	C6	C7	C8	C9
Matrouh	5798 km	442547 Citizen	120378163.9 EGP	56258	49020	96	3631327	3015262	15177
Alexandria	2779.9	5232812	371577894	74704506	68016273	4202	72389093	59816584	102121
El-Behaira	2635.8	6300531	3093311093	2475608	2029054	1873	13480142	10375525	73139
Kafr Elsheikh	2159	3428269	1356076681	3015839	2013518	816	10958833	6950726	30253
El- Dakahleya	2095.7	6601336	1522944808	8155785	7772430	1746	23714380	19023035	81923
Domyat	2129.3	1520245	234134656.7	951236	654244	474	13527392	9485992	32816
Port Said	2743.4	757062	93626195.58	6889397	5027362	951	9033011	7476660	24006
North Sinia	4234	457849	92268971.54	62395	51590	140	4221299	3278671	14146
El-Kharbeya	2007.9	5085110	861775845	8140554	7134949	2131	31802131	25912686	66073
El- Menofeya	1999.9	4380595	737585596.4	454882	355542	568	7139992	6150280	30904
El- Qalyobeya	2092.1	5719151	269427627.8	7593287	6307220	4201	23739967	19679561	68560
El- Sharkeya	2003	7292776	1691220548	7500868	5089732	1365	22247970	16806709	61850
El- Ismaielya	2677.8	1328771	287607976	1378346	1277613	678	5359803	4277950	23280
Average	2719.7	3734388.8	825533542.8	9336843.2	8136811.3	1480	18557333.9	14788433.9	48019

Table 1: complex multi stage ranking process for Delta region

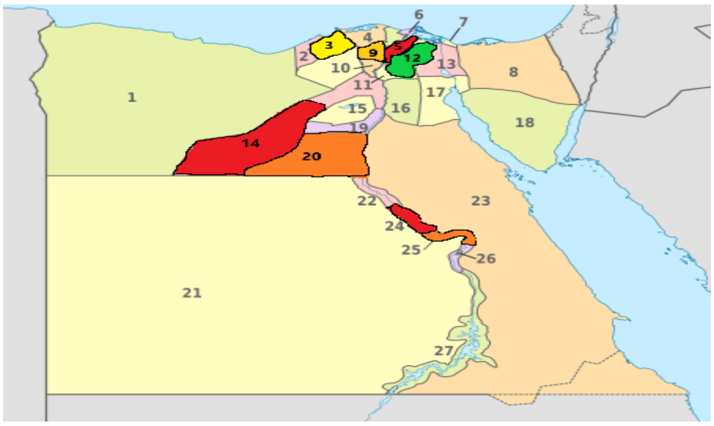
Governorate	Level 1	Level 2		Level 3					
	Min. Distance	Max. Demand & Supply		Max. Trade Capacity					
				Wholesale trade capacity			Retail trade capacity		
	C1	C2	C3	C4	C5	C6	C7	C8	C9
Asyut	1859.24	4491949	326806982.1	320308	284053	412	21516515	19145243	47719
Red Sea	1917	1507749	0	3011282	2639350	88	2241008	1711070	9094
Sohag	1461	5092790	379023567	1029928	836913	1255	14913844	12689795	55209
Qena	1121.2	3242941	395046871.8	2251925	2190	342	3512095	3016922	23393
Luxor	1165	1275026	240837340.5	196552	149135	249	10697655	8904792	42486
Aswan	1678	1507749	237984035.8	367123	263653	1083	5194366	3876185	25618
Average	1533.6	2853034	263283132.9	1196186.3	695882.3	571	9679247.2	8224001.2	33920

Table 2: complex multi stage ranking process for Upper Egypt region

Governorate	Level 1	Level 2		Level 3					
	Min. Distance	Max. Demand & Supply		Max. Trade Capacity					
				Wholesale trade capacity			Retail trade capacity		
	C1	C2	C3	C4	C5	C6	C7	C8	C9
Faiyom	1907	3680696	636772976.7	12619646	9946554	42251	345473	264350	685
Cairo	2120	9678726	1916078.84	195644788	178729837	131581	209713775	185876709	10346
Suez	2168	739847	28114993.6	6759609	5302867	16833	129957	96516	337
South Sinai	3186	104225	1333897.653	12493974	8707569	18871	96600	92000	80
Beni Suef	1749	3231318	571811912.5	6533090	5301041	30799	934903	679423	346
Minya	1796	5631872	939422977.3	14125520	11338718	56358	944428	871211	924
New Village	5261	245998	257003149.4	4140826	3397781	15617	136450	108920	153
Giza	2289	8785990	491325975.4	82915008	74069065	68684	72620905	60525492	2852
Average	2559.5	4012334	365962745.2	41904057.6	37099179	47624	35615311.4	31064327.6	1965

Table 3: complex multi stage ranking process for Middle Egypt region

Figure 3 illustrates the potential governorates for locating logistics centres. From a practical point of view, the results can be summarized as follows: in case of setting priorities or stages for investments, the best governorates for placing the logistics centres in their regions are El- Dakahleya (in Delta), El- Giza (in middle Egypt region) and Sohag (in Upper Egypt region) due to minimum average distance to other cities in the region, the highest demand and supply in terms of population and production and the maximum trade capacity. The second preferences should be El- Gharbeya (in Delta), El- Minya (in middle Egypt region), Qena (in Upper Egypt region).



Code	Governorate
3	El- Sharqya
5	El- Dakahleya
9	El- Gharbeya
12	El- Behaira
14	El- Giza
20	El- Minya
24	Sohag
25	Qena

Figure 3: the potential governorates for locating logistics centres.

Figure 4 illustrates the first phase of selection process, where the best governorates to locate logistics centres are identified following macro analysis criteria. At the second phase, specific locations within each governorate should be evaluated to select the best location following micro level analysis; where specific stakeholders, objectives, descriptor and perceptive are considered.

Phase 1: Macro level analysis ⟶ Select a governorate

- Level 1: Average distance
- Level 2: Population & production
- Level 3: wholesale value, whole purchase value, No of wholesale institutions, retail sale value, retail purchase value, No of retail institutions

Phase 2: Micro level analysis ⟶ Select a location in a governorate

- Stakeholder (public, private)
- objective (economic, efficiency, road-safety, environment, infrastructure & management, urban structure)
- descriptor (traffic flow, commodity flow)
- perspective (infrastructure, technology, behaviour, policy)

Figure 4: Logistics centre location modelling

CONCLUSION

The paper highlighted the complexity of logistics centre location selection given independent and partially conflicting criteria. The paper proposed multi stage process to locate logistics centre based on two phases for selection process in order to avoid biasness and misleading decisions. At the first phase, macro level decision is taken based on macro criteria to choose the most appropriate region/city in the country, then micro level analysis is conducted to choose a specific location with the region/city taking into consideration specific identified elements (stakeholders' involvement, objective of modelling, the descriptor for modelling and the perceptive).

The paper proposed complex multi stage ranking framework to select the most desirable location of the logistics centre at macro level. Multiple criteria evaluation of distance, demand, supply, trade capacity is considered. The decision problem is formulated as a multi stage ranking process based on three level hierarchical problem. An empirical study on the Egyptian governorates was conducted to rank their suitability from the best to the worst to locate logistics centre.

The proposed framework can be generalized to select location of the logistics centre in any region in any country. Further research can extend the methodology with adjustments of evaluation criteria to solve the location problem of any other categories of the logistics facilities, including shopping centres and transportation hubs. The proposed framework focuses on solving location problem at macro level to select the most suitable city. Further research should involve the micro analysis to select specific locations for the logistics centres in the selected cities.

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PLAYFUL TRAINING FOR UNDERSTANDING ACTIVITIES, ROLES, AND STAKEHOLDER IN URBAN LOGISTICS

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Purpose
Urban logistics involves a number of different stakeholders ranging from local decision makers, community groups, customers to larger companies. Governments and local authorities pay increasing attention for improving quality of life, reducing the emissions, and ensuring high service quality to all citizens. Successful urban city logistics require holistic and systematic approaches taking all perspectives and stakeholders' requirement into account on micro, meso and macro level (Weber, 2002). This requires a good understanding of the different stakeholders of their activities and roles at different levels to develop a common understanding and foster collaboration among them (Lindholm, 2012; Gammelgaard, 2015). We propose a cooperative digital game for training potential stakeholders in urban logistics. The emphasis lies on mutual understanding of different needs and requirements and that cooperative strategy are more likely to give an optimized, holistic solution than the competitive.

Design/methodology/approach
Serious games and game-based learning has been used for various task in the domain of logistics. In our work, we focus on two aspects that are particularly relevant in urban logistics, namely collaboration, and cooperation of players with different roles, capabilities, and interests. In designing the educational game, we wanted to embed the real-world settings deep into the game mechanics and not just add gamification into a training tool. The game mechanics we used have been adapted from a cooperative board game. In contrast to other games, players have different roles with different abilities and can only win when they cooperate and understand these different roles. Our prototype translates this into logistics problems in a digital multi-user game for training. In a proof of concept, we could show in a first qualitative analysis the feasibility of this approach.

Findings
This paper shows the potential of a game-based tool for training stakeholder involved in urban logistics with an emphasis on cooperative problem-solving.

Value
The visualization of the interaction and mutual influence on the decision-making process are difficult to visualize, therefore many problems in logistics have been simulated as optimization problems, where the different participants can individually follow their optimization strategy. Our setup focuses on logistics problems that require the cooperation of different stakeholders who have different roles and provides an environment in which

the participants can experience the dependencies and cooperatively develop suitable solutions to meet the needs of the different stakeholders.

Research limitations/implications
So far, our game prototype is still limited to simple logistics scenarios with a maximum of two players in different roles. We plan to extend the system into a flexible platform that can easily be adapted to a broader range of logistics applications

1. INTRODUCTION

Even though urban logistics is a subject that has been studied for several years, there is a continuous need for updates due to the continuous changes in citizens' habits and technological development that impacts the preferred delivery schemes which include electric vehicles, bikes, drones, and autonomous vehicles. Urban mobility solutions are often provided by authorities (Kornevs, 2019), but are used and need to be accepted by stakeholders like citizens, mobility and technology service providers, local companies, etc. For achieving this, it is imperative that stakeholders are involved in the decision-making process (Lagorio et al., 2016) and to understand how this can be nurtured (Lagorio et al., 2016; Gonzalez-Feliu, 2018). The Challenges in regard to the collaborative decision making process are the conflicting goals of the involved stakeholders as the high number of stakeholders makes it difficult to reach common agreements (Österle et al., 2015) and foster mutual understanding of the needs of the other stakeholders(Lindholm, 2012; Gammelgaard, 2015; Oliveira et al., 2018).

Games, in particular, simulation games can attract people to participate or learn about urban planning and mobility solutions (Poplin, 2011, Shreenath et al., 2015, Kornevs et al. 2018) as well as urban logistics (Anand et al., 2016, Raghothamaet al.,2018) in a playful way. Games can enable players to make decisions in an experimental, risk-free environment (Baalsrud Hauge & Riedel, 2012). Even if some relevant games are designed as role-playing games so that the players can experience different perspectives (Citylogisticsgame.com, 2019; Marcucci et al., 2018), it is difficult to understand and analyze the influence of the game mechanics versus the human-human interaction and the influence of these components on collaboration between players (Siu et al., 2014; Knöll et al., 2014). The main objective of this research is, therefore, to focus on analyzing the contribution to cooperation coming from the game-mechanics and from the human interactions with each other. For this purpose, we have modeled an entertainment game, with similar decision-making processes (in this case to cure the world) to urban logistics scenario.

The structure of this paper is as follows: in section 2, we describe methodology and approach. In section 3, we propose the requirements analysis on cooperation in urban logistics planning and operations. In section 4, we identify the game elements that we used for implementing our game prototype. In section 5, we describe the mechanics of the Pandemic game. In section 6, we show how to adapt Pandemic game for a scenario on urban logistics. Section 7, we describe the experiment. We then describe the results and the conclusion in section 8 and 9.

2. RESEARCH METHODOLOGY

Based on previous research (Kornevs, 2019, Slotterback, 2010, Macucci et al. 2016) it can be concluded that the usage of games in a participatory workshop setting may improve the stakeholders' involvement. Based on this finding, we have used action-based research to investigate how the game mechanics contribute to the in-game cooperation. A collaborative entertainment game with similar decision-making structure was selected and modded for an experiment with 30 participants. We conducted the experiment to investigate the mechanics of the game, which is to motivate players to cooperate as well as to make the players understand the role of their partner. Then, we evaluated the game by using a semi-structured interview with 30 participants — the details of this experiment are discussed in section 7. Further, we propose modifications to extend our game prototype for urban logistics scenario.

3. REQUIREMENT ANALYSIS ON COOPERATION IN URBAN LOGISTICS AND PLANNING

The number of stakeholders with conflicting or partly conflicting needs involved in many urban mobility solutions is high. It is, therefore, a need for tools that support effective cooperation of all stakeholders. There are available tools, like games, gamification, simulations, etc., for improving the involvement of the stakeholders into policy development and strategic planning processes, but due to lack of understanding, and often also the lack of sufficient adaptability for each single mobility solution, they often remain unused.(Lindholm, 2012; Lagorio et al., 2016).

As mentioned above, a key challenge is to foster mutual understanding and cooperation among the stakeholders (Graham et al., 2015). This again require that we have a clear understanding of how the cooperation elements (here the game mechanics) work and how they interact with the players.

4. MAPPING THE REQUIREMENT ON COOPERATION IN URBAN LOGISTICS AND PLANNING TO COOPERATIVE BOARD GAME (PANDEMIC GAME).

From the literature, it is proposed that the concept of collaborative board game can be used for developing digital cooperative games as the games have unique mechanics to engage people in collaborative activities in the decision level (Zagal et al., 2006; Linderoth, 2011; Xu et al., 2011; Olsson, Björk & Dahlskog, 2014).
We have selected a reference game based on the environment that would support in the design of a game for urban logistics. The scenarios of urban logistics from literature were analyzed and used in the selection. The main criteria used in the selection of the reference game are as follows:

- The games where the players need to deal with a map or a network as this match with the type of environment required for logistics game.
- The multiplayer games which require the players to help each other to complete the game goal.
- The games which mandate the players to cooperate on the decision level.
- The games where the players need to make decisions based on their roles.

We then looked at the possible board games that can serve the above requirements. We found that the Pandemic board game (Zmangames.com, 2019) is one of the possible games that can be used as a reference game for implementing our prototype. The Pandemic game was as it satisfies all the requirements in our criteria.

5. DESCRIPTION OF PANDEMIC GAME

We implemented the game prototype based on the gameplay of the Pandemic game. We decided not to put the urban logistics content in the game prototype as our main focus was to validate that the cooperative board games can make the participants (stakeholders) realize the importance of cooperation and to understand the role of their partners. The game premise of the original game was used for this version of the game prototype. However, we also discuss the implementation of the cooperative board game for the urban logistics content in the next section. The following are the game elements of our game prototype.

Game setting
The game consists of two regions from the world map with 24 major cities spread across continents. The two regions are shown in different colors. There are two diseases spreading through these regions, which are represented by small cubes which match the colors of regions from where they originate(Figure 20).

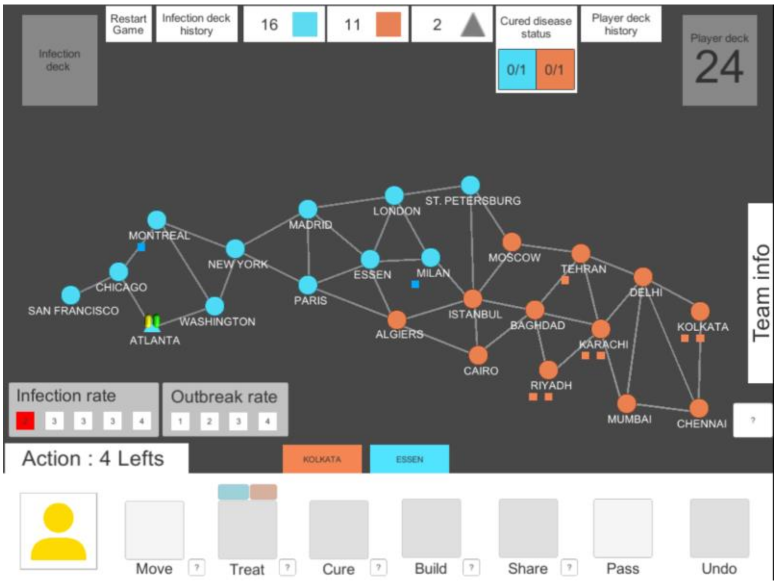


Figure 20 The example of the game prototype.

Game goal
The goal of the game is to stop the spreading of the diseases by discovering the cure of the disease before it turns pandemic. The players have to work cooperatively in order to win the game.

Gameplay
The game begins with the spreading of infection cubes from the infection deck. The number of cubes in each city indicates the infection state of the city. The players take turns while playing the game, and each player turn consists of three phases as described below. In other words, each player must carry out three tasks in each turn:

- Task 1 - Action phase: Here, the player needs to execute four actions of the total eight actions available. There are two types of actions, namely movement actions and actions for treating / discovering the cure for the diseases.
- Task 2 - Draw phase: The player draws two cards from the PLAYER DECK. There are two kinds of cards that players can receive from the player deck, namely city cards and epidemic cards. The players use city cards to travel. Sufficient city cards of the same region enable the players to discover the cure for the diseases, while the epidemic card increases the infection rate of the diseases.
- Task 3 - Infection phase: The player draws two cards from INFECTION DECK, and the infection cubes are placed on the respective cities as per the drawn cards.

The game ends when one of the following conditions occur:

- the player cards run out. At the end of the player turn, the player needs to draw cards from the player deck, and if there are no cards left in the player deck, the players lose the game.
- the infection cubes run out. At the end of each player turn, the player needs to draw cards from infection deck. If there are no infection cubes on the storage left, the players lose the game.

- "outbreak" occurs more than four times. An outbreak occurs whenever a city has more than three infection cubes and hence, leads to a cascade effect, spreading cubes to adjacent cities.
- players discover a cure for all two diseases. This is the only condition that the players win the game.

Since our study focuses on applying cooperative game for increasing the understanding among different stakeholder roles in logistics, we added an additional game element pertaining to the original Pandemic game in our experiment. This element is the special ability of players. The game in our experiment accommodates two players, each employing one of the three roles. The roles are dispatcher, medic, scientist, researcher, and operations expert. Each role has different special abilities which support their actions in the game.

6. IMPLEMENT THE CONCEPT OF COOPERATIVE BOARD GAMES FOR SUPPORTING AWARENESS OF STAKEHOLDERS INVOLVEMENT IN URBAN LOGISTICS

This section describes the relation between the requirements for urban logistics and the mechanics of the Pandemic game by using the Activity Theory-based Model for Serious Game (ATMSG) (Carvalho et al., 2015).

In the first step, it is described how the game prototype motivates players to cooperate. This is followed by a mapping of the game components with the requirements motivating higher stakeholders' involvement in the decision-making process.

The description of the gaming activity and identification of subjects/ players/ users, as well as the objective of the game, are given in Table 5.

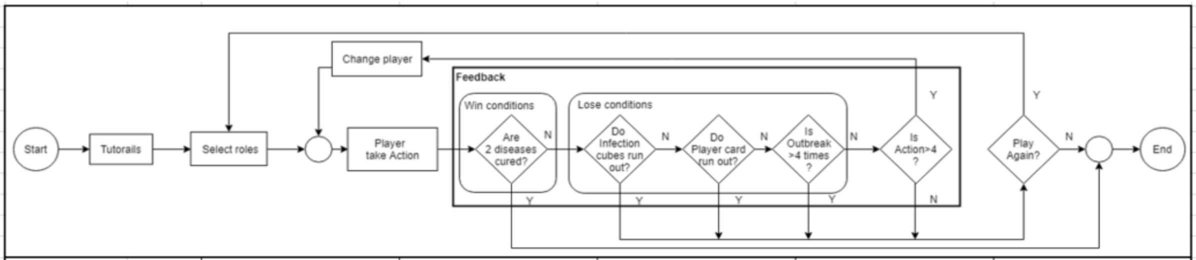
Activity	Subject / Actor	Description
Gaming	Students in Production Engineering Faculty	The objective of the game is motivating players to have awareness and understand the roles of different stakeholder in urban logistics
Learning	Students in Production Engineering Faculty	The students are able to remember and understand the role of their partner in order to cooperate for planing and decision making.
Instrinsic Instruction	Production Engineering Faculty	The participants realise the importance of involving in the planning and decision-making process in order to solve problems in urban logistics.

Table 5. Activity Description of cooperative board game.

Based on the ATMSG methodology and the identified subjects and activities in Table 5, as well as having the requirements on stakeholders' motivation in mind, we propose the design of a prototype for urban logistics scenario. The objective is to encourage the stakeholders to be more involved in the decision-making process by increasing the understanding of the role of the other player, with whom the player has to co-operate in order to win the game. The relation of the game components with the objective is present in Figure 21.

As explained in section 5, we have used an existing game and modify the game scenario to an urban logistics scenario.

Here, we propose the modifications to adapt the Pandemic game scenario to an urban logistics scenario. Firstly, we propose to change the game premise which is the story behind the game. Secondly, we propose to change the name of the actions that players need to take in the game. Thirdly, the roles of players also need to be adapted as they are different from the original Pandemic game version. However, the gameplay remains the same. The new game goal adapted to the urban logistics scenario is to ask players who play the roles as one of stakeholders in the city (Traffic police, Logistic Service Provider and Hub operator) to cooperate for solving the traffic jam and pollution problems. The examples for changing the game premise and roles from Pandemic game to urban logistics contents are shown in Table 6.



		Tutorail	Select role	Player take Action	Feedback	Change player
Gaming	Action	Obtain instruction	Select	Select the Actions: Move, Treat, Cure, Build	See performance evaluations	Change player turn
	Tool	Tutorail	Role play	Random scenarios, Events	Feedback: Give the reasons for Win and Lost	Role play; Limited turns of player; Events
	Goal	Config game	Learn to use special ability of the roles	Complete task	Maximize performance	Learn the different of the roles
Learning	Action	Read,Click	Read	Repetition; Experimenting	Verifying / Reviewing	Analyzing: Discover
	Tool	Tell story	Information	Challenge which require cooperation with other roles	Report	Interaction;Group discussion
	Goal	Remembering game rule	Remembering different role in urban logistic	Be aware of the importance for cooperation of different roles in urban logistics	Understanding	Understanding: to understand the importance of cooperation in urban logistics
Intrisinc Instrcution	Action	Demonstrating		Repetition	Present problem; Recover from errors	
	Tool	Event		Challenge; Multiple chance; Limited set of choice	Perfomance measure	
	Goal	Provide learning guidance		Gain attention	Providing feedback	

Figure 21. The relation of the game prototype components with the objective to motivate stakeholder involvement in the decision-making process (Game blueprint).

7. EXPERIMENT

In order to validate that our mechanics of the cooperative board game can also be used for motivating the players to have more understanding in cooperation mechanism in decision-making process, our experiment was conducted using the following procedure.

Procedure

The game prototype used in the experiments uses the same mechanics of cooperative board game (Zmangames.com, 2019), shown in Figure 21. 30 students and researchers at the University of Bremen participated in the experiment. The participants were randomly paired as a team to play in one session. Each participant completed a consent form, participated in two tutorials on the game's rules before playing two different modes of the game (regular and special ability mode). The difference between the two modes is that in the first mode, both the players in each session have the same abilities and role while in the latter mode, the players have individual roles and different abilities. For example, in normal mode, every player has the same role and abilities to travel along the map and to treat the infection by taking one action. In the special ability mode, the players have different roles, and each role has different special abilities that make them travel faster, treat infection faster, and build research center easier (see Table 6). Finally, each player was interviewed after the game play session.

	Pandemic	Urban mobility
Premise	Two of diseases (red and blue) are spreading around the world. You and your partner try to save the world by cure the diseases. You need to stop spreading of infections (red and blue cubes by treating and finding the cure for the diseases. The research centers are built for discovering the cure. The research center is required at least one for each color.	You and your partner are inhabitants and also stakeholder involved in the city freight distributions of the "Bre-Mai" city. There are several shops running business in the city center. The shops require service for distribution product from manufacturers which located outside the city center into the city. The city center has limitation of deliver the goods due to narrow streets and limitation of parking in front of the shops. This led to the traffic jams and pollution problems of the city. Our team need to stop the mentioned problems by discovering the solution of traffic congestion in each Street of the city.
Role	**Medic** **Special abilities:** a.Remove all cubes of one color when doing Treat diseases. b.Automatically prevent cube from the city you are in.	**Traffic police** **Special abilities:** a.Remove all kind of the transport of one color when doing Release traffic jam actions. b.Automatically solve traffic problem (any vechicle cannot be added) to the Street you are in.
	Dispatcher **Special abilities:** a.Move another player as it were yours. b.As an action, move any pawn to a Node with another pawn	**Logistic Service Provider** **Special abilities:** a.Move another player as it were yours. b.As an action, move any pawn to the Street with another pawn.
	Operational expert **Special abilities:** a.As an action, build research center on the Node you are in (No city cards needed). b.Once per turn as an action, move from a research center to any city by discarding any city cards	**Hub operator** **Special abilities:** a.As an action, build UCC on the Street you are in (No Street card needed). b.Once per turn as an action, move from a UCC to any Street by discarding any Street cards.

Table 6 The proposed idea to put urban logistics content into our game prototype.

Interview

The main objective of the experiment was to investigate if the gameplay (i.e., the game mechanics) motivated the players to cooperate in the decision-making process. We have done a semi-structured interview with 30 participants. The questions asked, therefore, relate to two issues: partner and to the roles of players.

For the questions related to the partner, we asked their opinions if they needed to play this game with another player. As the game mechanic here is collaborative playing, this question helps us to understand if the game mechanic is effective from the player's view of the game. We also would like to know when the players felt that they need another player during the game.

For the questions related to the roles of players, we asked their opinions on the special abilities. We would like to know what they remember about the roles and abilities of their partner. We checked the correctness of their answers to validate their understanding of the role of the other player. This helps us to understand if the players plan their moves cooperatively by using their special abilities, which directly measures the impact of the game mechanic.

8. RESULTS

To analysis the interview results, we first collected the answers and classify them into two main categories namely, Answers related to the partner and Answers related to the roles of players.

Then, we summarized the similar answers to reduce the number of statements. Then, when we scanned the answers, a new topic emerged besides the two that we had already defined for the interview. Hence, we added the newly identified topic called Cooperative planning into the categories. Finally, the answers were categorized into three categories: Answers related to the partner, Answer related to cooperative planning and decision-making, and Answers related to the roles of players. The results along with these categories are presented below.

We found that more than 90% of the participants prefer to play the game with another partner. Considering the interview answers, there are three major reasons. 24 of 30 participants mentioned that they require another player in the situations, when they were about to lose the game. 8 of 30 participants mentioned that they need another player to help them to make decisions and to confirm their decisions. 6 of 30 participants mentioned that they need another player to confirm the rules of the game. 2 of 30 participants mentioned that they could play the game by themselves; they do not need another player to support them.

From the reasons mentioned above, we found that there are two objectives for participants to cooperate during the game namely, cooperative planning and decision-making. The participants mentioned that after having the experience of losing the game once, 21 of 30 participants started to develop the plan together. The players started to plan their actions collaboratively with their partner's actions. For example, they planned to stay in the different continents in order to help each other to treat the disease in their own continents. Moreover, 28 of 30 participants considered the special ability for their planning and decision-making. Since the players tried to use the special ability for planning, they had to remember both their own special ability and the partner's special ability in order to develop the plan that can minimize their actions (e.g. to move, to treat).

Moving to another main point, the roles of the players, we asked the participants to recall what were the roles that their team selected to use in the special ability mode. Then, we asked them what the special abilities of those roles were. We found that 26 of 30 participants can remember all the special abilities of their partners. After that, we asked their opinion on the usefulness of the special ability mode with the gameplay. 24 of 30 participants mentioned that, use of the special abilities helped them to win the game easier compared to playing the normal mode (without special abilities).

9. CONCLUSION

In this section, we summarize the accumulated interview data related to our research questions. We can prove that the mechanics of cooperative board games can be used for motivating players to realize the importance of having another person as a partner for planning and making decisions. The evidence showed that the players realize that they require a partner, especially, when the players were in tough situations. This finding can be used to emphasize the need of understanding among stakeholders regarding their involvement in the decision-making process related to urban logistics. We should consider the conditions or situations that make stakeholders feel that the contribution from another stakeholder is required. For example, we can change the action 'Treat' in the Pandemic game to be 'Release traffic jam' in urban logistics scenario. Then, we consider the effect of a traffic jam of one junction to the adjacent junction as the situation, that forces the players to cooperate.

We found that role play is the mechanics that encourage participants to understand the role of their partner. The results were significant as the participants can compare between normal mode and the special ability mode. The participants found that it was easier for them to achieve the game goal if both of them can find a role which can support each other. It means that the participants found the importance of having another person with different ability to help them to solve the problems. Besides that, in the perspective of cooperation, it is important for the stakeholder to know their own tasks and the partner's tasks before they involve in any planning or decision-making process. However, this game prototype is limited to two players. We plan to improve the game to have more players.

In the future, we also plan to extend the game prototype by adding the content of urban logistics. Additionally, we will include the experts in the urban logistics area to test the game in order to retrieve the feedback related to the logistics content.

ACKNOWLEDGMENTS

Chiang Mai University is acknowledged, the H2020 Beaconing Project, Grant agreement no. 687676 and German Federal Ministry of Education and Research (BMBF) through the project DigiLab4U (No. 16DHB2112/3).

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LSP SELECTION IN THE CONTEXT OF PHYSICAL INTERNET: A COMPREHENSIVE ANALYSIS OF THE LITERATURE

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ABSTRACT
The impact of sustainable development elements is significant, especially in the context of logistics outsourcing decision-making. To achieve a more environmental, financial and social sustainable logistics, Physical Internet seems to be a promising area. Many academic works are looking into the importance of logistics service providers (LSPs), the evaluation of their performance, and their selection in the logistics outsourcing process. Furthermore, LSP selection involving sustainable development elements in a Physical Internet perspective and its impact need to be deeply studied. The extent to which sustainable development elements influence the supply chain system is discussed here based on Porter's (1985) value chain model.

INTRODUCTION
The modern globalized supply system requires great integration of transportation, quick response management and cooperative work (Christopher, 2016). It is not only about multi-service demand, but also multi-cooperation, multi-platform transformations, etc. Logistics management no longer plays the basic role of physically moving goods. Its evaluation principle is far more than just its economic performance (*tactical level*), integrating a supply chain perspective (*strategic level*). As a matter of fact, a current logistics trend is that a growing number of shippers –manufacturers and large retailers– and logistics service companies have already established the unification and integration of logistics resources based on those demands (Markillie, 2006). The examination of barriers and the perception of physical transportation process as a big unit corresponds to the concept of Physical Internet which means a precondition for open and collaborative logistics systems (Montreuil, 2011)[6].

On the other side, with the use of Internet, it is certain that the temporary logistical activities may cause several negative effects on their surrounding environment and Society. Relevant research are focusing on sustainable development (SD), technological innovation, energy efficiency, stockholders and organizational awareness, LSP operation, customer priorities, managerial complexity on standards, methods, platforms establishment, network imbalances in goods flow and system restrictions, material uncertainties, etc. (Abbasi and Nilsson, 2016). It appears that logistics management is not only about the internal activity, but also about how more than one major player engages with several different agents, as described by Jensen and Meckling (1976) in the agency theory. As also mentioned by Coase (1937), the company's activities can be performed in best-cost conditions by outsourcing these activities to external providers.

According to current logistics development trends, the appearance and implementation of Physical Internet will enhance the efficiency of the entire supply chain system. The reason for this is that it reflects the interactions in and between natural, social, and economic flows as described in the material flow theory (Hou *et al.*, 2017). This

[6] As underlined by Pan *et al.* (2017:2604), the Physical Internet can be defined as "an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols… It represents an open, global, interconnected and sustainable logistics system. This system is based on standard and smart modular containers that are easily transported through all transport means (e.g. planes, trucks, barges, drones and private cars)".

automatically avoids wasting resources and materials in an incomplete logistics integration that seems to have been affected by the sustainability debate (Centobelli *et al.*, 2017), and Physical Internet achieves the three bottom lines of environmental, economic and social sustainability (Slaper and Hall, 2011; Elkington, 2013; Lewis *et al.*, 2018). Although a Physical Internet trend exists, it could only take effect under the consideration of main logistical links with the SD factor and improve the entire logistics system (Ounnar and Pujo, 2016). While under this precondition, the consideration of multi-criteria on LSP selection decision-making while taking into account SD indicators can be more reasonable and meaningful.

The present work focuses on LSPs and more particularly on the LSP selection in the context of Physical Internet. Indeed, the importance of LSPs is raised along with its challenge about how to translate green efforts into practice (Fulconis and Paché, 2011; Evangelista, 2014). The three main reasons for choosing an LSP perspective are: (1) the dominant role of LSPs in handling freight due to the increased logistics outsourcing by shippers (Wolf and Seuring, 2010); (2) the significant enlargement of LSP skills covering the requirements of the supply chain members (Aguezzoul, 2013); and (3) the increasing research stream available with a LSP perspective on SD (Lieb and Lieb, 2010; Abbasi and Nilsson, 2016; Evangelista *et al.*, 2018). This paper thereby introduces the multi-criteria-aided research approach combined with Porter's (1985) value chain model. An analysis of how much SD criteria and other classic criteria are used in the LSP selection decision-making process is derived, and finally, a structured list of criteria that are most cited in the literature is proposed.

RESEARCH APPROACH

SCM is a combination of production management, logistics management and physical distribution management. Any supply chain system can be viewed as an organization composed of communication of data, movement of goods, system operation and system cooperation. From this point of view, many theories can be applied in a SCM perspective (Sarkis *et al.*, 2010; Touboulic and Walker, 2015; Gligor *et al.*, 2019). As underlined by Halldorsson *et al.* (2007), it is necessary to consider several theories and how they may complement one another in order to provide a more comprehensive view of SCM. The value chain model introduces a number of fundamental and classic components in the entire supply chain (Porter, 1985). According to the value chain model, several basic blocks are identified (see Figure 1), but while we consider the complexity of all SD elements (Porter and Linde, 1995a, 1995b), these blocks should contain a specific SD element as indicated in blue in Figure 2. This part of "blue" elements has a significant or reduced impact on each block (Gereffi and Kaplinsky, 2001).

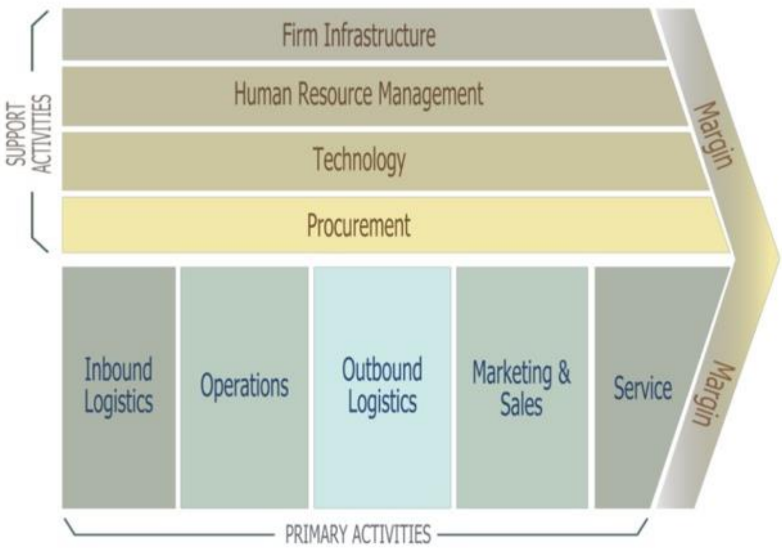


Figure 1. Porter's (1985) value chain model

Exhibit. What is value chain? Value chain analysis describes the activities within and around an organization and relates them to an analysis of the competitive strength of the organization. Therefore, it evaluates which value each specific activity adds to the organization products or services. This idea was built upon the insight that an organization is more than a random compilation of machinery, equipment, people and money. Only if these things are arranged into systems and systematic activates it will become possible to produce something for which customers are willing to pay a price. The ability to perform primary and support activities and to manage the linkages between these activities is a source of competitive advantage. Primary activities are directly concerned with the creation or delivery of a product or service. They can be grouped into five main areas: inbound logistics, operations, outbound logistics, marketing & sales, and service. Each of these primary activities is linked to support activities which help to improve their effectiveness or efficiency. There are four main areas of support activities: procurement, technology development (including R&D), human resource management, and infrastructure (systems for planning, finance, quality, information management, etc.). *Source*: Adapted from Recklies Management Project, 2001.

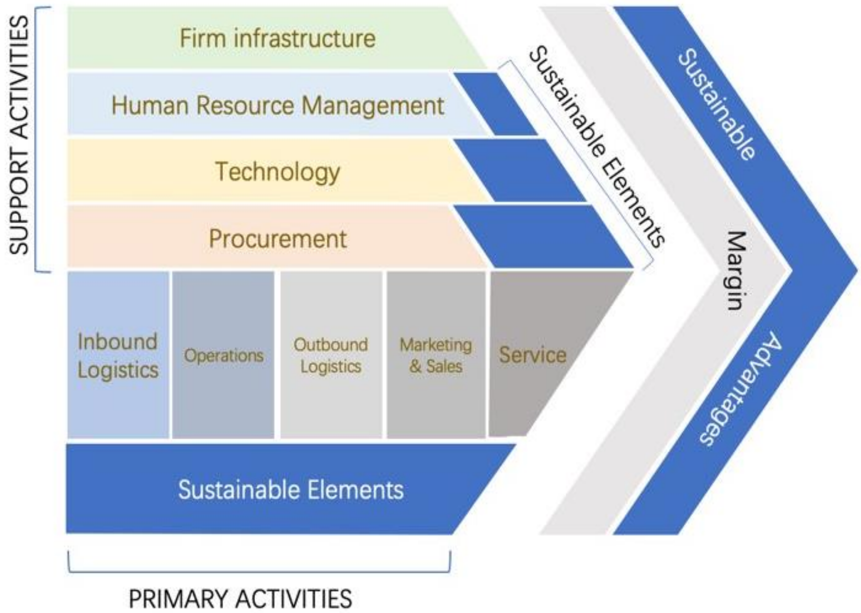


Figure 2. Proposed model

For a better understanding of our proposed model, some questions need to be further addressed. The three main questions are the following: (1) to what extent does the SD elements contribute to Porter's (1985) value chain blocks?; (2) will there be interconnection and interactivity among the blocks while in a SD context?; and (3) what indicators relative to SD should be considered during the LSP selection process not clearly identified yet?

METHODOLOGY

Which criteria and indicators are involved into the LSP selection decision-making process? This process can be analyzed in reference to three dimensions: (1) the *environmental performance*, based on sustainable standards defined by the company in terms of compliance with legal regulations, waste reduction and productivity (well developed); (2) the *economic performance*, based on inter-organizational business processes and the economic achievement (least mentioned); (3) the *operational performance*, based on the operations standard or indicators related to the efficiency and effectiveness of the process (well developed) (Centobelli *et al.*, 2017). This classification summarizes the evaluation principles in a macro perspective, but the identification of criteria/indicators and the multi-criteria decision structure should be constructed more precisely using a niche targeting approach.

According to the structure of Porter's (1985) value chain, a multi-criteria decision structure used during the decision-making procedure must thereby implemented. The first step of the investigation is based on a literature review. In this part of the work, we use 17 combinations of key words to identify the publications; all 689 indicators, including the SD indicators of 50 criteria, are identified throughout 86 publications relative to LSPs, SCM strategies, SD in the context of logistics outsourcing and SCM, and Physical Internet[7]. The second step aims at obtaining a comprehensive list of criteria and indicators that are most used in the literature.

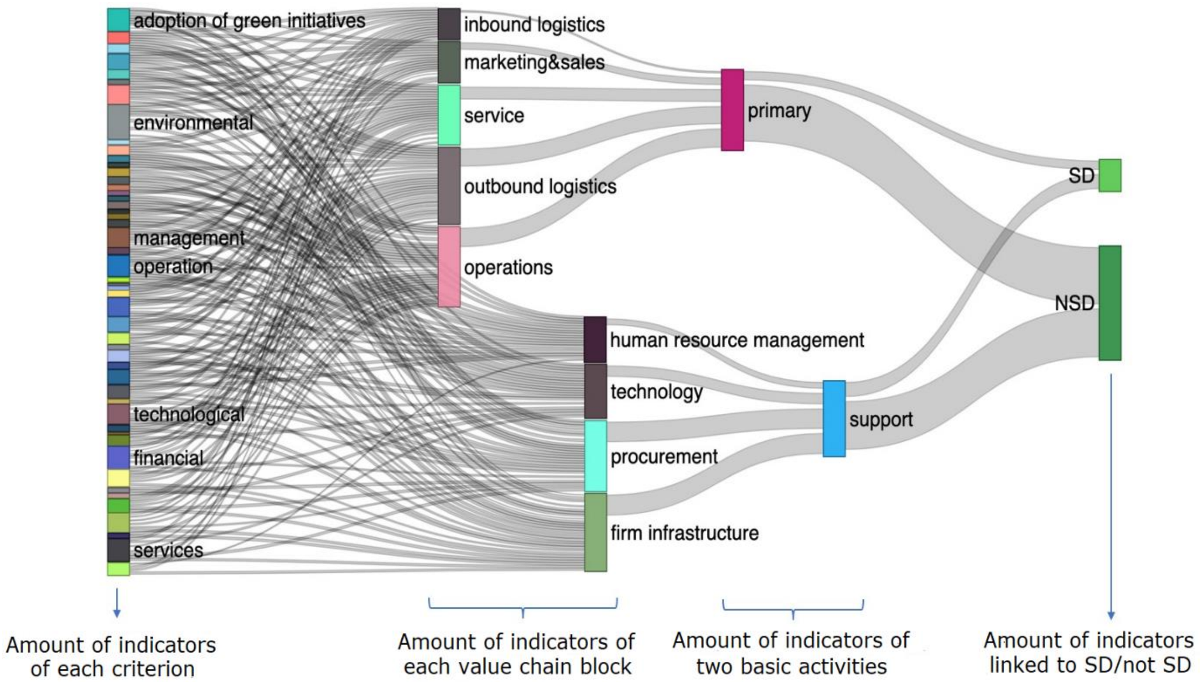
In order to categorize the different criteria, we consider the five following points: (1) by using a filter counting the number of occurrences cited in the publications, we can obtain a ranking of all the criteria mentioned in the collected publications; (2) each criterion contains several sub-criteria/indicators, a filtering of the total number of sub-criteria/indicators allows to have a ranking of criteria, in decreasing order; (3) according to Porter's (1985) value chain blocks, we can classify all the criteria by seeing what criteria are relative to which block; (4) according to Porter's (1985) value chain blocks, we can also identify which criteria take the most significant part of each value chain block; (5) from the sub-criteria involved in the SD elements, we can classify the criteria corresponding to the blocks in Porter's (1985) value chain.

The categorization will allow to select a criteria list in order to help making decisions on LSP selection. In a conventional way, the LSP selection is based on five methods widely investigated in the academic literature: the multi-criteria decision-making (MCDM) techniques, the statistical approaches, the artificial intelligence, the mathematical programming, and the hybrid methods (Galal *et al.*, 2018). In this paper, based on the previous points (3), (4) and (5), several data processing procedures have been done. The results are presented in the following developments; they suggest a list of criteria of selection according to the previous point (1). The LSP selection process considering SD criteria in the Physical Internet context could then be well identified.

ANALYSIS OF CRITERIA

The first step of criteria analysis gives a graphic description focusing on all the criteria and indicators collected from the literature review. The importance of each value chain block during the LSP selection process is exhibited in Figure 3. Each colored square shows a number of indicators from each item. Figure 3 indicates the "flow of indicators" that correspond to the use of these indicators in each part of the activities, and if they are SD indicators or not SD indicators (see Table 1). Under the framework of the value chain, we identify the distribution situation regarding the position of the considered indicators in the decision process of LSP selection in each block. Firstly, it shows that Porter's (1985) value chain model is suitable for this work, and secondly, as the indicators are distributed homogeneously, it also works with SD indicators.

[7] The list of publications is available from authors upon request.



*This does not show the absolute number of indicators, it only shows the proportion of each item within its own category.

Figure 3. Derived distribution map of criteria based on Porter's (1985) value chain model

Sustainable development (SD): **142**					Not sustainable development (not SD): **547**			
Support: 85			Primary: 57		Support: 253		Primary: 294	
Primary: 351					Support: 338			
Inbound logistics	Marketing & sales	Service	Outbound logistics	Operations	Human resource management	Technology	Procurement	Firm infrastructure
23	47	74	101	106	44	67	112	**115**

Table 1. Distribution of criteria composition by value chain blocks

It is obvious that the SD elements are still not properly taken into account these days, as there is a very significant difference between the total amount of SD and not SD indicators (142/547). Firstly, it is interesting to notice that the support activities seem to be more associated with SD elements while the inbound logistics and the outbound logistics resemble primary activities. At the present stage, companies are more likely to give attention to SD elements while making decisions on firm infrastructure activities as the financial cost, human cost and the facility cost are easier to control. Secondly, the more we study the figures, the more we can understand how many SD elements are used for LSP selection decision-making in each part of the value chain. Figure 4 is designed according to Table 2.

Value chain blocks	*Number of indicators not linked to SD elements*	*Number of indicators linked to SD elements*	*% of SD elements*
Firm infrastructure	78	37	32.17%
Procurement	73	39	34.82%
Operations	65	41	38.68%
Outbound logistics	94	7	6.93%
Service	91	3	3.19%
Technology	59	8	11.94%
Marketing & sales	43	4	8.51%
Human resource management	43	1	2.27%
Inbound logistics	21	2	8.70%

Table 2. Percentage of SD elements in each value chain block

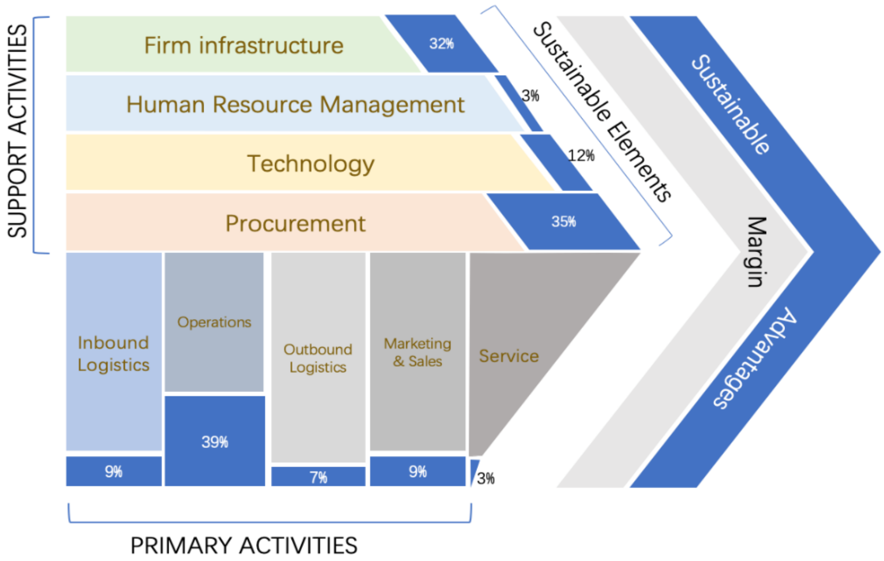


Figure 4. Value chain model with added SD elements

With this detailed model, it is easier to see that SD elements play a more important role in operational activities. These elements are significant for the firm infrastructure, but on the other hand, their application to inbound logistics and outbound logistics is very rare, as well as in terms of human resource management. Under the current logistical system, an environmentally friendly business might lead to a higher price downstream. However, it is possible to be optimistic about the societal recognition of SD elements; supply chain members seem to be able to bear the financial cost. In brief, efforts should be made in the future to find sustainable solutions using the Physical Internet approach.

The second step of criteria analysis is done according to the number of times the criteria are mentioned per publication. This method helped rank the importance of the criteria. Then, according to the Pareto principle[8], we obtain a list of 10 main criteria. This filtered list indicates the criteria citation compared with the distribution of the criteria composition table (see Table 3). Most criteria on the list are relative to support activities, in reference to Porter's (1985) value chain model, and only some criteria are relative to SD elements.

[8] A small quantity of work or resources (time, money, facilities, employees, etc.) can produce a large number of outcomes (Cambridge Dictionary, 2019).

Criteria	Definitions	Times mentioned	Cumulative %
FINANCIAL	Financial items leading to the financial cost or financial structure of the firm	23	16.24%
SERVICE	Capability and quality of service offering	15	23.86%
PERFORMANCE	Evaluation record of firm performance indicating business achievement	14	30.46%
CULTURE	Corporate culture, including the societal dimension	12	36.55%
TECHNOLOGICAL	Adoption of technologies supporting efficient routine operations, service and organization		42.64%
ENVIRONMENTAL	Efforts to take environmental issues into account	11	48.22%
FLEXIBILITY	Efforts to make the customer service offering more efficient and responsive		53.81%
MANAGEMENT	Measurements used to monitor and evaluate institutional governance	9	58.38%
QUALITY	Degree of evaluation of the service quality rate	7	61.93%
OPERATIONS	Principle and procedure actions from stocking, transportation, tracking, and physical distribution	6	64.97%

Table 3. List of criteria and the number of references per publication

CONCLUSION

The purpose of this paper was to introduce a content analysis of academic papers linked to the LSP selection in the context of Physical Internet, and to present an original multi-criteria decision structure. In order to address the topic, a general synthesis of comprehensive multi-criteria has been built, including an investigation about the weight of criteria, on one hand, the presence of SD indicators, on the other hand. Our contribution underlines how Porter's (1985) value chain model can be extended with a SD perspective. It gives a legible illustration of the integration of SD dimensions in the LSP selection process. Following different analysis, we propose a multi-criteria decision process that can be used. If sustainability is a major precondition of an efficient SCM, especially during the LSP selection decision-making, few publications offer a comprehensive list of indicators used during the decision-making process. This paper contributes to this part of the work and identifies which are the most important aspects of the process. It also shows to what extent SD elements are taken into account. Finally, this paper is the foundation of a future testing work to evaluate the impact of sustainability dimensions during the LSP selection process.

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AN EMPIRICAL ANALYSIS ON PRODUCTIVITY IMPROVEMENT FACTORS OF JAPANESE TRUCKING COMPANIES

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Purpose
In Japan where the rapid aging of the population continues because of the sharp decline in the birth rate, labour shortage has become an important issue. The driver shortage in the trucking industry is one of the most serious problem among all industries. The labour productivity of trucking industry is significantly lower than that of other industries. The government has implemented various measures with an aim of raising the labour productivity of the trucking industry by 20% from fiscal 2013 by fiscal 2020.
Kurokawa et. al. (2018) collected productivity data on a company level, designed a questionnaire to investigate factors affecting productivity, and analysed the relationship between them.
The purpose of this paper is to develop a questionnaire survey, perform factor analysis to extract factors that affect productivity, and consider measures to improve productivity. The questionnaire survey was conducted to grasp the explanatory factors of productivity. Utilizing commercial database that includes financial information, we created a data set linked with the questionnaire. By factor analysis using this data set, major factors are extracted and the influence on productivity is analysed.

Design/methodology/approach
The questionnaire survey was conducted to grasp the explanatory factors of productivity. Based on previous research and preliminary interviews, we designed the 35 survey items such as characteristics, business environment, activities, and strategy. The mail survey was conducted during February 24th to March 15th, 2018. The number of mailings was 1,995 and the number of respondents was 489 (24.5%). Utilizing database that included financial information, we created a data set linked with the questionnaire. By factor analysis using this data set, major factors are extracted and the influence on productivity is analysed.

Findings
By factor analysis, five factors were extracted. These factors may be named as (1) information utilization and KPI management, (2) power relationship with shippers, (3) Kaizen with shippers, (4) company-wide kaizen system, and (5) dependency on shippers. We find out that (3) Kaizen with shippers have a positive correlation with financial results.

Value
It has been an important issue to find out the productivity improvement factors, as many literature such as Japan Institute of Logistics Systems (2014) and Hamazaki et. al. (2004) show. This paper adds value to the literature accumulation in the field of logistics service

industry. Finding out factors such as the importance of Kaizen with shippers is original in this paper.

Research limitations/implications
Although the number of the respondents are enough for extracting factors, it may be not sufficient for analysing the concrete effects of factors on the productivity. Further efforts to gather more samples are necessary.

Practical Contribution
The paper suggests that Japanese trucking companies needs to pay more attention on Kaizen with shippers, and so on.

INTRODUCTION

In Japan where the rapid aging of the population continues because of the sharp decline in the birth rate, labour shortage has become an important issue. The driver shortage in the trucking industry is one of the most serious problem among all industries. The labour productivity of trucking industry is significantly lower than that of other industries. The government has implemented various measures with an aim of raising the labour productivity of the trucking industry.

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A REVIEW OF RELEVANT LITERATURE

Japan Productivity Centre (2018) pointed out that the labour productivity (added value per hour of work) of Japanese service industries was about 50.7 % of the one in the USA in 2015. It also calculated that the labour productivity of transportation and mail industry which include trucking in Japan was only 47.7 % of the one in the USA according to the survey.

Improvement of labour productivity has become an important issue in Japan. The Ministry of Land, Infrastructure, Transport and Tourism is aiming to improve the productivity of freight transport industry by 20% by fiscal 2020 from fiscal 2013. It has launched projects to revolutionise productivity and MLIT (2018) showed the progress of the projects.

As for a review of productivity of the trucking industry, Kurumizwa (2002) calculated TFP (total factor productivity) based on the macro data from MLIT and pointed out the decline of TFP was explained as the shippers' efforts to decrease logistics costs. This study focused on the TFP on industry level and did not analyse the labour productivity improvement factors based on company level.

There are some precedent studies that analysed the relationship between general management performance such as profit ratio, and characteristics of companies, environment, activities, etc. For example, Hamazaki et. al. (2004) developed Logistics Scorecard (LSC) and identify factors that affect company financial data using the LSC. JILS (2014) collected KPI (key performance indicator) data for evaluating logistics management and operation level by a questionnaire survey and analysed the relation between financial data and KPIs. Kurokawa et. al. (2018) collected productivity data on a company level, designed a questionnaire to investigate factors affecting productivity, and analysed the relationship between them.

QUESTIONNAIRE SURVEY ON FACTORS OF PRODUCTIVITY

Survey method

A questionnaire survey was conducted to obtain information on company characteristics, environment, and activities and so on, that are assumed to be factors for explaining productivity. The survey target was companies whose financial data were registered in COSMOS database by Teikoku Databank.

The implementation period was from February 24 to March 15, 2018. There were 489 responses (24.5%) to 1,995 shipments. 450 companies were able to acquire financial data from COSMOS database. We use this combined dataset for the study.

We interviewed with persons in charge of logistics business operations and referred to the existing research to set survey items which were the explanatory factors of labour productivity. Specifically, we created 35 questions on about logistics service, operation, human resource development, relationship with shippers, and so on. We asked them to give a five-step evaluation of "Agree = 4" to "Disagree = 0" for each question. The questionnaire sheets were sent and received by mail. We asked managers or executives to fill in the questionnaire sheets.

Overview of Respondents

Tables 1 shows the number of respondents and their average financial results (recurring profit margin and ROA) by the segments. FTL (full truck load) accounts for more than half of the respondents, followed by other trucking services, LTL (Less than truckload) and comprehensive logistics service. The recurring profit ratio of comprehensive logistics service provider and FTL tends to be higher than the one of LTL.

Table 2 shows the number of respondents and their average financial results by customers. The shippers are dominated by manufacturers, wholesalers and retailers. The recurring profit margin of companies doing business with wholesalers and retailers tend to be lower than the one with manufacturers. The recurring profit margin tends to be lower in the case of “mainly re-consignment from the logistics company” than in the case of “mainly direct business with shippers”. This is consistence with the results of previous surveys.

Labour productivity and financial results

Labour productivity can be calculated by “adding method”. The added value amount, which is the numerator of labour productivity, corresponds to the accumulated value of ordinary income, personnel expenses, taxes and duties, financial expenses, land charges, etc. The ratio of personnel expenses is extremely high in labour extensive logistics industry. Thus, the level of wages tends to overwhelm the effects of other factors.

Generally, the number of employees or total working hours is used as the labour input that is the "denominator" of labour productivity. Although the latter is preferable to reflect the difference in working hours between regular employees and part-time workers, it is difficult to grasp the total working hours of individual companies.

Because of these obstacles, we could not find out useful results when we use the labour productivity as explained variable. Thus, we use recurring profit margin and ROA as explained variable.

Table 1: Number of respondents and average financial results by segments

Segments	Number	Recurring profit margin (%)	Return on Assets (ROA) (%)
Trucking (Mainly LTL)	63	1.40	0.88
Trucking (Mainly FTL)	236	2.78	4.02
Trucking (Others)	75	1.74	2.68
Comprehensive logistics service	40	3.24	4.95
Forwarder, 3PL (Third party logistics)	11	2.40	5.35
Warehousing	1	3.96	4.25
Port cargo handling	3	-0.99	-1.09
Other logistics service	1	3.85	8.02
Not answered	20	2.29	4.92

Table 2: Number of respondents and average financial results by customers (shippers)

<table>
<tr><th>Customers</th><th>Type of business</th><th>Number</th><th>Recurring profit margin (%)</th><th>Return on Assets (ROA) (%)</th></tr>
<tr><td rowspan="6">Mainly direct business with shippers</td><td>Manufacturers (Consumption goods)</td><td>116</td><td>2.94</td><td>4.40</td></tr>
<tr><td>Manufacturers (Capital goods)</td><td>70</td><td>2.80</td><td>3.23</td></tr>
<tr><td>Wholesalers, Retailers</td><td>61</td><td>2.12</td><td>3.74</td></tr>
<tr><td>Service</td><td>14</td><td>3.84</td><td>6.21</td></tr>
<tr><td>Consumers or individuals</td><td>3</td><td>4.68</td><td>12.13</td></tr>
<tr><td>Others and not answered</td><td>49</td><td>2.08</td><td>-</td></tr>
<tr><td colspan="2">Mainly re-consignment from logistics companies</td><td>116</td><td>1.69</td><td>2.00</td></tr>
<tr><td colspan="2">Not specified</td><td>14</td><td>1.20</td><td>2.51</td></tr>
<tr><td colspan="2">Not answered</td><td>7</td><td>4.27</td><td>7.87</td></tr>
</table>

The results of questionnaire

Figure 1 summarises the results of questionnaire sheet. The horizontal bar shows the average points (from disagree=0 to agree=4).

The respondents strongly agreed "Q13 Grasp the service conditions etc. for each customer", "Q24 Executives also participate in Kaizen (improvement) activities", "Q62 Request for improvement through regular meeting with shippers", "Q75 Actively request Kaizen for shippers", and so on. Kaizen seems to be popular for logistics companies.

ANALYSIS

Factor Analysis

To identify the factors potentially explain the financial results, we applied factor analysis using Promax rotation. We used a measure factor method applying the 33 items indicated in Figure 1, excluding two items that showed low commonality (Q12: 0.010、Q41:0.087).

We adopted five factors of which eigenvalues exceeded 1.2. These cumulative percentage of variance was 47%. Table 3 shows the Promax rotated factor loadings, when we calculated after excluding questionnaire items (Q74、Q81、Q82) with low factor loading of less than 0.4.

Table 3 shows the results of the Promax rotated factor loadings with Kaiser normalization. Among the items of factor 1, the factor loadings of "periodical reports to customers by KPIs", "provide logistics information system to shippers", "actively invest in computerization", "implement of gain sharing, joint transport with multiple shippers" were high, so factor 1 was determined to be named as "utilization of information and KPI management".

Among the items of factor 2, the factor loadings of "unfair gain sharing or distribution", "insufficient human resources to make proposals to shippers", "difficulty of matching multiple shippers", and "insufficient know-how to make proposals to shippers" were high, so we decided to name factor 2 as "power relationship with shippers".

Among the items of factor 3, the factor loadings of "request for Kaizen through regular meeting with shippers", "Kaizen involving shippers", "actively request Kaizen for shippers", and" the shipper's organization, system and awareness are inadequate" were high, then we decided to name factor 3 as "Kaizen with shippers".

Among the items of factor 4, the factor loadings of "executives also participate in Kaizen activities", "utilize field data for employee evaluation", "capacity evaluation and training" were high, then we decided to name factor 4 as "company-wide Kaizen system".

Among the items of factor 5, the factor loadings of "capital relationship with shippers", "exchange of personnel with shippers", and "high degree of dependence on specified shippers" were high, then we decided to name factor 5 as "dependency on shippers".

Factor correlation matrix

Table 4 shows correlation matrix between factors obtained by factor analysis. Factor 1 "Information utilization and KPI management" have a low correlation with factor 2 "power relationship with shippers, but somewhat correlate with factor 3 "Kaizen with shippers" and factor 4 "company-wide Kaizen system". Factor 2 "power relationship with shippers" has a low correlation with other factors. Factor 3 "Kaizen with shippers" somewhat correlates with factor 4 "company-wide Kaizen system". Factor 5 "dependency on shippers" has low correlation with other factors.

Regression analysis of factors and financial results

Regression analysis was applied to investigate the relationship between the factors obtained by factor analysis and the financial results. In the regression analysis, two financial results, that is recurring profit margin and ROA were used as objective variables and factor scores were used as explanatory variables. Table 5 shows the results of regression analysis.

The value of adjusted R^2 (R^{*2}) for both cases were not desirable. And explanatory variables except for factor 3 "Kaizen with shippers" seems to be not significant for both cases. However only p-values of the factor 3 for both cases were significant in 5% level. These results imply that the improvement of the factor 3 "Kaizen with shippers" that includes "request for Kaizen through regular meeting with shippers", "Kaizen involving shippers", "actively request Kaizen for shippers" and so on may result in improvement of financial results.

Discussion

The preceding analysis revealed five factors that might influence on the financial results. Of all five factors, the factor of "Kaizen with shippers" may influence the financial results but the factor of "company-wide Kaizen system" is not significant. It may imply that company-wide Kaizen has been so common that it cannot influence on financial performance but that joint efforts of Kaizen with shippers can improve financial performance because these efforts are still not so popular in Japan. However, because of the limited number of observations and the wide variety of respondents, the relationship between other factors and financial improvements could not be investigated clearly. Further research is necessary to solve this question.

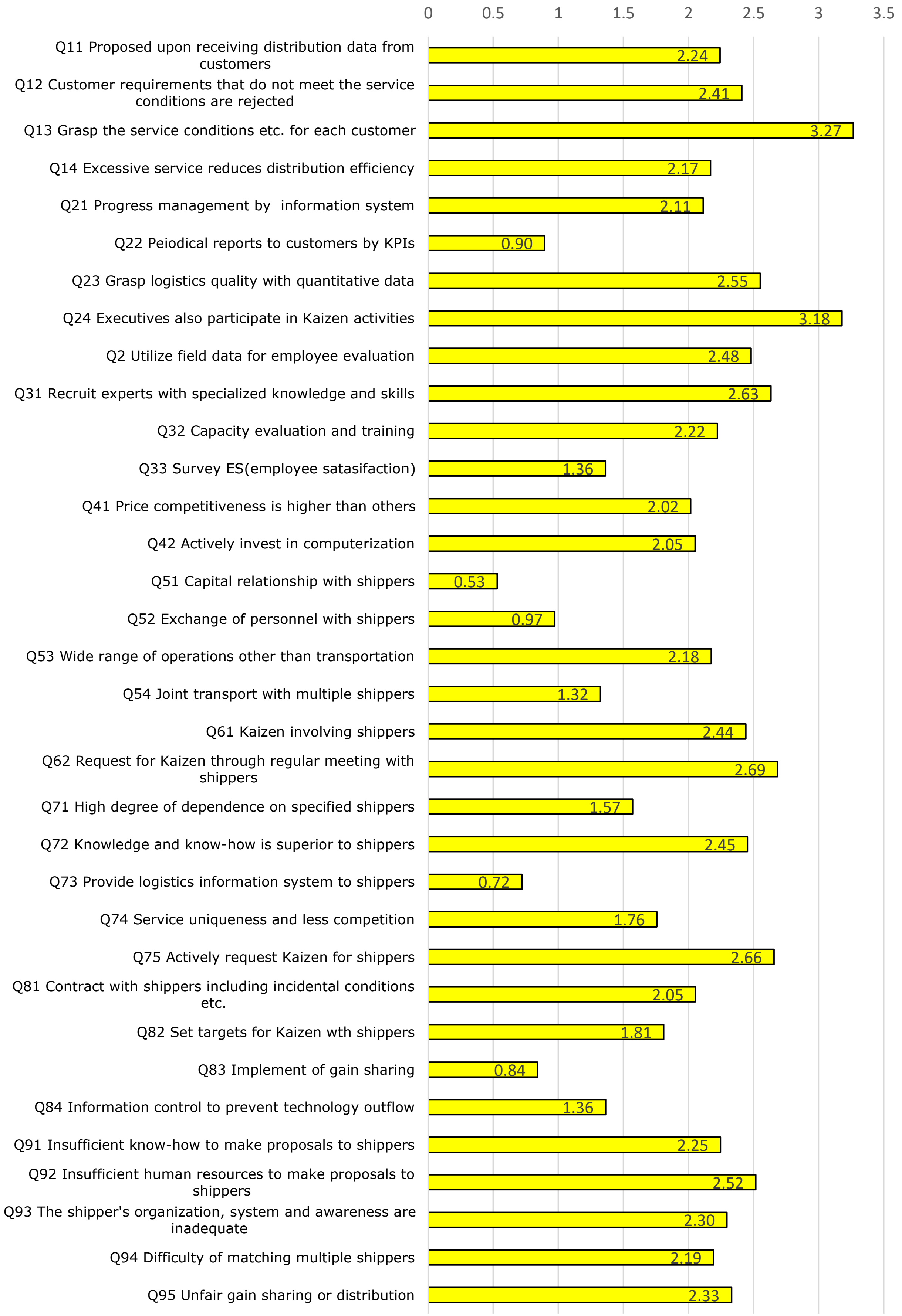

Figure 1: Results of questionnaire

Table 3: Rotated factor matrix[a]

Questionnaire item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Q22 Periodical reports to customers by KPIs	0.693	-0.055	-0.186	0.100	0.014
Q73 Provide logistics information system to shippers	0.627	-0.118	-0.070	-0.064	0.110
Q42 Actively invest in computerization	0.550	0.052	0.036	0.192	-0.152
Q83 Implement of gain sharing	0.467	-0.128	0.012	0.004	0.172
Q54 Joint transport with multiple shippers	0.466	0.057	0.328	-0.209	-0.032
Q21 Progress management by information system	0.403	0.043	0.011	0.262	0.051
Q33 Survey ES (employee satisfaction)	0.399	-0.061	-0.075	0.298	-0.033
Q84 Information control to prevent technology outflow	0.380	0.135	-0.065	0.056	-0.043
Q11 Proposed upon receiving distribution data from customers	0.356	0.094	0.313	0.032	-0.096
Q95 Unfair gain sharing or distribution	-0.054	0.729	0.045	0.037	-0.053
Q92 Insufficient human resources to make proposals to shippers	-0.067	0.699	-0.107	0.046	0.167
Q94 Difficulty of matching multiple shippers	0.092	0.637	0.009	-0.016	-0.033
Q91 Insufficient know-how to make proposals to shippers	-0.016	0.618	-0.243	0.037	0.216
Q93 The shipper's organization, system and awareness are inadequate	-0.031	0.548	0.098	-0.005	-0.111
Q14 Excessive service reduces distribution efficiency	0.049	0.415	0.202	-0.166	-0.057
Q62 Request for Kaizen through regular meeting with shippers	-0.101	-0.031	0.669	0.105	0.184
Q61 Kaizen involving shippers	-0.072	-0.048	0.654	0.108	0.219
Q75 Actively request Kaizen for shippers	-0.130	-0.055	0.542	0.218	-0.006
Q13 Grasp the service conditions etc. for each customer	-0.092	0.011	0.428	0.102	-0.167
Q72 Knowledge and know-how is superior to shippers	0.139	0.074	0.362	-0.019	-0.104
Q53 Wide range of operations other than transportation	0.355	0.053	0.361	-0.236	0.071
Q24 Executives also participate in Kaizen activities	-0.091	0.024	0.196	0.572	0.013
Q25 Utilize field data for employee evaluation	0.041	-0.026	0.099	0.565	-0.062
Q32 Capacity evaluation and training	0.233	-0.080	-0.007	0.460	0.077
Q31 Recruit experts with specialized knowledge and skills	0.047	0.003	0.010	0.326	0.037
Q23 Grasp logistics quality with quantitative data	0.263	0.137	0.238	0.313	-0.051
Q51 Capital relationship with shippers	0.082	-0.016	0.040	-0.044	0.623
Q52 Exchange of personnel with shippers	0.103	0.021	0.056	0.028	0.612
Q71 High degree of dependence on specified shippers	-0.095	0.056	-0.041	0.028	0.473
Eigen value	5.76	3.00	1.92	1.59	1.37
Cumulative % of variance	19.9	30.2	36.8	42.3	47.0

Extraction method: Major factor method
Rotation method: Promax with Kaiser Normalization
a. Rotation converged 8 iterations.

Table 4: Factor correlation matrix

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Factor 1: Information utilization and KPI management	1.000	-.006	.553	.452	.147
Factor 2: Power relationship with shippers	-.006	1.000	-.041	-.200	-.029
Factor 3: Kaizen with shippers	.553	-.041	1.000	.404	.201
Factor 4: company-wide Kaizen system	.452	-.200	.404	1.000	.024
Factor 5: dependency on shippers	.147	-.029	.201	.024	1.000

Table 5: Results of single regression analysis

	Coefficient	t-value	p-value
Objective: Recurring profit margin			
Factor 1: Information utilization and KPI management	-0.32	-1.00	0.32
Factor 2: Power relationship with shippers	-0.31	-1.35	0.18
Factor 3: Kaizen with shippers	0.73	2.34	0.02
Factor 4: company-wide Kaizen system	0.29	0.91	0.36
Factor 5: dependency on shippers	-0.01	-0.04	0.97
R^2=0.030, R^{*2}=0.019			
Objective: ROA (return on assets)			
Factor 1: Information utilization and KPI management	-1.01	-1.50	0.13
Factor 2: Power relationship with shippers	-0.21	-0.42	0.67
Factor 3: Kaizen with shippers	2.15	3.25	0.00
Factor 4: company-wide Kaizen system	0.02	0.03	0.98
Factor 5: dependency on shippers	0.39	0.73	0.47
R^2=0.033, R^{*2}=0.022			

CONCLUSIONS

The purpose of this paper was to find out factors to improve productivity of trucking companies. This paper developed a questionnaire survey by referring previous studies and utilized commercial database that included financial information. By factor analysis, five factors were extracted and the influence on financial results was analysed. This paper stressed on the importance of Kaizen with shippers of all five factors. It is often pointed out that Japanese trucking companies are subordinate to shippers and not willing to propose kaizen measures. This is consistence with the results of analysis that stresses the importance on Kaizen with shippers.

Although we revealed undisclosed factors, we have not investigated the relationship with these factors and productivity so clearly. Further research is required to collect enough quantity of respondents. Also, further research to investigate the relationship between productivity and financial results is necessary. Lastly, Japanese trucking companies have been affected by severe labour shortage, thereby increasing the importance of productivity study. This paper may contribute to Japanese trucking industry under these circumstances.

ACKNOWLEDGMENTS

We would like to thank everyone who cooperated with this research, including many companies that cooperated with questionnaire surveys and interview surveys.

This work was supported by JSPS KAKENHI Grant Number Basic Research (C) 16K03928.

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SUPPLY CHAIN NETWORK EQUILIBRIUM MODEL WITH THE CYBERSECURITY INVESTMENT CONSTRAINTS

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Abstract
Purpose of the paper: The supply chain network game consists of a tier of manufacturers, a tier of retailers and a tier of demand markets. Game players individually seek to decide their cybersecurity investments to resist possible cyberattacks on the supply chain network. However, the manufacturers and the retailers are subject to budget constraints for their cybersecurity investments. Introducing the optimal cybersecurity investments with budget constraints would dramatically increase complexities on computing equilibrium of the supply chain network game.

Design/methodology/approach: We construct a game model to describe interactions between directly linked tiers and apply the theory of variational inequalities to compute game equilibrium. We apply the Lagrange multiplier method to transform players' nonlinear investment cost function to be a solvable form of substitutional variational inequalities. And, applying the modified projection method, we calculate parameters such as budget constraints and cyberattacks loss through numerical examples for sensitivity analysis.

Findings: We apply the modified projection method, using MATLAB (2016a), to compute four numerical examples and discuss their results. (1) The supply chain network players are active to make the cybersecurity investments for improve their utility within a certain range. However, the marginal utility of cybersecurity investment is declining and this leads to some players may rely on their competitors' decisions. (2) The more players in the supply chain network, the more players in the top tier will get more profits. This illustrates that the supply chain network should be flattened.

Value/Originality: We combine cybersecurity investments with supply chain network equilibrium for studying. The numerical examples and their results would bring deep insights for theorists and practitioners about cybersecurity investment on supply chain network. Especially, the impact of changes in budget constraint, investment cost function, player numbers, and cyberattack loss, on equilibrium product transactions.

1. INTRODUCTION

Along with the process of economic globalization, the links between enterprises in various countries have become increasingly close, social and economic activities mainly operate in the form of supply chain networks. On the one hand, the uncertainty of the business environment reduces the ability of the supply chain network to resist risks; on the other hand, On the other hand, conflicts of interest often occur, due to the convergence of advantages and disadvantages in node enterprises. Therefore, how to describe the co-opetition relationship between supply chain network node enterprises and seek the equilibrium conditions of supply chain network is more and more valued by researchers and enterprise practitioners.

2. LITERATURE REVIEW

2.1 From the perspective of cost to study the network equilibrium

Hu J & Zhao G (2014) considered the loss aversion psychology of node enterprises, established two different supply chain network equilibrium models for retailers under the condition of whether exist out-of-stock cost or not. On the basis of describing the retailers' aversion by using piece-wise linear function, the optimal decision-making and utility of jointed enterprise are solved by using variational inequality tool. In addition, there are two kinds of assumptions about the cost function, linear and non-linear. The description of the linear cost function on the practical problem stays at the level of ideal hypothesis, while the non-linear cost function is more consistent with the reality. Yang J, Qi X & Yu G. (2005) assume that the production cost is a convex function. When the production cost is disturbed, to explore how the node enterprise make decisions to modify the original plan, which reduces the influence of disturbance factors on the related activities of the supply chain network and ensures the supply chain network maintains equilibrium.

2.2 Research on different demand assumptions

As far as the cost non-linear hypothesis is concerned, factors such as consumers' personalized requirements and retailers' differentiated marketing strategies increase the complexity of the demand market. The current research on different demand assumptions mainly includes two categories: random demand hypothesis and fuzzy demand hypothesis. As for the research on stochastic demand hypothesis, Nagurney, A.(2002) establish a two-level supply chain network equilibrium model composed of retailers and demand markets that takes random demand hypothesis into account, in which random demand applied the knowledge related to probability theory. Based on the previous research, Teng Chunxian increases the decision variables of the model and studied the network equilibrium problem with random demand in the case of multi-commodity flow. Based on the era background and benchmark model, Nagurney, A(2005) combines the physical marketing channel with the e-commerce sales channel, and sets up a supply chain network equilibrium model considering the random market demand of dual channels. As the representative of the research on the supply chain network equilibrium with fuzzy demand, Hu Jinsong studies the three-level supply chain network equilibrium composed of competitive manufacturers, retailers facing fuzzy demand and demand markets on the premise of considering the constraints of manufacturers' production capacity and the demand market's price ceiling.

3. ASSUMPTIONS

The supply chain network equilibrium model of cybersecurity investments with budget constraints consists of m manufacturers, with a typical manufacturer denoted by i, n retailers, with a typical retailer denoted by j, and o demand markets, with a typical demand market denoted by k.

Retailers maybe brick and mortar stores or online retailers. This paper assumes that the transactions between the nodes are homogeneous products; the transactions between the levels are carried out electronically; Consumers' preference for supply chain network information security is reflected by the demand price function.Node enterprises must need to make corresponding information security investments.

The cybersecurity level, each manufacturer i and retailer j must satisfy the following constraint:

$$0 \le s_i \le u_{s_i}, \qquad i = 1,\dots,m. \tag{1}$$

$$0 \le s_j \le u_{s_j}, \qquad j = 1,\dots,n. \tag{2}$$

where $u_{s_i} < 1, u_{s_j} < 1$ is fulfilled for all i, j. If the value of s_i, s_j is higher, indicates that the level of network security is higer, and the network is hard to be attacked. denote that the perfect security is impossible, and this situation can not be existed. $s_i = 0, s_j = 0$ means that a node enterprise does not have an information security level.

Cost of information security investment is expressed by h_i, h_j, and is assumed to be a continuous and differentiable convex function, which fulfills two basic conditions: $h_i(0) = 0$, $h_j(0) = 0$ indicates that node enterprises without information security level do not need to invest in information security; $h_i(1) = +\infty$, $h_j(1) = +\infty$ represents the cost of information security investment required for a node enterprise to achieve perfect security. This paper constructs $h_i(s_i)$, $h_j(s_j)$ that fulfills the above properties as follows:

$$h(s_i) = \alpha_i \left(\frac{1}{\sqrt{1-s_i}} - 1 \right) \tag{3}$$

$$h(s_j) = \beta_j \left(\frac{1}{\sqrt{1-s_j}} - 1 \right) \tag{4}$$

where $\alpha_i, \beta_j > 0$. α_i, β_j can ensure that different node enterprises can have different investment cost functions according to their size and needs.

Supply chain network node enterprises need to consider their own effectiveness. The model needs to focus on the budget constraints of node enterprises in information security investment, so the following nonlinear budget constraints must satisfy:

$$\alpha_i \left(\frac{1}{\sqrt{1-s_i}} - 1 \right) \le B_i, \qquad i = 1,\dots,m \tag{5}$$

$$\beta_j \left(\frac{1}{\sqrt{1-s_j}} - 1 \right) \le B_j, \qquad j = 1,\dots,n \tag{6}$$

The average safety level of manufacturers i and retailers j is expressed as:

$$\bar{s}_i = \frac{1}{m} \sum_{i=1}^{m} s_i, \qquad i = 1,\dots,m \tag{7}$$

$$\bar{s}_j = \frac{1}{n} \sum_{j=1}^{n} s_j, \qquad j = 1,\dots,n \tag{8}$$

The average level of security in the network is represented by the weighted average of the node companies. Due to the retailers play a role of taking up the products produced by the manufacturer and transfering the goods down to the demand market. We assume retail The commerce security level accounts for a large proportion of the average security level of the entire network. The overall network security level is expressed as:

$$\bar{s} = \frac{\bar{s}_i + 2\bar{s}_j}{3} \tag{9}$$

Referring to the research done by Nagurney and others, we record the probability of successful cyber attacks by manufacturers i and retailers j as:

$$p_i = (1 - s_i)(1 - \bar{s}) \tag{10}$$

$$p_j = \left(1 - s_j\right)\left(1 - \overline{s}\right) \quad (11)$$

$\left(1 - \overline{s}\right)$ indicates that the probability of network attack in the whole supply chain network, $\overline{v}$ denotes the level of network vulnerability. $\left(1 - s_i\right)$, $\left(1 - s_j\right)$ indicates the probability of suffering a cyber attack respectively.

4. MODELING

4.1 Manufacturer's equilibrium conditions

This paper considers the problem of network balance in a single commodity flow supply chain with information security investment constraints. The quantity of products that the manufacturer i sends to the retailer j is q_{ij} , the cost of Manufacturer i is c_i , $i = 1, \cdots, m$. The transaction cost of the products traded between the manufacturer i and the retailer j is provided by the manufacturer $i$and the transaction cost is denoted by c_{ij} . In the actual transaction, the following traffic equations must satisfy:

$$q_i = \sum_{j=1}^{n} q_{ij}, \qquad i = 1, \ldots, m, \; j = 1, \ldots, n. \quad (12)$$

q_i represents the total output of manufacturer i.The price of the product ρ_{1ij} traded between the manufacturer i and the retailer j is the intrinsic price in the supply chain network, which is a constant.

Without considering the network attack and information security investment, the manufacturer's profit is the difference between sales revenue and manufacturing costs and transaction costs:

$$f_i\left(q, s\right) = \sum_{j=1}^{n} \rho_{1ij} q_{ij} - c_i\left(q_i\right) - \sum_{j=1}^{n} c_{ij}\left(q_{ij}\right) \quad (13)$$

If a manufacturer i is successfully attacked by a cyber attack，the expected economic loss will be denoted by:

$$D_i \, p_i \quad (14)$$

Combining the above expressions, we can get the expected utility consistent with the manufacturer i expected profit as follows:

$$E\left(U_i\right) = \left(1 - p_i\right) f_i\left(q, s\right) + p_i\left(f_i\left(q, s\right) - D_i\right) - h_i\left(s_i\right) \quad (15)$$

The expected utility is the difference between the loss caused by the cyberattack and the weighted average of the sales profit and the information security investment cost, which is denoted by:

$$E\left(U_i\right) = f_i\left(q, s\right) - p_i D_i - h_i\left(s_i\right) \quad (16)$$

the manufacturer i expected utility is:

$$E\left(U_i\right) = \sum_{j=1}^{n} \rho_{1ij} q_{ij} - c_i\left(q_i\right) - \sum_{j=1}^{n} c_{ij}\left(q_{ij}\right) - \left(1 - s_i\right)\left(1 - \overline{s}\right) D_i - \alpha_i\left(\frac{1}{\sqrt{1 - s_i}} - 1\right) \quad (17)$$

M manufacturers engage in non-cooperative competition in providing product and information security investments, and single-node companies are trying to maximize their desired utility.

Definition K represents a set of strategies of all manufacturers, $(q, s) \in K$. The equilibrium condition of the manufacturer satisfies the following theorem:

Theorem 1: For each manufacturer i, $i = 1, \ldots, m$, the expected utility function $E\left(U_i\left(q, s\right)\right)$ is a continuous differentiable convex function on $(q, s) \in K$, and $\left(q^*, s^*\right) \in K$ is the manufacturer Nash equilibrium if and only if it fulfills the following variational inequality:

$$-\sum_{i=1}^{m}\sum_{j=1}^{n}\frac{\partial E\left(U_i\left(q^*,s^*\right)\right)}{\partial q_{ij}}\times\left(q_{ij}-q_{ij}^*\right)-\sum_{i=1}^{m}\frac{\partial\left(U_i\left(q^*,s^*\right)\right)}{\partial s_i}\times\left(s_i-s_i^*\right)\geq 0,\qquad\forall\left(q,s\right)\in K\tag{18}$$

Or, equivalently, the vector $(q^*,s^*,\lambda^*)\in K\times R$ is the solution of (18), only if it is the solution of the following variational inequalities:

$$\begin{aligned}&\sum_{i=1}^{m}\sum_{j=1}^{n}\left[-\rho_{1ij}^*+\frac{\partial c_{ij}\left(q_{ij}^*\right)}{\partial q_{ij}}+\frac{\partial c_i\left(q_i^*\right)}{\partial q_{ij}}\right]\times\left(q_{ij}-q_{ij}^*\right)\\&+\sum_{i=1}^{m}\left[\frac{\partial h_i\left(s_i^*\right)}{\partial s_i}+\left(\overline{s}^*-1+\frac{s_i^*-1}{3m}\right)D_i+\frac{\lambda_i^*\alpha_i}{2}\left(1-s_i^*\right)^{-\frac{3}{2}}\right]\times\left(s_i-s_i^*\right)\\&+\sum_{i=1}^{m}\left[B_i-\alpha_i\left(\frac{1}{\sqrt{1-s_i^*}}-1\right)\right]\times\left(\lambda_i-\lambda_i^*\right)\geq 0,\qquad\forall\left(q,s,\lambda\right)\in K\times R.\end{aligned}\tag{19}$$

4.2 Retailers' equilibrium conditions

The number of products that the retailer j transacts to demand market k is q_{jk}. The operating cost of the retailer j is c_j, $j=1,\cdots,n$, and the operating cost can be understood as the storage cost or the sorting cost, *etc*. The operating cost is a function of the retailer's holding volume q_j, where $q_j=\sum_{i=1}^{m}q_{ij}$, $j=1,\cdots,n$. The transaction fee paid by the customer for the product traded between the retailer j and the demand market k is expressed as c_{jk}. In actual transactions, since the retailer's shipment volume will not exceed the supply of all manufacturers, the transaction volume of product fulfills the following flow inequality:

$$\sum_{k=1}^{o}q_{jk}\leq\sum_{i=1}^{m}q_{ij},\qquad i=1,...,m,\ j=1,...,n,\ k=1,...,o\tag{20}$$

The retailer j's profit:

$$f_j\left(q,s\right)=\sum_{k=1}^{o}\rho_{2jk}q_{jk}-c_j\left(q_j\right)-\sum_{i=1}^{m}\rho_{1ij}q_{ij}.\tag{21}$$

If a retailer j is successfully attacked by a cyber attack, the economic loss is given by:

$$D_j p_j\tag{22}$$

That is, the expected utility is the difference between the loss caused by the cyberattack and the weighted average of the sales profit and the information security investment cost. Further simplification can be obtained:

$$E\left(U_j\right)=f_j\left(q,s\right)-p_jD_j-h_j\left(s_j\right)\tag{23}$$

Bringing into the function expressions to get the retailer's utility is:

$$E\left(U_j\right)=\sum_{k=1}^{o}\rho_{2jk}q_{jk}-c_j\left(q_j\right)-\sum_{i=1}^{m}\rho_{1ij}q_{ij}-\left(1-s_j\right)\left(1-\overline{s}\right)D_j-h_j\left(s_j\right).\tag{24}$$

where, $h_j\left(s_j\right)=\beta_j\left(\frac{1}{\sqrt{1-s_j}}-1\right)$

n retailers are engaged in non-cooperative competition in providing product and information security investments, and single-node companies are trying to maximize their desired utility.

The definition L represents the set of strategies of all retailers, $(q,s)\in L$ **,**and the equilibrium conditions of the retailer satisfy the following theorem:

Theorem 2: For each retailer j, $j=1,...,n$, the expected utility function $E(U_j(q,s))$ is a continuous differentiable convex function on $(q,s)\in L$, and $(q^*,s^*)\in L$ is the retailer Nash equilibrium if and only if it fulfills the following variational inequalities:

$$-\sum_{j=1}^{n}\sum_{i=1}^{m}\frac{\partial E\left(U_j\left(q^*,s^*\right)\right)}{\partial q_{ij}}\times\left(q_{ij}-q_{ij}^*\right)-\sum_{j=1}^{n}\sum_{k=1}^{o}\frac{\partial E\left(U_j\left(q^*,s^*\right)\right)}{\partial q_{jk}}\times\left(q_{jk}-q_{jk}^*\right)$$
$$-\sum_{j=1}^{n}\frac{\partial E\left(U_j\left(q^*,s^*\right)\right)}{\partial s_j}\times\left(s_j-s_j^*\right)\geq 0,\qquad (q,s)\in L. \tag{25}$$

Or equivalently, the vector $(q^*,s^*,\gamma^*)\in L\times R$ is the solution of equation (31), only if it is the solution of the following variational inequalities:

$$\sum_{i=1}^{m}\sum_{j=1}^{n}\left[\frac{\partial c_j\left(q_j^*\right)}{\partial q_{ij}}+\rho_{1ij}^*-\gamma_j^*\right]\times\left(q_{ij}-q_{ij}^*\right)+\sum_{j=1}^{n}\sum_{k=1}^{o}\left[-\rho_{2jk}^*+\gamma_j^*\right]\times\left(q_{jk}-q_{jk}^*\right)$$
$$+\sum_{j=1}^{n}\left[\frac{\partial h_j\left(s_j^*\right)}{\partial s_j}+\left(\overline{s}^*-1+\frac{2s_j^*-2}{3n}\right)D_j+\frac{\mu_j^*\beta_j}{2}\left(1-s_j^*\right)^{-\frac{3}{2}}\right]\times\left(s_j-s_j^*\right)$$
$$+\sum_{j=1}^{n}\left[\sum_{i=1}^{m}q_{ij}^*-\sum_{k=1}^{o}q_{jk}^*\right]\times\left(\gamma_j-\gamma_j^*\right)+\sum_{j=1}^{n}\left[B_j-\beta_j\left(\frac{1}{\sqrt{1-s_j^*}}-1\right)\right]\times\left(\mu_j-\mu_j^*\right)\geq 0,\quad (q,s,\gamma,\mu)\in L\times R^{2+}.$$

4.3 Demand markets' equilibrium conditions

Rational consumers will consider many factors when making decisions in the demand market. We have previously assumed that consumers have more willingness to pay in order to improve the level of safety, Therefore, consumers will consider the average information security level in the demand market, the price offered by the retailer and the transaction cost they have to pay for the product when making decisions.

When the price ρ_{3k} in the demand market is equal to the sum of the purchase cost ρ_{2jk} from the retailer and the transaction cost c_{jk} of the retailer, then the trade between the retailer and the demand market can proceed normally, and $q_{jk}>0$, on the contrary, when the price ρ_{3k} in the demand market is less than the sum of the two, the trade between the retailer and the demand market will result in the loss of the demand market, and the trade will be terminated, so there is $q_{jk}=0$. Combine the above mentioned, the equilibrium condition of demand market k is:

$$\rho_{2jk}+c_{jk}\left(q_{jk}\right)\begin{cases}=\rho_{3k} & \text{if } q_{jk}>0,\\ \geq\rho_{3k} & \text{if } q_{jk}=0.\end{cases} \tag{26}$$

In addition, after a long-term market choice, when the supply and demand of the products are equal, the market trading behavior will occur, which is denoted by $\rho_{3k}>0$, When the market supply exceeds demand, trading behavior will not happen, which is denoted by $\rho_{3k}=0$. In a nutshell, the equilibrium conditions of the demand market is changed into:

$$d_k\left(\rho_{3k},s\right)\begin{cases}=\sum_{j=1}^{n}q_{jk}, & \text{if } \rho_{3k}>0,\\ \leq\sum_{j=1}^{n}q_{jk}, & \text{if } \rho_{3k}=0.\end{cases} \tag{27}$$

Referring to the research of Anna Nagurney, the variational inequality model on the demand market can be expressed as ($\forall(q,\rho)\in R^{2+}$):

$$\sum_{j=1}^{n}\sum_{k=1}^{o}\left[\rho_{2jk}^{*}+c_{jk}\left(q_{jk}^{*}\right)-\rho_{3k}\left(q^{*},\bar{s}^{*}\right)\right]\times\left(q_{jk}-q_{jk}^{*}\right)+\sum_{k=1}^{o}\left[\sum_{j=1}^{n}q_{jk}^{*}-d_{k}\left(\rho_{3k}^{*},\bar{s}^{*}\right)\right]\times\left(\rho_{3k}-\rho_{3k}^{*}\right)\geq 0 \quad (28)$$

4.4 Supply chain network equilibrium conditions

The equilibrium state of the supply chain network refers to the node enterprise satisfying the variational inequality.

Theorem 3 Considering the information security investment constraints of the single commodity flow supply chain network equilibrium condition, looking for a set of numerical solutions, $w^{*}=\left(q^{*},s^{*},\lambda^{*},\gamma^{*},\mu^{*}\right)\in\Psi$, which satisfies the following variational inequalities:

$$\begin{aligned}
&\sum_{i=1}^{m}\sum_{j=1}^{n}\left[\frac{\partial c_{i}\left(q_{i}^{*}\right)}{\partial q_{ij}}+\frac{\partial c_{ij}\left(q_{ij}^{*}\right)}{\partial q_{ij}}+\frac{\partial c_{j}\left(q_{j}^{*}\right)}{\partial q_{ij}}-\gamma_{j}^{*}\right]\times\left(q_{ij}-q_{ij}^{*}\right)\\
&+\sum_{j=1}^{n}\sum_{k=1}^{o}\left[c_{jk}\left(q_{jk}^{*}\right)-\rho_{3k}\left(q^{*},\bar{s}^{*}\right)+\gamma_{j}^{*}\right]\times\left(q_{jk}-q_{jk}^{*}\right)\\
&+\sum_{i=1}^{m}\left[\frac{\partial h_{i}(s_{i}^{*})}{\partial s_{i}}+\left(\bar{s}^{*}-1+\frac{s_{i}^{*}-1}{3m}\right)D_{i}+\frac{\lambda_{i}^{*}\alpha_{i}}{2}\left(1-s_{i}^{*}\right)^{-\frac{3}{2}}\right]\times\left(s_{i}-s_{i}^{*}\right)\\
&+\sum_{k=1}^{o}\left[\sum_{j=1}^{n}q_{jk}^{*}-d_{k}\left(\rho_{3k}^{*},\bar{s}^{*}\right)\right]\times\left(\rho_{3k}-\rho_{3k}^{*}\right)\\
&+\sum_{j=1}^{n}\left[\frac{\partial h_{j}\left(s_{j}^{*}\right)}{\partial s_{j}}+\left(\bar{s}^{*}-1+\frac{2s_{j}^{*}-2}{3n}\right)D_{j}+\frac{\mu_{j}^{*}\beta_{j}}{2}\left(1-s_{j}^{*}\right)^{-\frac{3}{2}}\right]\times\left(s_{j}-s_{j}^{*}\right)\\
&+\sum_{i=1}^{m}\left[B_{i}-\alpha_{i}\left(\frac{1}{\sqrt{1-s_{i}^{*}}}-1\right)\right]\times\left(\lambda_{i}-\lambda_{i}^{*}\right)\\
&+\sum_{j=1}^{n}\left[\sum_{i=1}^{m}q_{ij}^{*}-\sum_{k=1}^{o}q_{jk}^{*}\right]\times\left(\gamma_{j}-\gamma_{j}^{*}\right)\\
&+\sum_{j=1}^{n}\left[B_{j}-\beta_{j}\left(\frac{1}{\sqrt{1-s_{j}^{*}}}-1\right)\right]\times\left(\mu_{j}-\mu_{j}^{*}\right)\geq 0. \qquad (29)
\end{aligned}$$

where $\Psi=\left\{\left(q,s,\rho,\lambda,\gamma,\mu\right)\mid q\geq 0,s\geq 0,\rho\geq 0,\lambda\in R,\gamma\in R,\mu\in R\right\}$.

From the demand market equilibrium conditions, it can be directly derived that the equilibrium price of retailers is $\rho_{2jk}^{*}=\rho_{3k}^{*}\left(q^{*},\bar{s}^{*}\right)-c_{jk}\left(q_{jk}^{*}\right)$, which is fulfilled for all j, k. The equilibrium price of manufacturers, according to Nagurney’s research results: $\rho_{1ij}^{*}=\left[\frac{\partial c_{i}\left(q_{i}^{*}\right)}{\partial q_{ij}}+\frac{\partial c_{ij}\left(q_{ij}^{*}\right)}{\partial q_{ij}}\right]$, is fufilled for all i, j.

5. NUMERICAL EXAMPLES

In this paper, Nagurney [1] proposed the improved projection algorithm to solve the model. Use MATLAB (2016a) to write a program to solve the numerical solution of the example and analyze the results.

5.1 Influence of budget constraints on model equilibrium solutions

The supply chain network consists of two manufacturers, two retailers, and two demand markets. The corresponding data is as follows:

Manufacturer's production cost: $c_{1}\left(q^{1}\right)=2.5q_{1}^{2}+q_{1}q_{2}+2q_{1}$, $c_{2}\left(q^{1}\right)=2.5q_{2}^{2}+q_{1}q_{2}+2q_{2}$

Transaction costs between manufacturers and retailers: $c_{ij}\left(q_{ij}\right)=0.5q_{ij}^{2}+3.5q_{ij}$

The retailer's operating cost is a function of q^1 and is expressed as: $c_1\left(q^1\right)=0.5\left(q_{11}+q_{21}\right)^2$, $c_2\left(q^1\right)=0.5\left(q_{12}+q_{22}\right)^2$.

Demand price function: $\rho_1=-0.5d_1+0.5\overline{s}+500$. $\rho_2=-0.5d_2+0.5\overline{s}+500$.

The transaction costs of retailers and customers in the demand market are as follows: $c_{11}\left(q^2\right)=q_{11}+5$, $c_{12}\left(q^2\right)=q_{12}+5$, $c_{21}\left(q^2\right)=q_{21}+5$, $c_{22}\left(q^2\right)=q_{22}+5$.

Manufacturer Information Security Investment Cost Function:

$h_1\left(s_1^1\right)=\frac{1}{\sqrt{1-s_1^1}}-1$, $h_1\left(s_2^1\right)=\frac{1}{\sqrt{1-s_2^1}}-1$.

Retailer information security invest-ment cost function:

$h_2\left(s_1^2\right)=\left(\frac{1}{\sqrt{1-s_1^2}}-1\right)\times 2$. $h_2\left(s_2^2\right)=\left(\frac{1}{\sqrt{1-s_2^2}}-1\right)\times 2$.

Budget constraint: $B_1^1=1$, $B_2^1=1$, $B_1^2=3$, $B_2^2=3$; Cyber attack loss: $D_1^1=50$, $D_2^1=50$, $D_1^2=70$, $D_1^2=70$.

Analysis of the example analysis 1 Supply chain network node enterprises are willing to invest in information security in order to improve their effectiveness within a certain range.

5.2 The effect of budget on model equilibrium solution after changing investment cost function

The parameters of the study are consistent with Section 5.2, except that the retailer's information security investment cost function becomes:

$$h_2\left(s_1^2\right)=\left(\frac{1}{\sqrt{1-s_1^2}}-1\right)\times 5,\quad h_2\left(s_2^2\right)=\left(\frac{1}{\sqrt{1-s_2^2}}-1\right)\times 5$$

Case Study Conclusion 2 The diminishing marginal utility of information security investments may cause some node companies to rely on their competitors.

This conclusion helps node companies analyze the decision-making behavior of their competitors and make more reasonable investment decisions to maximize their expected utility.

5.3 The influence of adding a node enterprise to model equilibrium solution

The added retailers have the following parameters: transaction costs between the manufacturer and the retailer: $c_{13}\left(q_{13}\right)=0.5q_{13}^2+3.5q_{13}$, $c_{23}\left(q_{23}\right)=0.5q_{23}^2+3.5q_{23}$

Retailer's operating costs: $c_3\left(q^1\right)=0.5\left(q_{13}+q_{23}\right)^2$

The transaction costs of retailers and customers in the demand market are as follows: $c_{31}\left(q^2\right)=q_{31}+5$, $c_{32}\left(q^2\right)=q_{32}+5$

Retailer's information security invest-ment function: $h_2\left(s_3^2\right)=\left(\frac{1}{\sqrt{1-s_3^2}}-1\right)\times 2$

The retailer's information security investment budget is: $B_3^2=3$, network attack loss, $D_3^2=70$.

The analysis of the example analysis 3 The more supply chain network nodes, the more top-level enterprises will get more profits, therefore, the supply chain network has a tendency to further flatten.

The conclusions of Section 5.3 help to understand that equilibrium prices and costs are very close in the complete market, leading to retailers' unprofit-able phenomena.

5.4 Impact of network attack loss on model equilibrium solution

Exploring the impact of network attack loss on the model uses the supply chain network structure. Only the retailer's utility is decreasing. This conclusion is obvious. The damage caused by cyber attacks will only make its own expectations. Reduced utility has no effect on other outcomes. The trust of the node enterprise in its own network security will affect its investment in information security. Section 5.2 has shown that increasing the information security investment can increase the utility of the node enterprise within a certain range.

6. CONCLUSIONS

In the three-stage supply chain network equilibrium model considering information security investment constraint, node enterprise has homogeneity in utility function, investment cost function and so on. The results show that node enterprise is willing to invest in information security in order to improve its own utility, and the diminishing marginal utility of inform-ation security investment may lead to the dependence of some node enterprise on its competitors. Moreover, the more node enterprises in the supply chain network, the more the top-level node enterprises will get more profit, which further shows that the supply chain network should be flat. Therefore, the following researches can further discuss the supply chain network equilibrium between node enterprise and stochastic demand and fuzzy demand.

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OPTIMIZATION MODEL FOR THE GENERAL SHARE-A-RIDE PROBLEM WITH ELECTRIC VEHICLES

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Purpose
This research introduces an extension of the general share-a-ride problem or G-SARP (Li et al., 2014; Yu et al., 2018), called the G-SARP with electric vehicles (G-SARP-EVs). This problem considers a taxi fleet with mixed plug-in electric vehicles (EVs) and gasoline vehicles (GVs) can service passenger and parcel requests simultaneously. In this problem, a taxi is allowed to convey more than one passenger at the same time, and there is no restriction on the maximum riding time of a passenger. In addition, the number of parcel requests that can be inserted between the pick-up and drop-off points of a passenger is limited only by vehicle capacity. This problem focuses on advance requests that are given prior to the beginning of the planning horizon.

Design/methodology/approach
This research develops a multi-layer time-space network to effectively describe the movements of taxis in the spatial and temporal dimensions (e.g., Mahmoudi and Zhou, 2016). While each EV operates on its own layer of the network, a dedicated layer is designed for the GVs in the taxi fleet. The EVs have the priority to service the passenger and parcel requests. Only when the number of EVs is insufficient to satisfy all the requests, will GVs be assigned to service some of them. An optimization model is formulated based on the multi-layer time-space network to determine a set of optimal routes and schedules for the taxi fleet to service the given requests, while satisfying operating constraints for EVs and GVs. The objective is to maximize the profit of the taxi company.

Findings
To examine the performance of the proposed model, this study generates a number of numerical instances with various sizes from the data provided by a logistics service provider in Taiwan. The results show that the proposed approach is able to effectively obtain the optimal routes and schedules for the taxi fleet to service all the requests.

Value
The obtained numerical results provide valuable insights into successfully implementing a taxi sharing service. We believe that the G-SARP-EVs and its optimization model should be able to assist taxi companies with heterogeneous fleets to solve scheduling problems in practice. In addition to brining benefits to the enterprises, replacing GVs with EVs will also reduce emissions and fuel consumption from the transportation sector.

INTRODUCTION

The reduction in greenhouse gas (GHG) emissions is one of the long-term environmental objectives all over the world. The statistics show that in 2017 Taiwan generated 269 million tonne CO_2 which contributes around 2% of Asia CO_2 emissions. The transport sector accounts for 13.5% of the nation's carbon dioxide emissions with 97.5% from road transport (MOE, 2018). Vehicle emissions give rise to many problems worldwide. Locally, the health effect of air pollution represents a serious problem in many of the most densely populated regions; while global carbon dioxide emissions are associated with climate change. Owing to the growing concern about sustainable development, the adoption of electric vehicles (EVs) has been a trend to ease the problems mentioned above. Some even predicted that EV fleets would play a critical role in the future market. The research on EVs has also increased in the past few years.

Ride-sharing services, which aim to bring together travellers with similar itineraries and time schedules, are another good idea for reducing traffic congestion, fuel consumption, and pollutions (Niels et al. 2012). Using empty car seats effectively may represent an important opportunity to increase the efficiency of urban transportation systems. Applying the concept on the People and Freight Integration Transportation (PFIT) problem, our research focuses on combining the people and freight networks in a mixed taxi fleet, which is the general share-a-ride problem with EVs. It can not only bring the benefits for the taxi company but also alleviate urban congestion and environmental pollution. The description of the problem is given as follows.

PROBLEM STATEMENT AND ASSUMPTIONS

The share-a-ride problem (SARP) was first introduced by Li et al. (2014) and it is an extension of the dial-a-ride problem (DARP). Comparing with DARP, it combines the people and parcel delivery which is usually serviced separately. The idea is that taxis could pick-up/drop-off parcels when they drive passengers for mitigating traffic congestion. One of the key assumptions in SARP is that the passengers have service priority over the parcels. Consider the example depicted in Figure 1. Vehicle 1 starts from the depot, and picks up passenger A and then parcel B. Afterwards, this vehicle drops off passenger A and then parcel B. Finally it returns to the depot. The SARP also considers the passengers' maximum riding time.

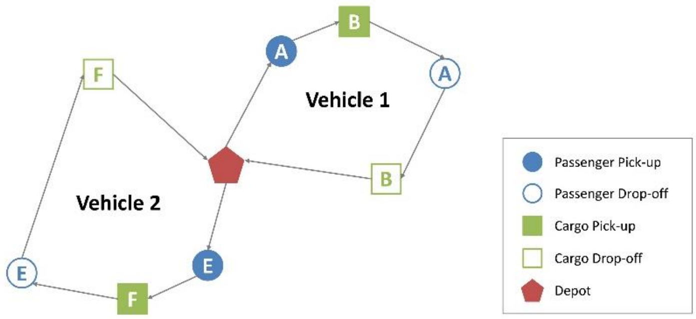

Figure 22 Share-a-ride problem (SARP)

The general share-a-ride problem (G-SARP), proposed by Yu et al. (2018), generalizes the SARP by relaxing some constraints. In G-SARP, if the time window of the requests and the capacity of the vehicles are satisfied, the vehicles can service as many requests as it can afford simultaneously. That is to say, there's no service priority between passengers and parcels, and also no consideration on maximum riding time for passengers. For instance, as shown in Figure 2, vehicle 2 starts from depot, picks up passenger E and then parcel F. After dropping off passenger E, vehicle 2 picks up parcel G, and then drops off parcel F and parcel G. Finally, it returns to the depot after completing all the service assignments. Both SARP and G-SARP aim to find a set of routes that maximizes the total profit obtained by serving all requests.

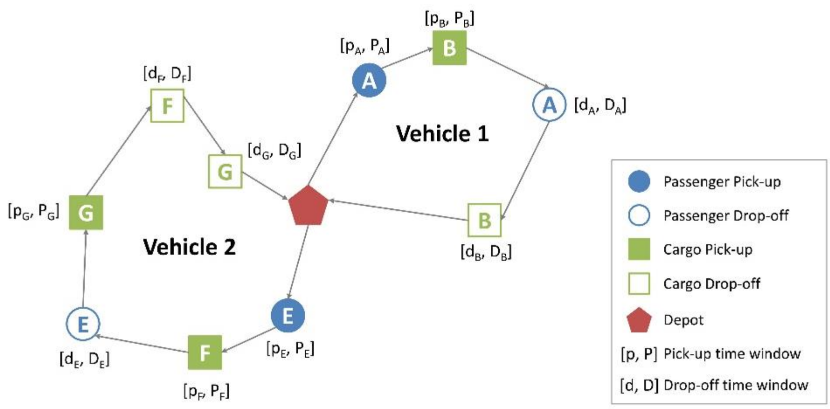

Figure 23 General share-a-ride problem (G-SARP)

In our research, the G-SARP is extended to the context where a mixed taxi fleet with plug-in electric vehicles (EVs) and gasoline vehicles (GVs) are employed to service passenger and parcel requests simultaneously. The new problem is called G-SARP-EVs. Several assumptions are made in the G-SARP-EVs. First, all the requests including passengers and parcels are known prior to the beginning of the planning horizon (i.e. pick-up station, delivery station, and time windows for pick-up and delivery). Second, EVs have priority over GVs while servicing requests. Third, both EVs and GVs must depart from the depot with full energy-level before servicing requests and return to the depot after completing all of their assignments. Fourth, vehicles cannot service a request if the capacity constraint will be violated after servicing that request. Lastly, EVs have to consider energy consumption and recharging plan additionally. The research aims to find a set of taxi routes and charging plans for EVs that services all requests while maximizing the total profit for the taxi company.

TIME-SPACE NETWORKS

This study adopts the time-space network flow technique to model the passenger, parcel and taxi flows in the system. There are two time-space networks constructed in this paper. The first is a single-layer time-space network (see Figure 24), which presents the given requests of the passengers and parcels; this network is called the demand-side network. The second is a multi-layer time-space network, which is used to describe the movements of the GVs' (see Figure 25) and the EVs' (see Figure 26) in the spatial and temporal dimensions; this network is called the supply-side network. Each layer in the multi-layer network corresponds to a GV or an EV.

For each layer, the horizontal axis represents the spatial dimension which consists of a set of locations including the origins/destinations of each requests and the set of charging stations. The vertical axis represents the planning horizon which is discretized into multiple equal-length time intervals. The detailed design of the networks is illustrated in the following.

Time-space Network for the Given Requests (Demand-side Network)

There are five types of nodes and two types of arcs in this network. Source node is a dummy depot where each vehicle departs from here to its first assignment; while sink node is another dummy depot to which every vehicle must return after finishing all of their assignments. Representing the locations of origins/destinations of each request are the location-time nodes. A pair of dummy pickup node and dummy delivery node are used to represent the pick-up location-time and drop-off location-time for each request, respectively. Both dummy pickup and dummy delivery nodes are associated with their corresponding location-time nodes. Pick-up arc represents a pick-up request while drop-off arc states a delivery request. For a pick-up arc, the upstream node is a station-time node and the downstream node is the corresponding dummy pickup node. The upstream node of a drop-off arc is a location-time node and the downstream node is the corresponding dummy delivery node.

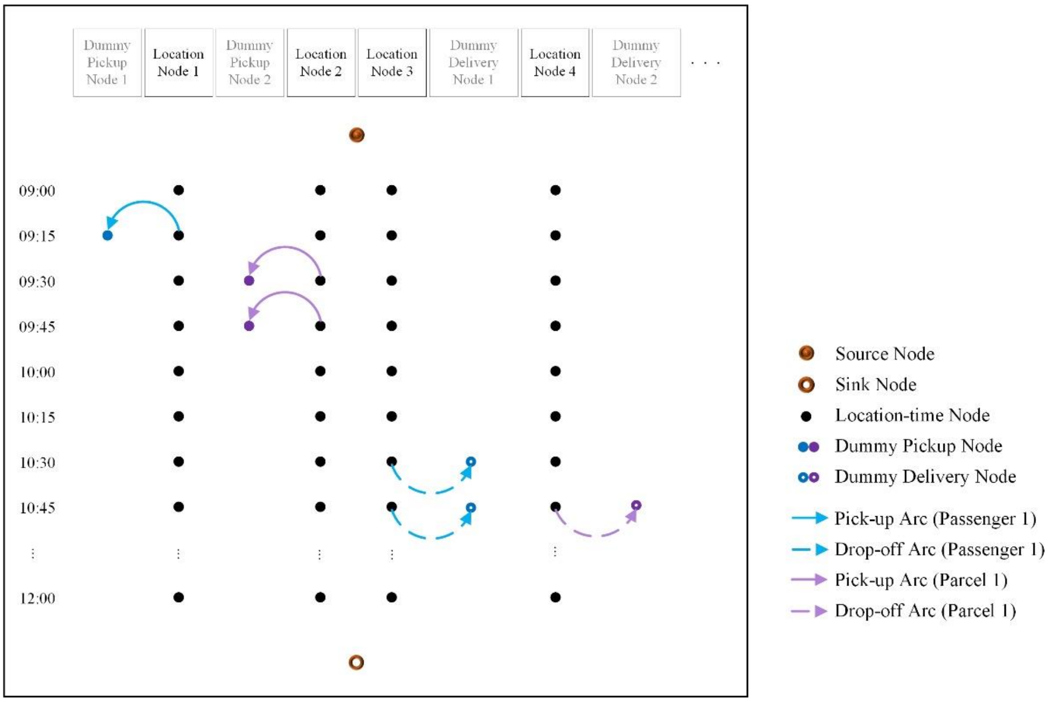

Figure 24 Illustrative example of the time-space network for given requests

Time-space Network for the EVs and GVs (Supply-side Network)

The types of nodes in the GV-flow networks are same as those in the demand-side networks. However, charging nodes are included in the EV-flow networks to represent the charging stations.

As for types of arcs, there are seven types of arcs in the supply-side network. They state the movements of the vehicles in the system. Supply arc connects the source node and a location-time node to represent the movement that vehicles depart from the depot to their first assignment. The supply cost consists of the travel cost from the depot to the downstream location-time node and the depreciation and maintenance costs of EVs or GVs. For the GVs' supply cost, there's an additional policy cost incurred due to the eco-friendliness consideration. The energy (or electricity) consumption of a supply arc in the EV-flow networks is a positive value proportional to the travel distance. A merge arc connects a location-time node and the sink node to present the movement from the last assigned request to the depot of that vehicle. The cost of a merge arc equals the travel cost from that location-time node to the depot. The energy consumption of a merge arc in the EV-flow networks is also a positive value proportional to the travel distance. A travel arc states the movement between two different location-time nodes. The electricity usage of a travel arc in the EV-flow networks is also a positive value proportional to the travel distance. The cost of a travel arc is the travel cost between two location-time nodes. Similarly, the GVs' travel cost includes policy costs for the eco-friendliness reason. Unused-taxi arc connects the source node and sink node and its cost and electricity consumption are both zero. The positive flow on an unused-taxi arc means the corresponding vehicle is not used. A waiting arc connects two location-time nodes for the same location in consecutive time intervals. It represents that the vehicle is waiting at the same location for some time intervals before servicing the next assigned request. In order to prevent vehicles from doing the unnecessary wait during its journey, the cost of waiting arc has to be a small constant instead of zero. In the EV-flow networks, the electricity consumption of a waiting arc is proportional to the waiting time. Virtual arcs, the opposite way of pick-up/drop-off arcs, are designed to comply with flow conservations. The cost and electricity consumption of a virtual arc are all zero. The last one is the charging arcs which appear only in the EV-flow networks. It connects two (charging) station-time node for a certain number of time intervals which represents the charging activity of an EV. The electricity consumption is a negative value proportional to the charging time; while the cost of a charging arc is a small constant for presenting vehicles from holding at the charging stations even if they are no need to recharge.

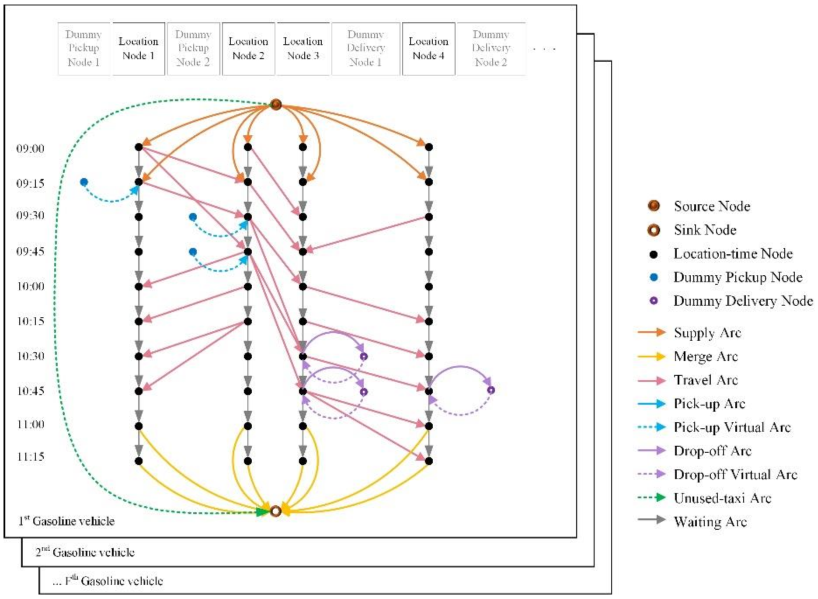

Figure 25 GV-flow time-space network

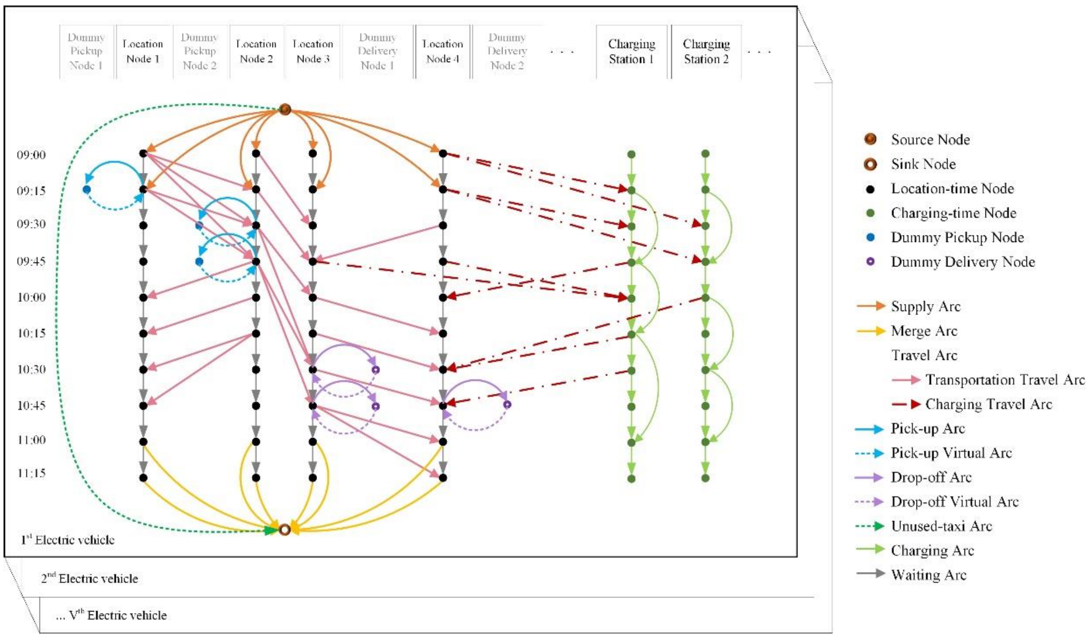

Figure 26 EV-flow time-space network

THE G-SARP-EV MODEL

Set	
Q	Set of requests
V	Set of EVs
N^v	Set of nodes in the *v*-th layer of the EV-flow network
K^v	Set of charging nodes in the *v*-th layer of the EV-flow network
O_q^v	Set of origin nodes for demand *q* in the *v*-th layer of the EV-flow network
G_q^v	Set of destination nodes for demand *q* in the *v*-th layer of the EV-flow network
A^v	Set of arcs in the *v*-th layer of the EV-flow network
S^v	Set of supply arcs in the *v*-th layer of the EV-flow network

M^v	Set of merge arcs in the *v*-th layer of the EV-flow network
T^v	Set of travel arcs in the *v*-th layer of the EV-flow network
W^v	Set of waiting arcs in the *v*-th layer of the EV-flow network
U^v	Set of unused-taxi arcs in the *v*-th layer of the EV-flow network
C^v	Set of charging arcs in the *v*-th layer of the EV-flow network
P_q^v	Set of pick-up arcs for request *q* in the *v*-th layer of the EV-flow network
D_q^v	Set of delivery arcs for request *q* in the *v*-th layer of the EV-flow network
H_q^v	Set of pick-up and delivery dummy arcs for request *q* in the *v*-th layer of the EV-flow network
F	Set of GVs
N^f	Set of nodes in the *f*-th layer of the GV-flow network
O_q^f	Set of origin nodes for demand *q* in the *f*-th layer of the GV-flow network
G_q^f	Set of destination nodes for demand *q* in the *f*-th layer of the GV-flow network
A^f	Set of arcs in the *f*-th layer of the GV-flow network
S^f	Set of supply arcs in the *f*-th layer of the GV-flow network
M^f	Set of merge arcs in the *f*-th layer of the GV-flow network
T^f	Set of travel arcs in the *f*-th layer of the GV-flow network
W^f	Set of waiting arcs in the *f*-th layer of the GV-flow network
U^f	Set of unused-taxi arcs in the *f*-th layer of the GV-flow network
P_q^f	Set of pick-up arcs for request *q* in the *f*-th layer of the GV-flow network
D_q^f	Set of delivery arcs for request *q* in the *f*-th layer of the GV-flow network
H_q^f	Set of pick-up and delivery dummy arcs for request *q* in the *f*-th layer of the GV-flow network

Parameter

c_{ij}^v	Cost of arc (*i, j*) in the *v*-th layer of the EV-flow network
r_{ij}^v	Revenue of arc (*i, j*) in the *v*-th layer of the EV-flow network
e_{ij}^v	Electricity consumption of arc (*i, j*) in the *v*-th layer of the EV-flow network
u^{max}	Upper bound of the battery capacity of an EV
cap^{max}	Upper bound of the spatial capacity of a vehicle
g_{ij}^f	Cost of arc (*i, j*) in the *f*-th layer of the GV-flow network
n_{ij}^f	Revenue of arc (*i, j*) in the *f*-th layer of the GV-flow network
p_i	Passenger pick-up/delivery quantity on node *i*; positive value if pick-up, negative value if delivery
m_i	Parcel pick-up/delivery quantity on node *i*; the quantity of parcels are passenger equivalent
M	Big positive constant

Variable

x_{ij}^v	flow on arc (*i, j*) in the *v*-th layer of the EV-flow network; $x_{ij}^v = 1$ if the *v*-th EV travels on arc (*i, j*); $x_{ij}^v = 0$, otherwise
z_{ij}^f	flow on arc (*i, j*) in the *f*-th layer of the GV-flow network; $z_{ij}^f = 1$ if the *f*-th GV travels on arc (*i, j*); $z_{ij}^f = 0$, otherwise
y_i^v	$y_i^v = 1$ if request at node *i* is serviced by the *v*-th EV; $y_i^v = 0$, otherwise
y_i^f	$y_i^f = 1$ if request at node *i* is serviced by the *f*-th GV; $y_i^f = 0$, otherwise
u_i^v	remaining electricity level of the *v*-th EV at node *i*
p_i^v	Passenger quantity of the *v*-th EV arriving node *i*
m_i^v	Parcel quantity of the *v*-th EV arriving node *i*
p_i^f	Passenger quantity of the *f*-th GV arriving node *i*
m_i^f	Parcel quantity of the *f*-th GV arriving node *i*

Mathematical model

Maximize

$\sum_{v\in V}\sum_{q\in Q}\sum_{(i,j)\in P_q^v} r_{ij}^v x_{ij}^v + \sum_{f\in F}\sum_{q\in Q}\sum_{(i,j)\in P_q^f} n_{ij}^f z_{ij}^f - \sum_{v\in V}\sum_{(i,j)\in A^v} c_{ij}^v x_{ij}^v - \sum_{f\in F}\sum_{(i,j)\in A^f} g_{ij}^f z_{ij}^f$	(1)

Subject to

$\sum_{(i,j)\in S^v \& U^v} x_{ij}^v = 1$	$\forall\, v \in V$	(2)
$\sum_{(i,j)\in M^v \& U^v} x_{ij}^v = 1$	$\forall\, v \in V$	(3)
$\sum_{(i,j)\in S^f \& U^f} z_{ij}^f = 1$	$\forall\, f \in F$	(4)
$\sum_{(i,j)\in M^f \& U^f} z_{ij}^f = 1$	$\forall\, f \in F$	(5)
$\sum_{v\in V}\sum_{(i,j)\in P_q^v} x_{ij}^v + \sum_{f\in F}\sum_{(i,j)\in P_q^f} z_{ij}^f = 1$	$\forall\, q \in Q$	(6)
$\sum_{v\in V}\sum_{(i,j)\in D_q^v} x_{ij}^v + \sum_{f\in F}\sum_{(i,j)\in D_q^f} z_{ij}^f = 1$	$\forall\, q \in Q$	(7)
$\sum_{(i,j)\in P_q^v} x_{ij}^v \geq \sum_{(i,j)\in D_q^v} x_{ij}^v$	$\forall\, q \in Q, \forall\, v \in V$	(8)
$\sum_{(i,j)\in P_q^f} z_{ij}^f \geq \sum_{(i,j)\in D_q^f} z_{ij}^f$	$\forall\, q \in Q, \forall\, f \in F$	(9)
$\sum_{j\in N^v} x_{ij}^v - \sum_{\mathrm{k}\in N^v} x_{ki}^v = 0$	$\forall\, i \in N^v, \forall\, v \in V$	(10)
$\sum_{j\in N^f} z_{ij}^f - \sum_{\mathrm{k}\in N^f} z_{ki}^f = 0$	$\forall\, i \in N^f, \forall\, f \in F$	(11)
$\sum_{j\in N^v} x_{ij}^v + \sum_{k\in N^v} x_{ki}^v = 4 - 4(1 - y_i^v)$	$\forall\, i \in O_q^v \cup G_q^v, \forall\, q \in Q, \forall\, v \in V$	(12)
$\sum_{j\in N^f} z_{ij}^f + \sum_{k\in N^f} z_{ki}^f = 4 - 4(1 - y_i^f)$	$\forall\, i \in O_q^f \cup G_q^f, \forall\, q \in Q, \forall\, f \in F$	(13)
$u_i^v - u_j^v + M(1 - x_{ij}^v) \geq e_{ij}^v$	$\forall\, (i,j) \in A^v, \forall\, v \in V$	(14)
$p_j^v - p_i^v + M(1 - x_{ij}^v) \geq p_i$	$\forall\, (i,j) \in A^v \backslash P_q^v \cup D_q^v \cup H_q^v, \forall\, v \in V$	(15)
$m_j^v - m_i^v + M(1 - x_{ij}^v) \geq m_i$	$\forall\, (i,j) \in A^v \backslash P_q^v \cup D_q^v \cup H_q^v, \forall\, v \in V$	(16)
$p_j^f - p_i^f + M(1 - z_{ij}^f) \geq p_i$	$\forall\, (i,j) \in A^f \backslash P_q^f \cup D_q^f \cup H_q^f, \forall\, f \in F$	(17)
$m_j^f - m_i^f + M(1 - z_{ij}^f) \geq m_i$	$\forall\, (i,j) \in A^f \backslash P_q^f \cup D_q^f \cup H_q^f, \forall\, f \in F$	(18)
$a_i^v = 0$	$\forall\, i \in K^v, \forall\, v \in V$	(19)
$x_{ij}^v \in \mathbf{B}$	$\forall\, (i,j) \in A^v, \forall\, v \in V$	(20)
$z_{ij}^f \in \mathbf{B}$	$\forall\, (i,j) \in A^f, \forall\, f \in F$	(21)
$0 \leq u_i^v \leq u^{max}, u_i^v \in \mathbf{R}_+$	$\forall\, i \in N^v, \forall\, v \in V$	(22)
$0 \leq p_i^v + m_i^v \leq cap^{max}, p_i^v, m_i^v \in \mathbf{R}_+$	$\forall\, i \in N^v, \forall\, v \in V$	(23)
$0 \leq p_i^f + m_i^f \leq cap^{max}, p_i^f, m_i^f \in \mathbf{R}_+$	$\forall\, i \in N^f, \forall\, f \in F$	(24)

The objective of the model is to maximize the profit defined in Eq.(1), including the revenue obtained from passenger and parcel services, and the operational costs of EVs and GVs. Eq.(2) and eq.(4) state that each EV and each GV starts its route at the depot. Eq.(3) and eq.(5) state that each EV and each GV must return to the depot after their assignments. Eq.(6) and eq.(7) guarantee that each request must be picked up and delivered exactly by one EV or one GV. Eq.(8) and eq.(9) ensure that the origin and destination node of the same request are visited either by the same EV or by the same GV. Note that Eq.(10) and Eq.(11) indicate the flow conservation constraints in each layer of the EV-flow network and the GV-flow network, respectively. Eq.(12) prevents the formation of sub-tours in the EV-flow networks. Similarly, eq.(13) is referred to as sub-tour elimination constraint in the GV-flow network. Eq.(14) computes the remaining electricity level for the downstream node (j) of each arc (i, j) in each layer of the EV-flow network. For the electricity consumption, travel arcs and waiting arcs are positive; charging arcs are negative; and all the other arcs are zero. Eq.(15) and Eq.(17) calculate the quantity of passengers after visiting the pick-up or delivery arcs in the EV and in the GV, respectively. Similarly, Eq.(16) and Eq.(18) calculate the quantity of parcels in the EV and in the GV. Eq.(19) guarantees that the EVs can recharge only if there is no passenger in the vehicle. Eq.(20) and Eq.(21) require that the arc flows in the EV-flow network and in the GV-flow network are binary. Eq.(22) defines that the remaining electricity level at each node of the EV-flow network must lie within the upper bound and 0. Eq.(23) and Eq.(24) ensure that the total quantity of passengers and parcels at each node of the EV-flow network and at each node of the GV-flow network must not exceed GV's capacity.

NUMERICAL EXPERIMENT

To examine the proposed G-SARP-EVs model, this study conducted numerical experiments using the test instances generated from the data provided by a logistic company in Taiwan. There are four instances for testing the model (i.e. 6a, 6b, 12a, 12b). The number in the name of the instances represents the quantity of demand; while the alphabet in the name of the instances is used for indicating the ratio between the quantity of passengers and the quantity of parcels. Specifically, 'a' means that the quantity of passengers and the quantity of parcels are the same and 'b' shows that the quantity of passengers is twice than the quantity of parcels. The planning horizon is set to half operation day (e.g. 9AM to 12PM), and divided to equal-sized time intervals which is 15 minutes. The size of each instances can be viewed in Table 7.

The test instances of the G-SARP-EVs optimization models were solved using Gurobi. The computational experiments were conducted on the personal computer with Intel(R) Core(TM) i5-8250U CPU@1.60GHz and 12.0GB RAM and the operating system is Microsoft Windows 10. The computational results are summarized in Table 8.

For all the instances, the optimal solution is obtained by Gurobi; that is, the gap is 0%. For the instance 6a and 6b with six requests, both of them could be solved in five seconds; while the other two instances with twelve requests took around two hours to be solved.

Table 7 Size of the time-space networks and the model

Item		**6a**	**6b**	**12a**	**12b**
Quantity	Number of passengers	3	4	6	8
	Number of parcels	3	2	6	4
GV-flow time-space network	Number of network layers	2		2	
	Number of nodes per layer	229		241	
	Number of arcs per layer	3,399		3,435	
EV-flow time-space	Number of network layers	2		5	
	Number of nodes per layer	301		313	

network	Number of arcs per layer	5,809	5,845
Total number of arcs		18,416	36,095
G-SARP-EVs model	Number of constraints	51,400	106,264
	Number of continuous variables	3,620	6,878
	Number of integer variables	19,864	38,629

Table 8 Computational results

Item	6a	6b	12a	12b
Service revenue (NT $)	993	893	2,476	2,699
Operational cost (NT $)	496	487	723	867
Total profit (NT $)	497	406	1,753	1,832
Computational time (sec)	4.08	2.40	7,020	6,320
Gap (%)	0.00	0.00	0.00	0.00
Number of EV used	2	2	5	5
Number of GV used	1	1	1	2
Number of EV unused	0	0	0	0
Number of GV unused	1	1	1	0

CONCLUSION

The above numerical results show that the design of the time-space networks and G-SARP-EVs model can correctly show the flows of people, parcel and vehicles. Also, the schedules of each vehicle can be clearly arranged in order to maximize the profit of the taxi company. However, the more quantity of demand, the computational time would be higher. In order to solve this problem more efficiently, future research may focus on developing heuristics for G-SARP-EVs.

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VOLUMETRIC OPTIMIZATION OF FREIGHT CARGO LOADING: CASE STUDY OF A SME FORWARDER

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ABSTRACT

Purpose: Freight forwarders faces a challenging environment of high market volatility and margin compression risks. Hence, strategic consideration is given to undertaking capacity management and transport asset ownership to achieve longer term cost leadership. Doing so will also help to address management issues, such as better control of potential transport disruptions, improve scheduling flexibility and efficiency, and provide service level enhancement.

Design/methodology/approach: The case company currently has truck resource which is unprofitable, and the firm's schedulers are having difficulty optimizing the loading capacity. We apply Genetic Algorithm (GA) to undertake volumetric optimization of truck capacity and to build an easy-to-use platform to help determine potential costing savings that can be attained, and whether if the business should expand its internal truck fleet.

Findings: Our analysis suggests that the case company's truck resource is underutilized by about two-thirds of capacity. Through a proposed mathematical model and GA heuristic, the case company can potentially save up to S$567K per annum.

Value: By using a simple GA and incorporating a visually appealing user interface, we have helped a freight forwarder improve her financial and operational efficiency. The game changer is the scalability of the solution to include more resource optimization across the fleet and across more freight forwarding firms.

Keywords: Case study, Fleet management, Genetic algorithm, Bin packing, Freight

Type of Paper: Case study

1. INTRODUCTION

The International Federation of Freight Forwarders Association defines freight forwarding as the "services of any kind relating to the carriage, consolidation, storage, handling, packing, or distribution of the goods as well as the ancillary and advisory services in connection therewith, including but not limited to customs and fiscal matters, declaring the goods for official purposes, procuring insurance of the goods and collecting or procuring payment or documents relating to the goods." In essence, forwarders value-add in the logistics spectrum through the bundling of customer (shipper) demands, and procuring of transport capabilities with volume rebates, coordinating the many transport players, and enhancing transport management with value-added services.

The freight forwarder market is highly fragmented, driven by very low entry barriers in the industry. Basic transportation service is mainly delivered by the local players, with several large international players. Market competition is characterized by low product differentiation, causing price to be a main competitive lever. (Stålbrand et. al., 2005) (Wulyo, 2017). While there are limited value-added services that may be provided through different ancillary and advisory offerings to act as differentiators, process efficiency and network cost are key areas where the freight forwarders focus on to reduce price and maintain cost competitiveness. (Burkovskis, 2008).

In this case study, the case firm, one of the SME freight forwarders with presence across the ASEAN region, has internal freight resource which is unprofitable, and the firm's Schedulers are having difficulty optimizing the loading capacity of its freight fleet.

For the freight forwarders as such, fleet optimization among the freight forwarding community is both an art and science. For the smaller local freight forwarders, with pressing concerns on cash flows and asset utilization, there is the imperative to volumetrically optimize the freight carried in a truck wherever possible. Unfortunately, for such smaller freight players, the presence of efficient and intelligent, albeit expensive, load schedulers is often a luxury that the freight company can ill afford. Often times, the loading of the cargo (pallets or cartons or boxes) onto a truck is done by sight and with the scheduler having some prior knowledge of the shipment to realise speed and workflow efficiency. Clearly, this community of freight forwarders recognizes the need to improve this aspect of the traffic process, namely, by incorporating a smart scheduler which can allow for more flexibility in shipment request without sacrificing on capacity optimization and management.

This paper therefore presents an effort to apply mathematical modelling and Genetic Algorithm (GA) to volumetrically optimize the cargo loading for a freight forwarder.

Through this case study, the community can then appreciate the value of using mathematical techniques imbedded within a smart optimization engine and a visually acceptable user interface to rapidly load small pieces of cargo (crates, boxes, cartons) onto a truck. Specifically, we show the economic efficiency of applying this to the operations and capacity management of the freight traffic process and determine the potential cost savings of applying technology in a prudent manner.

The rest of this paper is set as follows. Section 2 presents the necessary literature review. Section 3 develops the model used on the case study. Section 4 discusses the findings, with graphical evidence of the visual interface. Section 5 concludes the paper with some recommendations for future research.

2. LITERATURE REVIEW

The bin packing problem which refers to orthogonally packing a fixed number of crates into finite sized bins using the least number of bins (Martello et al., 2000). A general classification of the bin packing problem is found in Dyckhoff (1990). For instance, the classical knapsack problem (Diedrich et al., 2008) is a combinatorial optimization packing of many different volumetric items into an allocated bin with the objective to minimize wasted space and maximize value. Gehring et al. (1990) effectively applied such combinatorial decision problems on various sizes of shipping containers using a heuristics solution. Each item is generally categorized by their mass, volume and monetary value, such that a subset of items can be packed into this knapsack to obtain the maximum profit possible subject to the total capacity constraint.

In a similar vein, there is the container loading problem which seeks to find a feasible arrangement of containers in a container yard or on board a ship. In such problems, height is generally not constrained to finite stacking, but rather used as the objective function such that it is minimized to obtain an optimal loading solution. The solution space of heuristic solutions for the container loading problem can be found in George and Robinson (1980), and Bischoff and Marriott (1990).

Both the bin packing and container loading problems typically operate under a 3-D environment and use a cost function (Gehring et al., 1990). Due to the case company's existing concern of capacity under-utilization in managing the freight, and the need to understand how much additional load is needed to maximize the trucking capacity (so that they can cargo space more proactively), this study will focus solely on optimizing the capacity utilization, and show to the case firm the overall incremental profit that can be gained based on an optimized load plan by relying on a bin packing solution.

There are several ways to find good feasible near optimal solutions to the class of NP-hard 3-D bin packing problem, see for example, Martello et al. (1990), and Scheithauer (1991), and the references therein. The solution techniques can be categorized under three categories: (i) mathematical, (ii) heuristics, and (iii) meta-heuristic approaches.

Multiple integer linear programming (MILP) as proposed by Chen et al. (1995) and others is a mathematical approach that focuses on using mixed integer programming to pack cartons of non-uniform sizes, taking into consideration the carton orientations and overlapping of cartons in a bin. A proposed method to improve the relaxed lower bound of MILP is discussed in Hifi et al. (2010), using identical bins to minimize the number of used bins. Similarly, den Boef et al. (2005) proposed a solution approach with a softer lower bound. Fekete et al. (2007) developed a separate mathematical model with a two level tree search algorithm, however this is limited to two dimensional packing problems. Yang and Leung (2003) also developed a model, an open-ended branch and price algorithm, in which the cargo cartons follow a sequence.

Next, a popular heuristic is the wall or layer building model explored by George and Robinson (1980) with identical cartons and no boundaries to the crate orientation. Non-identical crates with stability of stacking have been studied by Bischoff et al. (1995), and Baltacioğlu et al. (2006), where a new heuristic was created that follows humanistic thinking to aid packing. Pisinger's (2002) approach was to apply the strip and layer building method to decompose the problem down into simpler sub-forms. A heuristic to generate a solution with a minimum number of bins required using a guided local search with no crate rotation is found in Faroe et al. (2003).

The meta-heuristic models generally comprise tabu search, simulated annealing, and GA. Fanslau and Bortfeldt (2010) have discussed the different meta-heuristic models used. For instance, Bortfeldt and Mack (2007) suggested integrating a layer packing heuristic model with a tree search algorithm to obtain the best layer depth, dimension, and direction. Simulated annealing has been used together with heuristic methods to solve a generic 3-D bin packing problem, as found in Zhang et al. (2007). Egeblad and Pisinger (2009) further looked at 2D and 3D knapsack problems using simulation annealing. A hybrid of layer building and GA is also employed by Goncalvez and Resende (2012). Lodi et al. (2002) used a tabu search approach to qualify the neighbouring spaces with no crate orientation.

3. RESEARCH METHOD, DATA, and ASSUMPTIONS

In this paper, we elected to use GA as the meta-heuristic to imbed into the user interface built for the case firm.

The case firm has provided three months of cargo data, consisting of the cargo dimensions, estimated charging rates and order fulfilment timing. In the 3 months' worth of data, 76 working days were identified in the freight operations. Daily operations are performed once in the morning and once in the afternoon. On Saturdays, the operations are carried out only in the morning and Sundays are designated as non-work days. This data set has a total of 140 trips of freight operations, an average daily volumetric utilization at 34.6% and an average load of 578 kg. (See Table 1 for the capacity utilization).

Table 1: Daily volumetric utilization (in percent)

	Mon	Tues	Wed	Thurs	Fri	Sat	Overall
Mean	56.3	44.1	37.4	24.8	34.7	8.8	34.6
Median	36.7	35.9	26.9	21.1	33.0	4.2	27.1
Standard Deviation	48.0	53.0	36.9	24.3	15.5	8.9	36.9
Max Vol. Utilization	166.7	207.4	137.7	97.4	61.9	25.7	166.1

At the same time, the bin packing engine had to accommodate the regulatory constraints. For starters, regulations govern how much weight can be carried based on the truck size and this serves as another important constraint to our bin packing issue. The total tonnage cannot exceed 2 tonnes. We had to collect the finer details of these constraints from the relevant agencies and from the case firm's operational team. (Table 2 shows the relevant statistics.)

Table 2: Weight capacity utilization (kg)

	Mon	Tues	Wed	Thurs	Fri	Sat	Total
Mean	911.6	540.5	573.9	486.5	723.5	115.0	578.1
Median	766.0	591.0	427.0	387.0	705.0	97.5	437.0
s.d.	790.6	289.3	530.7	537.6	332.9	108.9	544.5

From the initial data collected, a q-q plot was undertaken and it showed that as the daily total weight carried increased, so too does the total freight volume carried, albeit by a smaller margin, as expressed by the relationship *Volume = 3.929 + 0.05298 x Weight. (This suggests that weight has a greater bearing than volume in the pricing negotiations).*

Finally, the other practical constraints which had to be factored include the cargoes that were typically heterogeneous in weight and size. In the loading sequence of the cargo plan, we had to pre-plan for the sequence of unloading for delivery. In short, the cargoes had to be packed in a sequence such that it facilitates the ease of unloading in an order of priority. We assume that the cargoes are free to rotate in all directions for the packing during loading and unloading. Fourthly, we are looking at a fast solution generation which is practical and does not delay the trucking schedule as the working hours are limited and costly.

4. MODEL SELECTION AND RESULTS

The mathematical model used to build the smart engine for the bin packing for the case firm is stated as follows:

Maximize $$f(r,c,t) = \sum_{p=1}^{n} \sum_{q=1}^{2} (r_{pq} - c_{pq})\, t_{pq}$$

where
$f(r,c,t) =$ Total monthly profit earned the firm
$p = \{1, \dots, n\}$; Truck number
$q = \{1, 2\}$; truck types, where 1 refers to 14 ft trucks and 2 refers to 24 ft trucks
$r_{pq} =$ Monthly revenue gained for truck p of type q
$c_{pq} =$ Monthly operational cost for truck p of type q
$t_{pq} = \{1, 0\}$; Binary variable, denoting the existance of a particular truck p of type q

with the respective constraints

$$\sum_{p=1}^{n} \sum_{q=1}^{2} \frac{m \bullet a \bullet V_{pq} \bullet \mu}{V_s}\, t_{pq} \leq \delta$$
$$\sum_{p=1}^{n} \sum_{q=1}^{2} t_{pq} \leq s$$
$$t_{pq} = 0 \text{ or } 1; \quad r_{pq,} c_{pq} \geq 0 \;\&\; integer$$

where
$s =$ Maximum number of trucks as decided by management
$m =$ Number of working days in a month
$a =$ Average number of trips per day
$V_{pq} =$ Bin volume capacity
$V_s =$ Total monthly cargo volume carried
$\mu =$ Optimized fill rate
$\delta =$ Max possible volume for cargo
$\sigma =$ Cargo volume volatility based on historical cargo volume data

Using this model and implementing GA onto the case firm's platform, we were able to modify the sequence of the freight loading plan, as shown in Figure 1.

The GA model was coded on the GAMS platform using CPLEX 11.0, running on an i5 2.53 GHz dual core Intel processor with 4 GB RAM. CPLEX was allowed to run for 180 seconds to obtain the optimal packing results. The inputs used for the optimizer were the number of crates for the day's delivery, and the dimensions of each piece of cargo. From thereon, the outputs provided through the model and GA were the sequence of loading of the cargoes, the dimensions of the cargoes in their rotated positions. The last output attributes were similar to Wu et al. (2010).

A simulation was then built on Excel where a random sampling pick is taken in each of the various cargo base categories, namely long, rectangle, and square crates. This will create a representative selection of the case firm's cargoes within the data pool of 976 crates for an accurate test sample. In each sample, a list of n item sizes of crates are chosen uniformly and independently at random within each base category, upon which the sum of the crate volume is computed. Each randomised output is thus an assortment of cargo crates which will fill the total bin (truck) volume by a certain percentage. The *fill rate* is defined as the sum volume of each randomized assortment of cargo crates divided by the total bin volume. The results suggest that a 100% packing success rate can be achieved when the fill rate is less than or equal to 80%. The *packing success rate* is defined as the probability of being able to optimally pack a random assortment of cargo crates into a truck bin volume. In the simulation, the packing success rate for each fill rate range is calculated based on the cumulative results of 50 runs. Further, the packing success rate reduces rapidly between fill rates of 80% and 88%, upon which it reaches a packing success rate of zero. The packing success rate drops rapidly to zero, when the capacity utilization reaches a maximum and exceeds the capacity. Our results compared fairly well to Wu *et al.* (2010) who had reported an optimal fill rate with 100% packing success at a range of 82.7% – 85.1%, based on an arbitrary data set.

From a practical perspective, an 80% fill rate also allows for a reasonable 20% buffer to account for practical constraints which cannot be inserted into the algorithm, such as packing inefficiencies and odd shaped cartons.

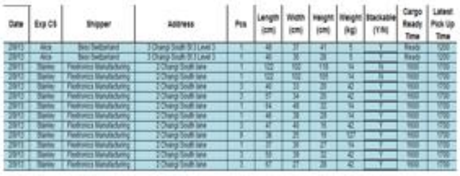
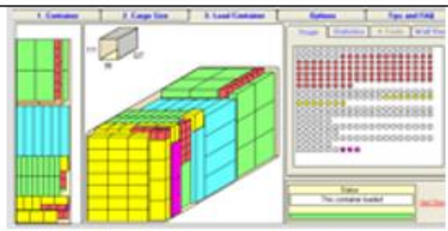
1		Scheduler receives and accepts the customer orders. Delivery and collection information is filled in the database of the system.
2		Import database into 3D BPP software. Key parameters include: a) Shipper – Customer name b) Quantity – Quantity of the cartons c) Length, Width, Height – Dimensions of the carton in centimeter (cm) d) Weight – Weight of the carton in kilogram (kg) e) Stackable (Y or N) – To determine whether the cargo is stackable.
3		Scheduler optimizes the truck capacity with loading planner. Then, sends out the 3D Packing Illustration Map to the Logistic Manager and notifies the Truck Driver.
4		Logistics Manager receives the delivery/ collection schedule, loading items and the 3D Packing Illustration Map. These information are printed and handed to the Truck Driver, who now has all the necessary information to perform the packing and delivery task.

Figure 1: Improved freight loading plan using GA and mathematical modelling

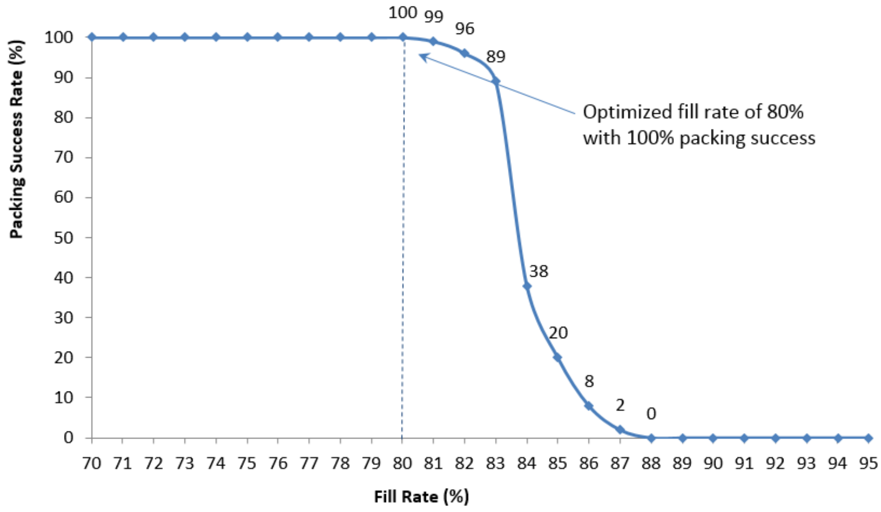


Figure 2: Packing success rate vs. fill rate

5. CONCLUSION

In this paper, we have applied mathematical modelling and GA to build a visually friendly user interface to help freight cargo schedulers responsively organise their cargo in three dimensions, in the most expedient manner, and pack the latter as optimally as possible to maximum capacity utilization. Our simulated results show that a fill rate of 80% is optimal to yield the best packing success under the existing set of operational constraints. This optimal value is obtained after factoring in the unloading demand on the cargo and other regulatory constraints. By using a simple GA and incorporating a visually appealing user interface, the case firm can improve her financial and operational efficiency, saving up to S$567K per annum. The practical scalability of the solution in the case firm suggests implementation applicability to fleet resource optimization across freight forwarding firms.

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INCORPORATING CARGO LOADING FEASIBILITY INTO A B2B DELIVERY VEHICLE ROUTING PROBLEM

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Purpose
The vehicle routing problem (VRP) with loading constraints is a widely studied combinatorial optimization problem in freight transportation and distribution industries, which aims to minimize the total system routing costs for covering customers demand and determine a feasible loading plan of the shipments into the available storage space.

Design/methodology/approach
It should be noted that most above studies tend to apply the 'packing first, routing second' strategies to solve this combinatorial problem. Different heuristic approaches will be examined in this study.

Findings
A practical B2B data analysis will be implanted first, to explore the features and linkages of the studied database. Furthermore, an integrated VRP with practical loading constraints with B2B data analysis will be conducted in this study.

Value
Since the combinatorial loading and routing optimization problem becomes one of the great challenges faced by logistics service providers, this paper aims to develop a 'feasible packing with optimal routing-based' heuristic algorithm to solve this problem in a timely manner

1. Introduction

Incorporating cargo loading feasibility into a B2B delivery capacitated vehicle routing problem (CVRP) is a challenging issue in practice. First, the traditional VRP may only consider the weight or volume of shipments. These routing results may yield the feasibility of routing but not into the loading side. Second, three-dimensional loading is another NP-hard problem. The problem considering the cargo loading feasibility while solving the vehicle routing problem was namely the capacitated vehicle routing problem with three-dimensional loading constraints (3L-CVRP, Gendreau et al., 2006.) The combinatorial problem has been widely studied in freight transportation and distribution industries fields. In the loading problem, there are a lot of constraints should be satisfied, e.g. orientation of cargo, supporting area, LIFO policy, etc. Moreover, the B2B shipments own the characteristics with irregular sizes also increase the complexity of the studied problem.

The main idea of this paper was to solve 3L-CVRP by the proposed heuristic algorithms, based on "Routing first- Packing- second" strategy with the modified CVRP and packing logic to solve a real database from a B2B service company.

This paper is organized as follows: Section 2 reviews the relevant literature. In Section 3 describes the problem. In Section 4 presents our idea of the solution. In Section 5 does some numerical experiments. In Section6 makes a short conclusion.

2. Literature review

Vehicle routing problem with three dimensional loading constraints (3L-CVRP) was the integration of two classical NP-hard problems: Capacitated vehicle routing problem(CVRP) and container loading problem (CLP). In the Literature review. We will explain the idea of the solutions of each problem.

2.1 Capacitated Vehicle routing problem

Capacitated Vehicle routing problem was initially presented by Dantzig and Ramser in 1959. Every customer has their demand of cargo and the trucks have the limit space. How to deliver the cargo to each customers and trucks should depart from and return to the depot was the basic description of this problem. No matter the objective, there are several ways to find a feasible solution. Exact methods, like linear programming, branch and bound, had the ability to find the exact solution. But when the scale of the problem become larger, time spending will also extend. Therefore, we usually use the heuristic algorithms to solve it. Saving algorithm by Clarke and Wright (1964) and sweep algorithm by Gillett and Miller (1974) were classical heuristics algorithms. But the week point of them was the solution might be the local optimal solution. To avoid it, meta-heuristic algorithms can find a feasible solution in short time and also can jump out the local to find the global optimal solution. Common meta-heuristic algorithms were simulated annealing (SA), genetic algorithm (GA) and ant colony optimization algorithm (ACO), etc. Osman (1993), Chiang et al., (1996) and Wei et al., (2018) all utilize the SA to solve the vehicle routing problem and had good results.

2.2 Container loading problem

In this paragraph, all the items and containers mean the rectangular boxes. Container loading problem is classified as the three dimensional (3D) rectangular packing problem in the general cutting and packing problem (C&P) (Chen et al.,1995). The main idea of C&P problem was put the smaller "items" into the bigger "containers". And we usually depend on the requirement of the problems to create the sub-problem based on the main idea. Dyckhoff (1990) and Wäscher et al. (2007) were clearly detailed the definition and the sub-problem in C&P. In our knowledgement, there were three or more kinds of sub-problems in C&P belong to container loading problem: 3D-BPP, 3D-ODPP and 3D-KPP. In three dimensional bin packing problem (3D-BPP), lengths of each side of every items and containers were fixed. How to put the items into containers with the least numbers of containers was 3D-BPP. Three and open dimensional packing problem (3D-ODPP) also called the strip packing problem(SPP). Let two of length, width and height of a container be fixed, and how to put the items into the container to make the non-fixed side be minimized was the main idea of 3D-ODPP. Three dimensional knapsack packing problem(3D-KPP) was the extending problem from knapsack problem. In addition to the length of each side of items, each item had their own value, how to put the items into the limit containers and make the value in the containers maximized was the idea of 3D-KPP. The concepts of three problems above-mentioned were usually appear in 3L-CVRP.

CLP was NP-hard problem and we usually use the heuristic method to get solutions. Vega-Mejía et al. (2017) divided the past heuristic methods into two categories: Placing algorithms, and grouping techniques. The concept of placing algorithm was searching the free space and determine the placing point, e.g. Back-Bottom-Left-Fit algorithm. Common group techniques like wall/layer building and block building take grouping concept to do the packing. Besides develop the heuristic methods to solve the loading problem, Krishna et al., (2017) use the "CargoWiz", a packing software, to do the research about the optimization of truck loading and got a good result.

2.3 Vehicle routing problem with three dimensional loading constraints

3L-CVRP also was the NP-hard problem. There are three strategies to find the solution:" Packing First-Routing Second", "Routing First-Packing Second" and "Pack while Routing" (Vega-Mejía et al.,2017). Bortfeldt and Homberger (2013) presented a way of Packing First-Routing Second. They solving 3D-SPP for each customer first, and solving the CVRP while the total length cannot over the limit of truck by using TS algorithms. For "Routing First-Packing Second", Moura and Oliveira (2009) make the loading problem be a sub-problem. They solving the CVRP at first, and trying to adjust the customer if they cannot fit in the truck. The adjustments included (i) changing the loading sequence and (ii) putting the non-loaded customer to other routes or (iii) creating a new route. Also in Miao et al., (2012), it combined the SA and GA to generate a lot of initial solutions and sort them by the objective functions. And check the feasibility of loading problem one by one until the cargo completely be loaded. Gendreau et al., (2006), which presented 3L-CVRP solving by "Pack while routing". By savings algorithm for CVRP, each customer was a route. Trying to do the combination of routes and check the feasibility simultaneously until the amount of truck reduce to the limit.

There were several papers solving 3L-CVRP by the three main ideas. Vega-Mejía et al., (2017) sort them by three ideas. "Routing First-Packing Second" was the most common to solve the 3L-CVRP. There were many papers concentrated on develop the better heuristic methods to find initial solution or solve loading problem and make the cargo be feasible.

In our opinion, we divided Routing First-Packing Second way into two different methods, one is "Routing First-Packing Second-Fixing third", like Moura and Oliveira (2009), and another one is "Routing First-Packing Second-Rerouting, like Miao et al., (2012). Fixing means based on the initial solution to make it become feasible. Rerouting means if this route were not feasible, we will find another initial solution to check the feasibility.

3. Description of problem

Following the base problem description of 3L-CVRP in Gendreau et al., (2006). Different from them. We allow the cargo can be rotated by 90° on the $length - width$, $width - height$ and $length - height$ plane. The conditions should be satisfied also not completely equal. Following were the supposing and constraints:

(1) Vehicles depart from depot and should back to depot.
(2) Use the identical vehicles and the amounts are unlimited.
(3) Each customer has to be served in one time by one vehicle.
(4) Weight and volume limit of vehicle, cargo size of customer are known.
(5) Total weight of cargos in one route cannot exceed the limit of vehicle.
(6) Cargos cannot out of the vehicle's each side when finishing the loading.
(7) Fully supporting area. (Fig.1)
(8) Loading priority*.

The most different were (7), (8). Fig.1 shows that the position cargo placed shouldn't let itself be probably felt down. (A)(C)(D) were satisfied and (B) was unsatisfied. Load cargos by the sequence of delivery was equal to the LIFO policy, but loading priority would influence the feasibility of loading. In the next chapter, we will present two solution methods to solve two situations, considering loading priority and un-considering priority. And our objective function was minimizing the numbers of vehicles used.

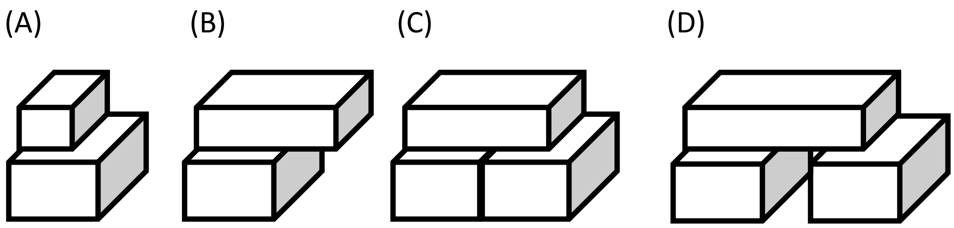

Fig. 27 Demonstration of supporting area

4. Solution methods

The new method was "Routing First-Packing Second-Fixing third". We solve the improved CVRP by simulated annealing (SA) algorithm and check the feasibility by commercial packing software "CargoWiz" to get feasible solutions.

Fig.2 Flow chart of the method

4.1 Routing

In routing step, we will get the initial solution. The method of "Routing First-Packing Second" usually solve base CVRP first, they didn't consider the "volume" of cargo, often just consider the weight of cargo and truck limit. Volume means the length × width × high of item. In that way, the initial solution might emerge the total volume of the cargo in one route was over the limit of truck. We solve the improved CVRP which each customer's demand including the weight and volume first. This step could make the initial solution more likely to loaded in the truck than considering without volume. After routing step, we got an initial solution. But it might be unsuccessfully loaded in truck.

4.2 Packing

This step was packing the cargo in each route by CargoWiz and spilt the routes if necessary. We formulated two rules for un-considering and considering the loading priority. For un-consider the loading priorities. We sort the cargo's volume from big to small in each route. And put them into truck in order from the biggest one. When the cargos cannot load, it will load into extra truck. Loading sequence was based on the volume, and usually trying to load into the first truck, unless the first truck didn't allow to put into. For considering the loading priority. First, we will check the cargo in route could be loaded in two directions or not. If two directions are not. We will make it fixed which the last customer's volume was larger than first. And We try to load more customer's cargo from the first to last customer. When the condition that a customer cannot be loaded, skip it and try the next one until the truck cannot load any other one. The customers who were skipped were loaded in extra truck by the fixed sequence. Two rules were creating the extra route if necessary. After this step, we already make the solution, routing and packing plan could be loaded successfully. It can be double check by CargoWiz.

4.3 Fixing

At this time, the utilization in some routes might be low. We follow to two heuristics trying to merge them. Sort the routes from low to high utilization and keep the list, then merge them based on the utilizations and travel distances. For utilizations, we merge the lowest utilization route and the highest one. If they could load in feasible loading plan, they would be merged and the list will update. If the highest one cannot be merged, try the second highest and so on. For travel distances, we also try to merge routes from lowest one, but the route would from near to far, wasn't based on the utilization. We use the centre point to determine the route's distance between each other. Two heuristics were trying to merge the lower one in advanced. Until each routes cannot be merged anymore, the fixing was complete. It should be note the loading priority when merge two routes in considering loading priority should follow the traveling salesman problem(TSP) results. The TSP was also solved by SA. After fixing part, the travel sequence in un-considering loading priority should be determined by solve TSP, too.

5. Numerical experiments

We use MatlabR2017b to implement the SA to solve improved CVRP and use free trial CargoWiz to implement the loading plan. Take an instance from Gendreau et al.,2006: 3L-CVRP19 for experiment. That was 50 customers and 99 items. The limit demand of a vehicle was 160. It should be noted we didn't consider the fragility even if the CargoWiz able to do. Because it was more complicated. The initial solution (route) was trying ten times in Matlab and pick the best one. When the vehicle used were equal, we picked the one that had minimum travel distance.

5.1 Non-considering loading priority

Initial solution

No.	Routes	Demand(160)	Feasibility
1	[11,16,50,34,21,29,2]	114	✘
2	[15,33,45,44,37,12]	97	✘
3	[6,24,43,7,23,48]	88	✘
4	[17,42,40,19,4,47]	66	✔
5	[18,41,13,25,14]	140	✔
6	[27,8,26,31,28,1]	77	✘
7	[5,49,10,39,30,9,38,46]	108	✘
8	[22,3,36,35,20,32]	87	✘

Fig.3 Initial solution by SA

Splitting routes

No.	Routes		Split routes	Vol. used
1	[11,16,50,34,21,29,2]	➞	[11,16,21,29]	55.99%
			[50,34,2]	41.46%
2	[15,33,45,44,37,12]	➞	[33,44,37,12]	67.14%
			[15,45]	22.61%
3	[6,24,43,7,23,48]	➞	[43,7,23,48]	53.96%
			[6,24]	22.45%
4	[17,42,40,19,4,47]	➞	[17,42,40,19,4,47]	66.01%
5	[18,41,13,25,14]	➞	[18,41,13,25,14]	49.74%
6	[27,8,26,31,28,1]	➞	[27,8,28,1]	64.13%
			[26,31]	13.71%
7	[5,49,10,39,30,9,38,46]	➞	[5,49,10,39,30,9]	66.14%
			[38,46]	9.35%
8	[22,3,36,35,20,32]	➞	[3,36,35,20,32]	66.27%
			[22]	10.98%

Fig.4 Check feasibility and split customers by CargoWiz

Merge by utilization-oriented

No.	Routes	Demand (160)	Vol. used	Travel distance
1	[18,41,13,25,14]	140	49.74%	64.43759
2	[2,50,34,38,46]	86	50.81%	73.28142
3	[29,21,16,11]	48	55.99%	68.42301
4	[6,24,26,31,45,15]	63	58.77%	150.70023
5	[27,28,8,1]	59	64.13%	65.08361
6	[22,48,7,43,23]	71	64.94%	96.34232
7	[17,42,40,19,4,47]	66	66.01%	90.71212
8	[9,30,39,10,49,5]	88	66.14%	83.61779
9	[3,36,35,20,32]	79	66.27%	90.26672
10	[33,44,37,12]	77	67.14%	76.15530
		Total		859.0201

Fig.5 Merge routes by utilization -oriented

Merge by travel distance-oriented

No.	Routes	Demand (160)	Vol. used	Travel distance
1	[18,41,13,25,14]	140	49.74%	62.76776
2	[43,7,23,48]	63	53.96%	79.32989
3	[11,16,21,29]	48	55.99%	74.22781
4	[15,45,26,31,6,24]	63	58.77%	68.42301
5	[38,46,22,50,34,2]	94	61.79%	111.26064
6	[27,8,28,1]	59	64.13%	65.08361
7	[17,42,40,19,4,47]	66	66.01%	90.71212
8	[5,49,10,39,30,9]	88	66.14%	83.61779
9	[3,36,35,20,32]	79	66.27%	73.09986
10	[33,44,37,12]	77	67.14%	90.26672
		Total		862.21290

Fig.6 Merge routes by travel distance -oriented

We got 8 routes by solving the improved CVRP, which only two routes can be loaded successful. After the packing step, that were transformed to 14 routes. The fixing step were taking two heuristics to combine the routes. The results were the same, 10 vehicles used.

5.2 Considering loading priority

Initial solution

No.	Routes	Demand(160)	Feasibility
1	[2,29,21,34,50,16,11]	114	✘
2	[15,33,45,44,37,12]	97	✘
3	[48,23,7,43,24,6]	88	✘
4	[17,42,40,19,4,47]	66	✔
5	[14,25,13,41,18]	140	✔
6	[27,8,26,31,28,1]	77	✘
7	[46,38,9,30,39,10,49,5]	108	✘
8	[22,3,36,35,20,32]	87	✘

Fig.7 Initial solution by SA

Splitting routes

No.	Routes		Split routes	Vol. used
1	[2,29,21,34,50,16,11]	→	[2,29,21]	36.79%
			[34,50]	35.24%
			[16,11]	25.42%
2	[15,33,45,44,37,12]	→	[15,33,45,44]	38.56%
			[37,12]	51.19%
3	[48,23,7,43,24,6]	→	[48,23,7,24]	59.68%
			[43,6]	16.73%
4	[17,42,40,19,4,47]	→	[17,42,40,19,4,47]	66.01%
5	[14,25,13,41,18]	→	[14,25,13,41,18]	49.74%
6	[27,8,26,31,28,1]	→	[27,8,26,31,28]	54.66%
			[1]	23.18%
7	[46,38,9,30,39,10,49,5]	→	[46,38,9,30,39,10,5]	63.45%
			[49]	12.04%
8	[22,3,36,35,20,32]	→	[22,3,36,35,20]	63.19%
			[32]	14.06%

Fig.8 Check feasibility and split customers by CargoWiz

Merge by utilization-oriented

No.	Routes	Demand (160)	Vol. used	Travel distance
1	[1]	7	23.18%	27.78489
2	[16,11]	34	25.42%	44.06431
3	[34,50]	36	35.24%	64.35613
4	[15,33,45,44]	59	38.56%	78.69617
5	[6,43,2,29,21]	70	53.52%	129.56247
6	[27,8,26,31,28]	70	54.66%	75.58785
7	[48,23,7,24]	62	59.68%	70.38629
8	[49,41,13,25,14,18]	158	61.78%	115.24389
9	[22,3,36,35,20]	75	63.19%	90.70205
10	[46,38,9,30,39,10,5]	90	63.45%	81.99933
11	[32,37,12]	50	65.25%	52.85077
12	[17,42,40,19,4,47]	66	66.01%	90.71212
		Total		921.94627

Fig.9 Merge routes by utilization -oriented

Merge by travel distance-oriented

No.	Routes	Demand (160)	Vol. used	Travel distance
1	[34,50]	36	35.24%	64.35613
2	[2,29,21]	44	36.79%	69.35272
3	[11,16,49]	52	37.46%	57.27637
4	[15,33,45,44]	59	38.56%	78.69617
5	[14,25,13,41,18]	140	49.74%	79.32989
6	[37,12]	38	51.19%	36.22290
7	[32,1,43,6]	45	53.97%	85.00577
8	[27,8,26,31,28]	70	54.66%	75.58785
9	[48,23,7,24]	62	59.68%	70.38629
10	[22,3,36,35,20]	75	63.19%	90.70205
11	[46,38,9,30,39,10,5]	90	63.45%	81.99933
12	[17,42,40,19,4,47]	66	66.01%	90.71212
		Total		879.62759

Fig.10 Merge routes by travel distance -oriented

We finally conclude 8 routes by solving the improved CVRP, which also two routes can be loaded successful. Set loading priority probably let the loading feasibility be more difficult to reach. After the packing step, the previous routing results were transformed to 15 routes. The fixing processes were taking into two heuristic algorithms.

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EVOLUTION OF LOGISTICS FUNCTIONS OF E-BUSINESS FIRMS: A FINANCIAL ANALYSIS

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Purpose of this paper: Recent development of the e-business brings in diversification of way of doing commerce. A distinctive trend is that e-business firms are evolving from non-asset platform businesses to physical asset-based business. This is attributed to strengthening physical logistics functions by in-sourcing the fulfilment process within their boundaries (Yu et al., 2017). As the logistics functions of e-business firms are strengthened, convergence of logistics functions is taking place between e-business and logistics firms with their boundaries blurring. In this regard, the purpose of this paper is to explore how logistics functions of e-business firms have evolved and to examine how convergence between the e-business and the logistics firms is taking place using financial data analysis.

Design/methodology/approach: This paper takes a two-step approach: first, in-depth interviews are undertaken to explore the evolution of the logistics functions of the e-business firms; second, clustering is conducted for the e-business and the logistics firms. The clustering uses financial data of the sample firms (Capece et al., 2010). Sample firms are global e-business and logistics firms in the US, China, Japan and Korea, where the e-business and logistics industries are comparatively developed (Terzi, 2011).

Findings: Clustering shows that they have the same financial and management structure. It is attributed to the evolution of the e-business firms into firms with functioning logistics activities for their physical assets. The global e-business firms tend to run their own warehouses and logistical assets and provide logistics services under their business boundary.

Value: We examines overlapping functions/competitive relationship of the e-business and the logistics firms through result. In addition, it is meaningful to suggest the blurring boundaries and similarities between the e-business and the logistics firms through quantitative analysis. According to the trend in the e-business industry, the e-business firms can be redefined as 'e-business logistics firm' which is a new type of firm. Also, this paper is significant in that it provides a new paradigm for e-business research.

INTRODUCTION

While the development of Internet technology has changed consumer behaviour and demands, service such as fast and on-time last-mile delivery have currently become a 'must-have' attribute in e-business market (Faqih, 2016; Sohn et al., 2017). However, when e-business emerged in the 2000s, it was common that e-business firms provided sales platforms and third-party logistics (TPL) firms were responsible for the fulfilment process, including pick-up and delivery (Liu et al., 2015). While a variety of fulfilment networks could have been used for e-business supply chains, e-business firms began to build their own logistic systems instead of outsourcing logistic services (Chopra, 2003; Liu et al., 2015). It was not only because the service capability of TPL firms did not meet e-business firms' requirements but also because the significance of logistics services had increased and e-business firms needed to have a higher degree of control over the fulfilment process (Chopra, 2003; Kim et al., 2016).

As e-business markets have matured, customers' expectations about deliveries have increased dramatically. Logistics, in particular, is the most significant service area where e-business customers can have more and direct interaction with service providers. In the early stages of e-business adoption, online purchasers demanded relatively fast delivery at a low-cost point, preferably free. However, as these markets matured, customers became accustomed to greater choice, and expectations on delivery speed, quality, certainty, cost and flexibility increased. Customers want to get products soon after ordering, so they tend to use platform services that provide fast and convenient last-mile delivery services (Transport Intelligence, 2018). Therefore, e-business firms began to consider logistics services as core competencies and they have been making efforts to provide better service to customers (Ramanathan, 2010; Oh and Woo, 2018). Online market is no longer just a market for commerce. It is evolving into a market that combine logistics, payment technology, big-data and robot. It is reason that we should call it e-business, not e-commerce.

In order to address these changes, e-business firms may consider either selective outsourcing which uses TPL firms with customized last-mile service or in-sourcing. However, e-business firms want to own logistics functions (He et al., 2019). Existing researches are mainly focused on logistics functions using case study such as Amazon, Alibaba. They were not sufficiently research to trends in e-business industry such as competitive relationship with logistics firms. The purpose of this paper is, therefore, to research how the logistics functions of the e-business firms have evolved and to research how convergence between the e-business and the logistics firms is taking place.

THEORETICAL BACKGROUND

Paradigm shift in e-business

The Internet has changed the way firms communicate, how they share information with business partners, and how they buy and sell (Damanpour et al, 2001). As firms start electronic businesses, new sales channels are created. Emergence of new sales channels using Internet technology has led to changes and expansion of the business paradigm. In the early 2000s, e-business was defined as the electronically based organizational activities that support a firm's market exchanges including a firm's entire information system infrastructure (Rayport and Jaworski, 2003). As time went by, e-business was no longer simply defined as 'digital activities'. E-business firms control entire systems of supply chains as market players. E-business firms provide transaction platforms, warehouses, logistics services and business consulting to customers (Oh et al, 2018). E-business firms can't explain that firms only act as an electronic platform.

At the beginning of e-business, most entrepreneurs simply considered an e-business to the degree that it targeted the market opportunities of conducting business under new electronic channels, which revolved around the Internet (Gartner Advisory, 2000). Many users only perceived the e-commerce market as an online platform for selling products. However, the rise of e-business technology created opportunities for entrepreneurs, destroyed many businesses, and most importantly, changed the business structure of commerce (Synder, 2013). E-business technology can improve a firm's operations management system by enabling the real-time interchange of information across the supply chain (Benitez et al, 2018).

E-business is undergoing an evolution through the adoption of capabilities to enhance customer participation and achieve greater economic value (Huang et al., 2013). Players in E-business supply chains provide sophisticated service to customers in e-market places. And highly formalized business processes and standardized data formats enable to supply chain partners to coordinate their activities and to share information about customers and products, respectively (Martinsons, 2008).

Recently, the desire to seize this growth opportunity is driving many traditional brick-and-mortar retailers to expand their e-commerce channel to omni-channel capabilities (Ishfaq et al., 2016). This create a seamless customer shopping experience through the retailer's multiple channels (Harsha, 2016). It requires retailers to align their physical (store-based) and virtual (online and mobile) channels through the coordination of order management, fulfillment, and logistics processes (Burt and Sparks, 2003). These new channels allow sellers to beat the competition in e-business market.

Changes of logistics value in e-business market

E-business requires a different logistics approach from the retail market. Daily order volumes, small order size, small parcel shipments, and same-day shipments are common. Getting goods delivered to a customer's doorstep in a timely manner is an essential task (Cho et al., 2008). In this situation, e-business firms require new distribution infrastructure to handle the demands of customers. In the 1990s, demand for distribution infrastructure was met through outsourcing firms and TPL firms had many opportunities (Deckmyn, 1999; Scheraga, 1999; Kroll, 1999).

Recently, the success of firms in the e-business market depends on the efficiency of distribution networks and self-logistics models (Oh et al, 2018). The physical distribution of goods is important in e-commerce. Some firms don't need to outsource because of strong logistics capabilities (Cho et al, 2008). The strength of outsourcing in e-business market is getting lower.

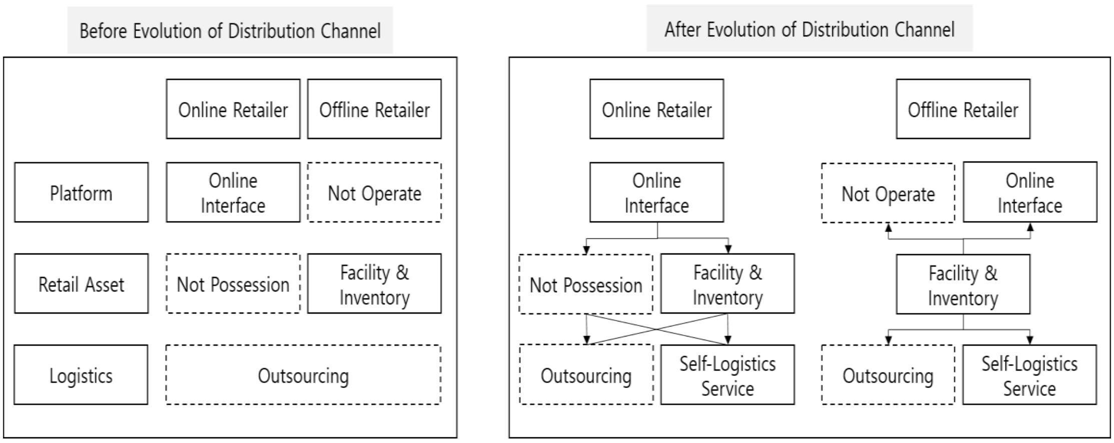

Figure 1. The change of distribution channel

Changes in e-business market may derive from a number of factors, such as increased information technology usage, redesign or use of additional packaging (Williams & Tagami, 2002), and the physical distribution of items. Among these factors, logistics activities such as transportation and warehousing are core competencies among the entire supply chain (McKinnon, 2012). And logistics and supply chain management has been greatly influenced by the booming of e-business (Yu et al., 2017).

Today, most e-business firms face challenges as to how they can increase value using their resources. They have provided logistics services to customers using their own warehouses or transport. In this situation, e-business firms are competing with logistics outsourcing firms. Providers of TPL services have been increasing investments in expanding their competencies. Major e-business players such as Amazon, Ebay and Alibaba have invested heavily in creating their own logistics facilities such as distribution center, and transportation (Ellinger et al., 2003). Management in e-business firms want to change the market (Yu et al., 2017) by a paradigm shift in logistics. In a change of business paradigm, logistic function has a much more valuable and important role than before.

EMPIRICAL ANALYSIS

Research approach

We take a two-step approach in this study. First, we research the evolution of logistics functions in e-business market using in-depth interviews. In this step, we will become familiar with management methods in the e-business market. For this step, we will interview experts who work for e-business firms. In-depth interview work is not as concerned with making generalizations to a larger population of interest and does not tend to rely on hypothesis testing but rather is more inductive and emergent in its process (Dworkin, S. L., 2012). As such, the aim of grounded theory and in-depth interviews is to create "categories from the data and then to analyze relationships between categories" while attending to how the "lived experience" of research participants can be understood (Charmaz, 1990). Therefore, in-depth interviews involve the posing of open-ended questions and follow-up probes designed to obtain an in-depth understanding of participants' experiences, perceptions, opinions, feelings, and knowledge (Patton, 2002).

First of all, we question the interviewee to suggest a direction of research. And then we have in-depth interview with them. To check the reliability of results, we have cross-checked our results with the interviewees.

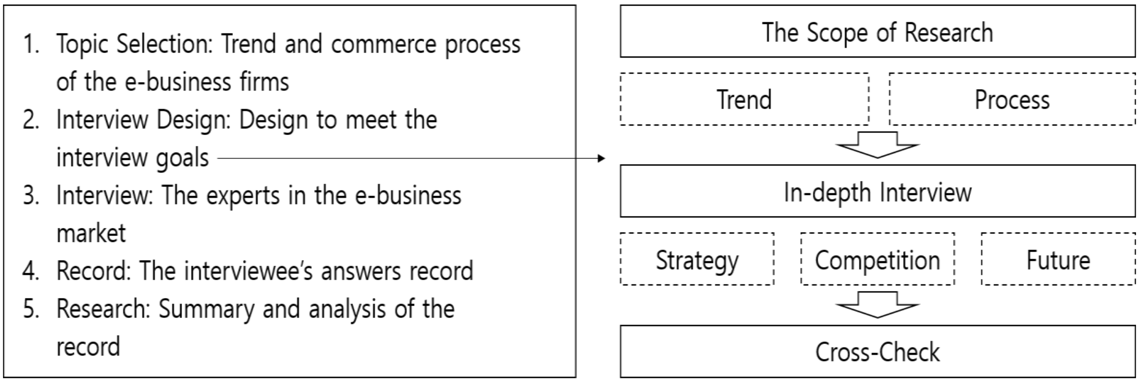

Figure 2. In-depth interview method

Source: Kvale(1996), Oh and Woo(2016)

Second, we compare e-business and logistics firms using cluster analysis. Sample firms for analysis are e-business and logistics firms which are in developed countries (Terzi, 2011). Cluster analysis uses the financial data (Capece et al., 2010; Oh et al., 2018) of the e-business and the logistics firms. Clustering method use k-means clustering. K-means clustering is one of the non-hierarchical data clustering methods that classify data in the form of one or more clusters (Sari et al., 2018). The data that have the same characteristics are grouped in one cluster. And the data having different characteristics are grouped with other clusters so that the data in one cluster has a small variation level (Satria and Aziz, 2016). According to Shakeel et al (2018), this method is as follows:

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(i)} - c_j \right\|^2 \qquad (1)$$

As shown in Eq. 1. Where, $\left\| x_i^{(i)} - c_j \right\|^2$ is the distance measure among data point x_i and cluster center c_j. $x_i^{(i)}$is the i^{th} load data, i= 1,2,3,…, n, and c_j is the j^{th} cluster center, j =1,2,3,…, k. k is the number of cluster (Ali and Wu, 2016; Sari et al., 2018).

Interview 1: Evolution of logistics functions in the e-business firms

In-depth interviews were had with five experts in e-business market of South Korea. The purpose of the interviews was to get to know the changes in logistics functions and competition between the e-business and the logistics firms.

The results of the interviews are summarized as follows. The logistics functions of the e-business firms were divided into three generations. The first generation was simply a way to order and receive goods. It was mainly used in the 1990s. It was simply a commerce method between suppliers and customers.

In the second generation, the e-business firms only served as intermediary platforms for customers and the logistics firms. It was used in the early 2000s.

In the third generation, the e-business firms acted like the logistics firms as they managed logistics warehouses as well as intermediary platforms and delivered products directly. This was used in the 2010s and the e-business firms mainly use it.

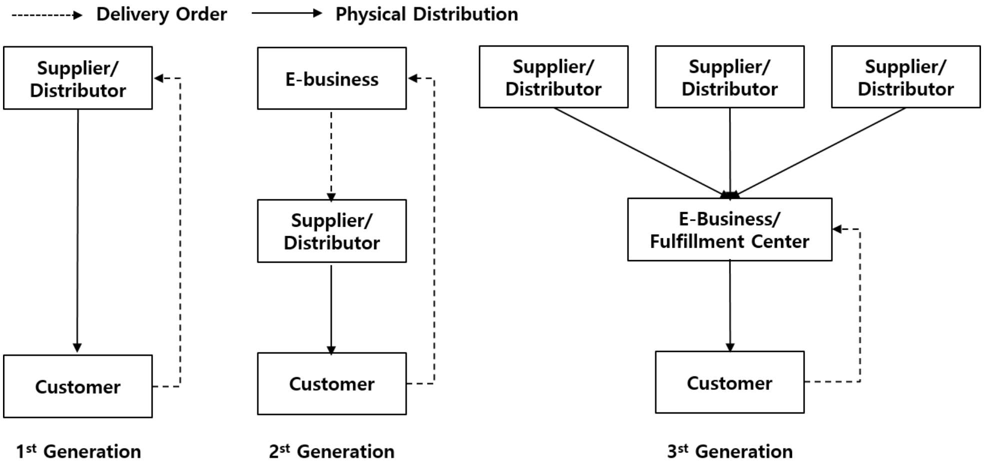

Figure 3. Changes in logistics functions

Interview 2: Change of distribution model in e-business firms

The e-business firms use 3 types distribution model. The distribution model used by the e-business are the dropship Model, pick-up & delivery model and inventory management model. These are used differently depending on logistics strategy of the e-business firm.

Drop ship model is method in which manufacturer and distributor deliver directly to customers. The e-business firms aren’t necessary to inventory management. The e-business firms only provides electronic platform to customers. But it has disadvantage. Seller in platform must delivery product to customer using outsourcing firms. And customers must pay high delivery cost.

Pick-up & delivery model is as follow. Once the orders are received to customers, the e-business firm purchased/collected products from manufacturer or distributor. And staffs of e-business pack products in the logistics center. After that, product is delivered to customers by outsourcing firms. It has advantage of low Inventory cost. But it has disadvantage of slow delivery lead-time. Firms with high inventory burdens are using it. It is used for high-value products.

Inventory management is currently used by most firms. Product are stored in advance in logistics center of the e-business firms. When they received orders from customers, the e-business firms deliver the products using own transportation/logistics center. It has advantage of speedy delivery to customers and inventory management service to manufacturer/distributor. It is possible to deliver within 24 hours or 3 hours. But it has disadvantage of high inventory management costs. Firms which have an offline/online store and warehouse usually use it. It is used as core logistics strategy for most firms.

Competition in logistics functions is becoming fierce in the area of inventory managements. The e-business firms don’t use third party provider anymore because they have own process using their transportation and warehouse. The service is called ‘Fulfillment service’. It is possible to manage the supply chain of the e-business firms. The e-business firms are transforming into new businesses through the evolution of logistics functions and the boundaries of traditional business are disappearing.

Empirical analysis of firms using financial activities

Sample firms of analysis

For the analysis, we analyzed firms providing fulfillment services among the developed e-business industries. And logistics firms were selected as the analysis targets for firms with large scale in 2017(Logistics Management, 2018). For accuracy of analysis, firms that didn’t provide independent financial data and firms with outliers (L8: UPS) were removed from the data. Thus, we analyzed 9 e-business firms and 18 logistics firms. It use averages of data from 2015 to 2017 because we can collect financial data of some firms from 2015.

Table 1. Classification of firms analyzed

E-business		Logistics			
Code	Company	Code	Company	Code	Company
E1	Amazon	L1	DHL Supply Chain & Global Forwarding	L11	Kintetsu World Express
E2	Ebay	L2	Kuehne + Nagel	L12	Yusen Logistics
E3	Groupon	L3	DB Schenker	L13	Kerry Logistics
E4	Alibaba	L4	DSV	L14	C.H Robinson
E5	Jingdong	L5	Expeditors	L15	Agility
E6	zalando	L6	Panalpina	L16	Hitachi Transport System
E7	Rakuten	L7	Nippon Express	L17	Toll Group
E8	Asos	L9	Bolloré Logistics	L18	XPO Logistics
E9	Interpark	L10	CEVA Logistics	L19	Cj Logistics

* L8(UPS) is removed

Analysis of Independent sample test using financial activities

We analysed sample firms using financial ratio. Financial data represent the characteristics of the industry in which the firms are located.

First of all, we conducted an analysis to understand the financial differences between groups. Financial data is divided into four main categories. It is divided into liquidity, profitability, activity and solvency. Detailed variables and their descriptive statistics are presented in Table 2. The analysis in Table 2 shows that there is no statistical difference between firms except the gross profit. It is means that they are little difference in financial characteristics among the firms. And we will know that the profit ratio is different depending on industry. This difference occurred due to the appearance of large e-business firms such as Amazon and Alibaba. When comparing management type of the e-business firms and the logistics firms, it can be seen that the e-business firms are larger or similar to the logistics firms. In this analysis, the size and difference of groups can be checked. It was confirmed that it is little difference in financial statements between the e-business and the logistics firms.

Table 2. Independent sample t-test

Financial Ratio		Average		t	p-value
		E-business	Logistics		
Liquidity	Total Current Assets	0.590	0.462	1.79	0.08
	Total Non-Current Assets	0.469	0.538	-0.816	0.42
	Property/Plant/Equipment	0.101	0.210	-1.805	0.08
	Intangibles	0.075	0.044	1.14	0.27
Profitability	Gross Profit	0.451	0.284	2.27	0.03
	Total Operating Expense	0.917	0.955	-0.96	0.35
	Operating Income	0.083	0.045	0.96	0.35
	Selling/General/Admin. Expenses	0.305	0.206	1.78	0.08
	Net Income	0.092	0.026	1.72	0.09

Activity	Return on Assets(ROA)	4.849	4.892	-0.17	0.98
	Return on Common Equity(ROE)	8.760	11.092	-0.38	0.7
	Fixed Asset Turn Over	19.065	15.461	0.43	0.66
	Asset Turn Over	1.288	1.523	-0.63	0.53
Solvency	Total Current Liabilities	0.452	0.332	1.91	0.06
	Total Long Term Debt	0.116	0.166	-0.83	0.41
	Total Liabilities	0.677	0.653	0.33	0.74
	Total Equity	0.323	0.347	-0.33	0.74

Analysis of K-means clustering

Logistics asset are core competency of logistics firms. But e-business firms are gradually increasing assets such as logistics facilities and transportation. As shown in figure 1, it is a key strategy in e-business market. In this situation, we researched how much difference the asset-level of the e-business firms and the logistics firms. For the research, we used asset data in Table 2 and k-means clustering. The results of K-means clustering are shown in Figure 4. The result showed that the e-business firms were clustered with the logistics firms. Cluster 1 is group including Amazon, Ebay, Alibaba and DHL. Cluster 2 is group including Jingdong, Interpark and Expeditors. Some e-business firms and most logistics firms were grouped in cluster 1. The e-business firms in Cluster 1 are group which they are evaluated as having high logistics capacity. Cluster 2 was clustered with firms with relatively low logistics capabilities compared to Cluster 1. But this is just relative results. As shown in Table 2, there isn’t much difference in management type between the e-business firms and the logistics firms.

We conducted another analysis to understand that. We used independent sample t-test to find out why this difference was observed. As shown in Table 3, groups were classified differently due to the total current assets and the total non-current assets. Clusters were found to be affected by assets size. In that case, the e-business firms with large logistics capabilities were grouped in cluster 1. The e-business firms grouped as cluster 1 regard core values of logistics capabilities than others. The e-business firms that invest heavily in logistics capabilities are grouped with a large number of the logistics firms. We can think that the e-business firms with high logistics capacity are changing similarly with the logistics firms. Especially, logistics capability is important management strategy for Amazon and Alibaba. In the case of Amazon, Competition between Amazon and the logistics firms seems to be strong. As Amazon emphasizes logistics functions, Amazon has the characteristics of the logistics firms. Logistics functions are evolving because the e-business firms have own warehouses and transportation. The e-business firms played the role of logistics firms as they are taking goods, sorting and delivering products directly using theirs. ‘Overlap of logistics functions’ is taking place between e-business firms and logistics firms. This trend has also affected the character of firms. As a result of the analysis, boundaries in the market between the firms were found to be meaningless. Competitions in the e-business market is being intensify because of collapsing boundaries within the industry.

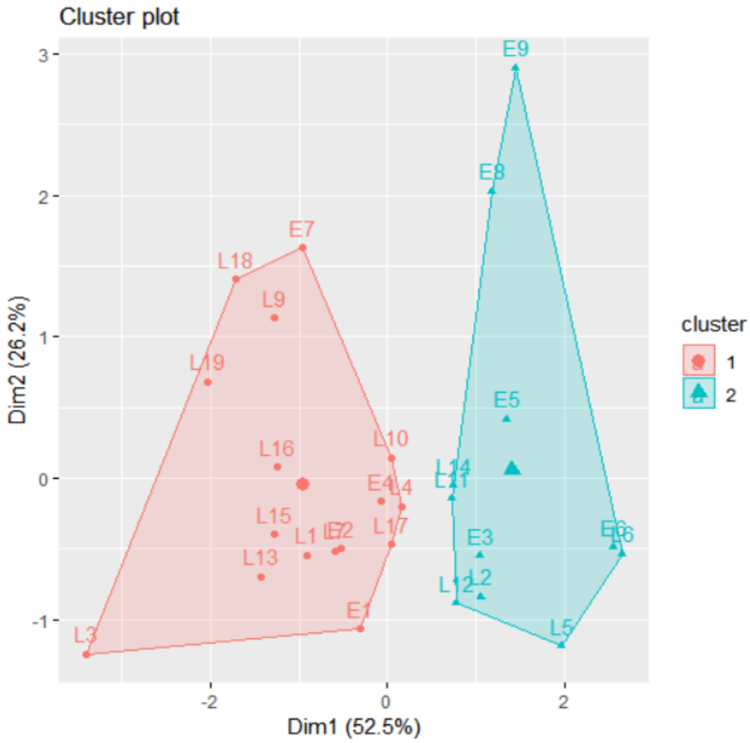

Figure 4. Analysis of k-means clustering

Table 3. Independent sample t-test of Cluster 1 and 2

Financial Ratio	Average		t	p-value
	Cluster 1	Cluster 2		
Total Current Assets	0.378	0.687	-7.927	.000
Total Non-Current Assets	0.654	0.312	7.378	.000
Property/Plant/Equipment	0.208	0.122	1.672	.109
Intangibles	0.485	0.062	-0.568	.579

CONCLUSION

The results of the cluster analysis show that the financial structure of the e-business firms and the logistics firms are the same. The e-business firms now act as logistics firms with physical assets. It was from innovation by e-business firms. Global e-business firms tend to run their own warehouses and provide logistics services to customers.

The logistics capabilities of e-business firms are being enhanced around the world. E-business firms are innovating through the introduction of new technologies and investment in logistics facilities. The scope of service for e-business firms is gradually expanding into all areas of supply chain management.

E-business firms are trying to manage entire supply chains including logistics services. E-business firms consistently want changes and competition among other industries. In this paper, we found ‘overlapping functions’ and a competitive relationship between the e-business firms and the logistics firms. It is meaningful to research disappearing boundaries and similarities among firms. According to the current trend of the e-business industry, e-business firms are being redefined as ‘e-business logistics firm’ a new type of firm. Also, this paper is significant in that it provided a new paradigm for e-business research.

A paradigm shift in e-business is related to the strength of logistics functions. E-business firms have changed management strategies by introducing big data and AI technologies in logistics functions. Ironically, e-business firms are leading innovation in the logistics industry. On the other hand, logistics firms are providing consulting services such as e-business management (e.g. fulfillment service). The boundaries of the industries are blurring and innovation of management will continue in the e-business market.

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DECISIVE ENGAGING FACTORS IN CROWD LOGISTICS: THE CASE OF CHINA'S TAKEAWAY/HOME DELIVERY INDUSTRY

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ABSTRACT
This study examines the role of crowd logistics (CL) in takeaway/home delivery service in the context of food industry in China. A decision model is also proposed to help the decision makers understand the issues in CL holistically in the context of takeaway/home delivery services. We empirically examine the factors that influence private agent participation (attraction and retention) in CL in the context of takeaway/home delivery food market in China. We identify key motivations for web-based self-enrollment by private agent, the enabling skills and perceived risks associated with participation in takeaway/home delivery service. This study finds that the relationship between capability and attractiveness is positive and strong, whereas risk and attractiveness is very weak but positive. Also, it is evident that the main reason for joining CL is for most private agents is the potential for career development rather than economic benefit. Attractiveness to CL is significantly increased when delivery agents see a clear work-life balance in their tasks as part-time workers.

Keywords: Crowd logistics, home delivery, workforce, China

INTRODUCTION
Crowd logistics (CL) is an information connectivity enabled marketplace, that matches supply and demand for logistics services with an undefined and external crowd that has free capacity with regards to time and/or space, participates on a voluntary basis and is compensated accordingly (Rai et. al., 2017). A particular business sector currently experiencing rapid increase in the utilization of CL is online takeaway/home food delivery service; the focus of this study. Market report on takeaway/ home food delivery in 2017 indicates the revenue generated in the food delivery segment globally amounts to US$72.9 billion in 2016, with China as the world's biggest takeaway/home food delivery market with a revenue of US$29.8 billion in 2016 (Statista Digital Market Outlook, 2018). CL enables enhanced utilization of excess capacity in term of both time and resources such as private use of one's time and vehicles to deliver goods or services (Arslan et al., 2016). Essentially, CL concept entails the use of a willing private agent for delivering light-weight items to destinations along his/her trip route (or to a destination with minimum detour from planned route). This provides the freelance agents efficient capacity utilization (in time and vehicle space utilization) while gaining reasonable economic return (Allen et al., 2018; Marcucci et al., 2017).

While ubiquitous inexpensive technological factors and decent financial returns for private agents influence the growth of CL, very little is known about the key factors that impact on attraction and/or retention of private agents in CL other than financial returns. This is perhaps not surprising given the very limited studies dedicated to CL so far (Rai et al., 2018). Most of the limited extant studies have focused on assessing CL business models

(Frehe et al., 2017); the environmental impact and sustainability of CL (Rai et al., 2017; Rai et al., 2018); CL types and stakeholders support (Rai et al., 2018); delivery consolidation evaluation (Cherrett et al., 2017) and; success factors in home delivery (Punakivi & Saranen, 2001).

We empirically examine the factors that influence private agent participation (attraction and retention) in CL in the context of takeaway/home delivery food market in China. Specifically, we attempt to answer the research question "what factors attract private individual in a given community to self-enroll in an online based systems (beyond financial gain), to work as a part-time employee in food delivery service?"

The rest of the article is organized as follows. Section 2 reviews the literature in CL in detail. Section 3 explains methodology adopted to find the relationship among the factors influencing the participation. Final section consolidate the outcome of this work, limitations and directions for future research in this topic.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

CL is a part of crowd sourcing, in which the interested private individual in the general public is utilized by companies to deliver their goods for a token financial reward. Factors influencing people's participation in crowd sourcing

Financial returns

Like most human endeavors, financial return has significant impact on the participation in CL. Extant literature suggests that monetary gains is the primary motivation for participating in CL (Peng and Zhang, 2010; Brabham, 2010; Sun et al., 2015; Marcucci et al., 2017). It has also been noted that if participants perceive sufficient financial reward , they are more likely to be inclined to do more for the company (Chris Zhao & Zhu, 2014).

The nature of task

Task complexity have great influence on willingness to participate in CL (Sun et al., 2015). In other words, the more complicated the tasks the less the willingness to participate in the given task, especially for private agents unfamiliar with such given task. . To encourage participation in complex tasks, firms need to to simplify such tasks and/or provide more incentive, such as more monetary rewards, to stimulate participantion (Chris Zhao & Zhu, 2014). The autonomy and variety of the tasks also have positive influence on the participation, with task that are highly autonomous, explicitly specified, less complex, as well as requiring a variety of skills attracting more participation (Zheng et al., 2011). Other studies suggests how meaningful people perceive a given task also has great influence on the participation (Chandler & Kapelner, 2013).

The company practices

How a company treats its crowd-sourced participants is an import motivational factor for he retention and growth of its self-enrolled part-time employees . Similar to full-time formal employees' motivation, companies need to understand, communicate and treat their "informal employees" with utmost respect and care to retain and ultimately obtain best performance from such participants (Chris Zhao & Zhu, 2014; Chandler & Kapelner, 2013). Sun et al. (2015) opined that trust from company can motivate people to work harder. Companies with open business model can collect ideas or utilize the power of the crowd to help it operate better (Djelassi & Decoopman, 2013).

The development of technology

The development of e-commerce, online shopping and other technologies such as smart mobile phones, GPS, and other advanced online mobile applications has enabled CL and motivated crowd (the public) to participate in CL. as. Essentailly, these technological developments makes it easier and diminishes the limitation of the time and space, and hence motivate people to join CL (Rai et al., 2018; Li and Yu, 2017; Nadange, 2014; Jackson et al., 2015).

Social influence
The social effect in terms of peer influence where a friends and/or relative is already engaged in CL reports positively its activity on should act as a strong attraction to CL (Rouges and Montreuil, 2014; Djelassi & Decoopman, 2013)., Peer-to-peer influence therefore impact on the participation in CL activities. Additionally, social need suc as having fun, contributing to collaborative effort and/or overcoming boredom can be satisfied by joining CL to increase the potential for meeting and make more friends (Chris Zhao and Zhu, 2014; Brabham, 2012).

Skill improvement
Humans have always been attracted to endeavors that sharpen their skills, creativity and innovation. According to Chris Zhao and Zhu (2014), people join the crowd sourcing are mainly because they want to achieve ego-enhancement to improve personal skills. Therefore, the need for both the skills learning and career development are significant to motivate join the CL (Goncalves et al., 2015).

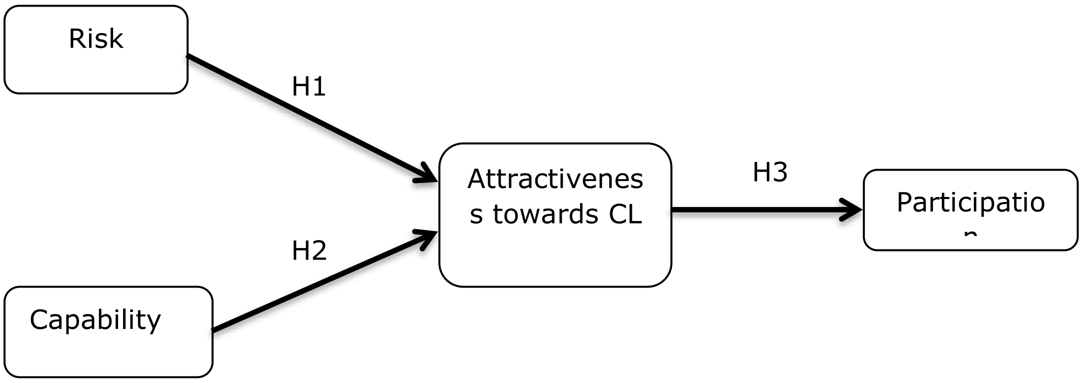

Figure 1: The research model and hypothesis

H1: The higher the Risk involve in CL activity the less attractive to participate.

H2: Capabilities of potential participants has positive influence on attractiveness towards CL activities.

H3: The higher the attractiveness of CL activity the greater the number of participation

METHODOLOGY
A questionnaire was developed to collect data online through SOJUMP, one of the biggest Chinese online data (questionnaire) collection websites (www.sojump.com). SOJUMP is the earliest and largest online data collection services platform with over 9260 thousands questionnaires published since 2006 and over 4.93 million questionnaires available to researchers in Chinese universities and professional market investigation companies. The questionnaire was first written in English and then translated into Chinese, because the online users of SOJUMP are mainly Chinese. The translation of questions from English to Chinese is done with the support of linguistic experts in order to ensure accuracy and reliability of the information. All measures were on a 7-point Likert scale where 1 refers to strong disagreement and 7 depicts strong agreement and 4 for neutral opinion. Likert 7-

point scale is preferred over 5-point scale as more accurate opinions can be recorded or reflected in the final outcome of the study (Vagias, 2006). Table 2 shows the key variables in our questionnaire.

Data was obtained through a combination of direct and online survey modes. In both cases, the respondents were given clear instruction to ensure understanding before answering the questionnaire.

A total of 170 responses were received with over 90% contribution from online survey mode. All the responses received are scrutinized for incompleteness resulting in 6 responses being rejected and remaining 164 valid responses considered for further analysis. IBM SPSS statistics 23 package is used to check the consistency (reliability) of data obtained. Cronbach's alpha is the most common measure here in this test that shows internal consistency. Cronbach's alpha coefficients for all four variables considered for the study is greater than the benchmark value of 0.7 indicating reliability of the study instrument and data obtained (Nunnally, 1978). AMOS Graphics 23 package is used to build and estimate the structural model as shown in Figure 2.

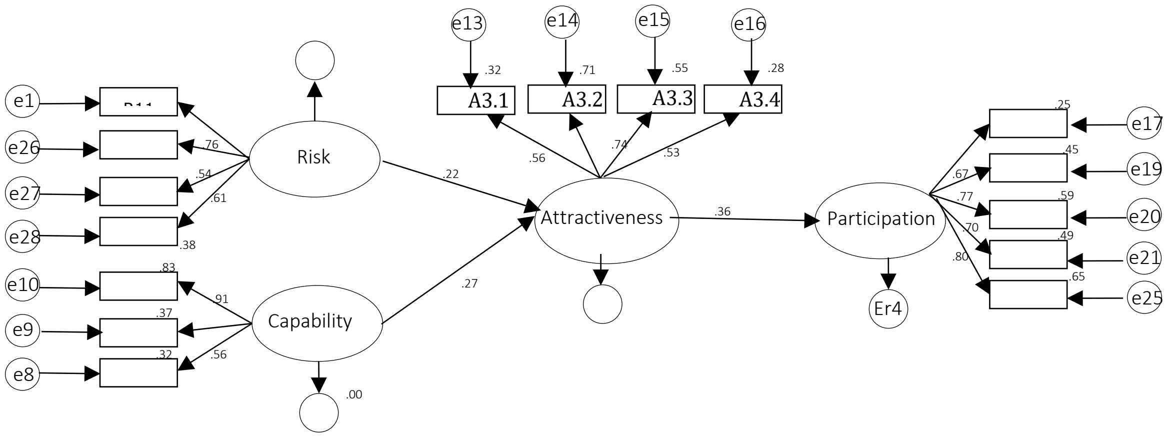

Figure 2: Structural model

The Measurement model results summary (table 10 and Fig. 3) shows that compare with risk, capability has the high influence on attractiveness toward CL, H1 (β = 0.22, p = <0.001) < H2 (β = 0.27, p = <0.001). Similarly, attractiveness has a strong and positive influence on participation, H3 (β = 0.36, p = <0.001), as shown figure 3. The results indicate the influence of financial returns is only moderately regarded by participants in the study. There are a number of possible reasons for the downplay of financial gains by participants. First, the margin in the takeaway/home food delivery is very small due to fierce competition the delivery participants are being reasonable in not expecting high remuneration for their services as they would in other business sectors. The finding is also in line with literature that states "crowd shipping should not be considered and, consequently, expected to provide a remuneration comparable to that of a regular job. Rather, it should be viewed as a way of obtaining a reimbursement (partial) for a trip that would have taken place anyway" (Marcucci et al., 2017). Second, the delivery agents may be more interested in continued patronage with that the company due to perceived strong future prospect they considered more important compared to immediate monetary return.

DISCUSSION

Based on the outcome of the SEM, we further develop a conceptual and decision model to show the enablers, barriers and motivators for participation in CL (figure 4). The model (figure 4) shows individual's mobile and online technological knowhow and transportation capability encourages them to participate in CL. Similarly, the opportunity and scope for developing their skills and career play a major role in their decision for participation. On the other hand, if the CL activity takes more of private agent's personal time and/or create hardship in relationship with the end customer (recipient), people will be reluctant to join CL activities.

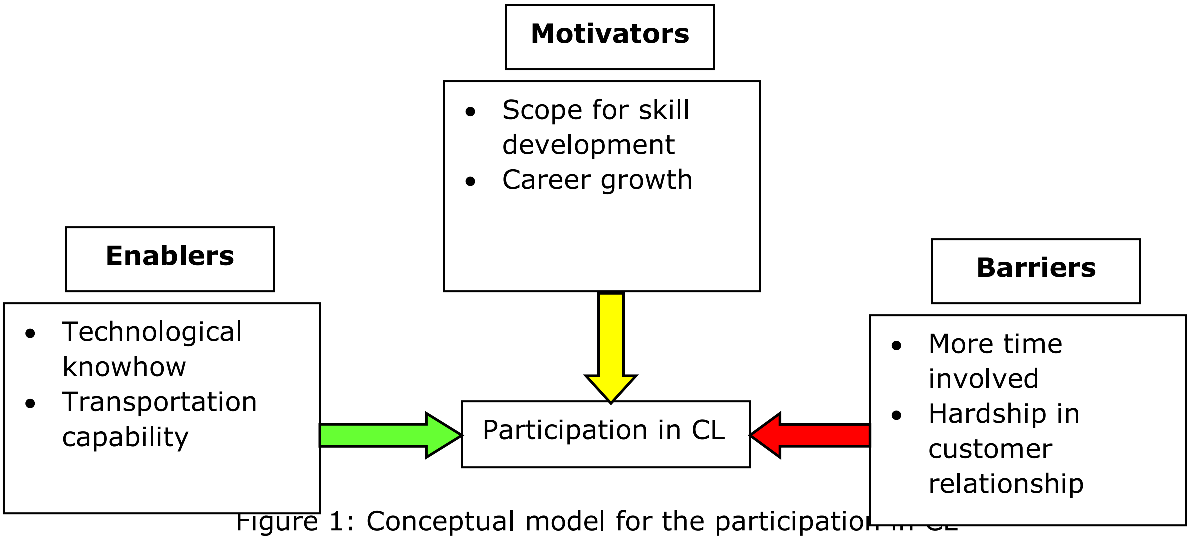

Figure 1: Conceptual model for the participation in CL

To facilitate understanding and decision-making about the phenomenon of participation, a two stage rational decision model is proposed based on the conceptual model shown in the figure 4.

$$P = \sum E_i - \sum B_j \qquad (1)$$

Where, P - Participation in CL

Ei = Enablers of participation i = 1 to m

Bj = Barriers to participation j=1 to n

On the other side, people may take the CL either as a regular career or sometimes, as a part time job. People who take CL as their main source income are willing to spend time and take on more deliveries to improve their earnings. Such people are also more tolerant of perceived negative customer behavior. However, for people who have taken CL as a part-time job, the time spent and dealing customers will be a cause of concern and a disincentive for continuing participation. Managers should therefore pay particular attention to part-timers and, where possible, provide some assistance to the part timers to overcome these barriersas this will improve the chances of participation of part-timers in CL.

$$P = \sum E_i - \sum B_j + \sum M_k \qquad (2)$$

Where, Mk = Motivators to participation k = 1 to s

CONCLUDING REMARKS

This research work provides an overview of the key influencing factors in CL participation based on Chinese takeaway/home delivery industry setting. Key factors investigated in this research include risk associated with delivery of goods, capabilities of potential CL participants in terms of knowhow in and utilization of modern web-based technologies and mobile apps., attractiveness towards CL and resultant participation in CL. This study found that the relationship between capability and attractiveness is positive and strong, whereas risk and attractiveness is found to be weak but positive. Also, it is evident that the main reason for joining CL is for most private agents is the potential for career development rathr than economic benefit. In other words, financial benefits and the usage of free time matters less to those investigated . Also, a conceptual and two stage decision model is proposed for the decision makers to understand the core issues in CL and how such issues affect the voluntarily participation in CL activities. Also, this research work comprehends and emphasizes the need for developing a new theory on labor/owner relationship to suit the current globalized business environment.

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MULTI OBJECTIVES LOCATION ALLOCATION MODEL CONSIDERING PROVIDER'S SATISFACTION FOR MOBILITY SERVICE

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Abstract
We focused on a replacement driver service which is popular mobility service in Japan especially in suburb area. In the service, manager has to not only reduce the operational cost but also maintain balance of service provider's workloads. This characteristic is popularly seen in Mobility Sharing Economy.

First, we formulate two objectives Location-Allocation problem in which one objective function corresponds to reducing total travel distance, i.e. cost reduction, and the other one corresponds to workload balance among drivers, i.e. provider's satisfaction. Here, Location Allocation problem is a problem to obtain the optimal facility location to minimize total distance among the facility and demand points. We have introduced a genetic algorithm to solve the model and carried out series of Numerical Experiment to evaluate performance of proposed model.

According to the series of Numerical Experiment, our proposed method obtains better allocation compared to manager of actual replacement driver service company. Here we achieve higher balance among drivers compare to actual one. Through the approach, we present that our solutions provide both traditional goal and a new goal considering provider's satisfaction.
Keywords: Location-Allocation Problem, Multi Objective Optimization, Mobility Service

INTRODUCTION
Recently, Sharing Economy is obtained with much attentions including mobility service. To operate the service, balance among cost, customer satisfaction and provider's satisfaction becomes important to achieve high market share. Namely, low operation cost provides lower fare for the service. And high customer satisfaction provides more frequent request. Not only these traditional aspects but also service provider's satisfaction will be affect performance of the sharing economy because enough number of server is necessary to continue service.

We focused on a *replacement driver service* which is popular mobility service in Japan especially in suburb area. In the service, replacement driver taking steering wheel instead of especially drunk driver to take he and his car to the home. For the service, we have one-year operation data obtained from actual replacement driver service company. In the service, it is important to determine waiting points and their number of driver teams.

A problem to determine waiting point under condition of given demand distribution is generally called Location-Allocation Problem. The Location-Allocation Problem has been studied for many area, see for (Farahani and Hekmatfar 2009). (Taniguchi et al. 2004) proposed hybrid Genetic Algorithm combined with Fuzzy Logic Controller to solve Location-Allocation Problem with polygonal obstacles. (Polo et al. 2015) used Location-Allocation model for improvement of accessibility for public health services.

In this paper, we formulate the problem of replacement driver service as a Location-Allocation Problem including provider's point of view. For the objective function, we apply two objectives: minimizing the total traveling distance and maintain workload balance between driver teams. Using Genetic Algorithm based methodology, we obtain better

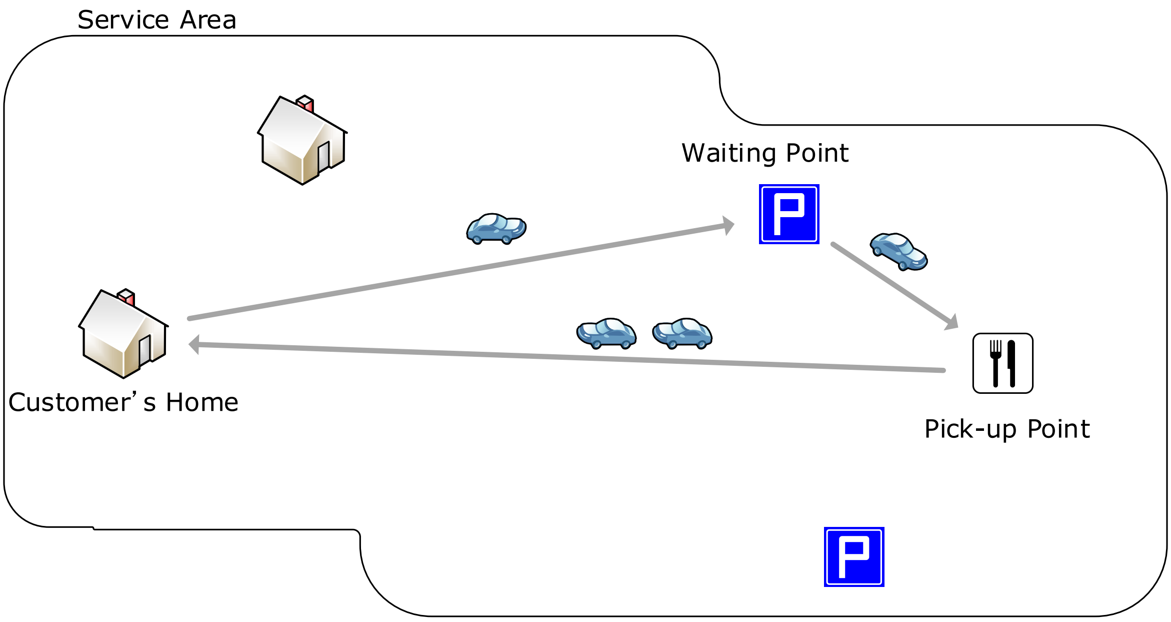

Figure 1. Replacement driver service Model

solution considering such aspects compare to outcomes in actual company. The method can be applicable similar Mobility Service.

Model

Consider a system consists of one service area, driver team with a car being standby at waiting point, customers and pick-up point such as restaurants. A driver team consists of two drivers and a car. For the trip from pick-up point to customer's home, first driver takes the wheel of customer's car. And second driver takes the wheel of the team's car. For the trip from customer's home to waiting point, one of drivers takes the wheel of the team's car. There are several waiting points where the team are waiting for customer's call.

A customer makes a phone call for a new request. Then manager of replacement driver service company assigns a driver team whose waiting point is nearest to the customer's pick-up point. If there are more than one driver team waiting at the point, then manager takes a team whose workloads is the smallest on the day. On the other hand, if there is no driver team at the point, manager look for another waiting point to satisfy customer demand. According to the circumstance, it may be reasonable to wait for driver team coming back to the nearest waiting point. In this research, we do not adopt the option because it may cause another risk.

Income of the replacement driver service company depends on distance from pick-up point to customer's home. Cost depends on number of operating driver team and fuel used by team's car. A problem how many teams should be in service on certain day depends on medium-, long-term plan derived from demand forecasting and employment plan. On the other hand, an assignment problem of driver teams to suitable waiting point affect the revenue of the day. Furthermore, poorly assignment may cause unbalanced workloads among driver teams. Operation availability is expected to well balanced.

SERVICE AREA AND CASE STUDY

We have obtained actual operation data of actual replacement driver service company. We formulate the problem into mathematical programming with this operation data.

We have about one-year operation data from 4th January 2012 to 29th December 2012. The service area of the company consists of three cities: Komoro, Tomi and Saku. Total population of the area is about 160 thousand. There are six candidates for waiting points near downtowns of the area. For customer's home, there is no detailed address in the operation data. Therefore, we divide the service area into 20 zones and assign customer's home into each zone. We set a represented point for each 20 zones selected from place where houses are relatively concentrated. The represented point is used for calculation of distance related to the zone.

FORMULATION

Location-Allocation Problem seeks the optimal assignment of facilities, waiting point in this case, that maximize or minimize objective functions. Here, assignment of driver teams to waiting point is updated on every day. Therefore, models are assumed to solution for one service day without description.

Let D_i, $i = 1,2,3,\dots,I$, be a customer's demand defined request time, pick-up point and delivery point. Let d_i, $i = 1,2,3,\dots,I$, be a travelling distance to complete task related to demand D_i. In other words, traveling distance from a waiting point to a waiting point via pick-up restaurant, represented point of the zone where customer's home is. Let W_j, $j = 1,2,3,\dots,J$, be a waiting point j. Let C_k, $k = 1,2,3,\dots,K$, be a driver team k.

In this problem, there are two decision variables: one is corresponding to which customer, D_i, should be assigned to which driver team, C_k. The other one is corresponding to which driver team C_k should be wait at which waiting point W_j. We set x_{ik} and y_{jk} as follows.

$$x_{ik} = \begin{cases} 1 & D_i \text{ is assinged to } C_k \\ 0 & \text{otherwise} \end{cases}$$

$$y_{jk} = \begin{cases} 1 & C_k \text{ is assinged to } W_j \\ 0 & \text{otherwise} \end{cases}$$

In this research, we introduce two objective functions: one is the minimization of the total traveling distance of whole driver team (1).

$$\text{Minimize } Z = \sum_i \sum_j \sum_k d_{ij}\, x_{ik} y_{jk} \tag{1}$$

The other one is maintenance of workloads among driver teams. There many approach to maintain workloads among the teams. Therefore, we have prepared two objective functions for this purpose. The first one aims to minimizing the difference of travelling distance between the longest team and the shortest team (2a).

$$\text{Minimize } Z = \max_k \left(\sum_i \sum_j d_{ij}\, x_{ik} y_{jk} \right) - \text{mix}_k \left(\sum_i \sum_j d_{ij}\, x_{ik} y_{jk} \right) \tag{2a}$$

The second one, thinking more simply, aims to minimizing the total travelling distance of the longest distance team (2b).

$$\text{Minimize } Z = \max_k \sum_i \sum_j d_{ij}\, x_{ik} y_{jk} \tag{2b}$$

Here, Model comprised with objective function (1) and (2a) is refer to Model A. Model comprised with objective function (1) and (2b) is refer to Model B.

Followings equations are constraints of this model. At first, every customer demands have to assign to certain driver team (3).

$$\sum_{k} x_{ik} = 1, \qquad {}^{\exists}i \in I \tag{3}$$

Every driver teams have to assigned to certain waiting point (4).

$$\sum_{j} y_{jk} = 1, \qquad {}^{\exists}j \in I \tag{4}$$

GENETIC ALGORITHMS

To solve the problem, we conduct Genetic Algorithm approach. As the model has multi objective functions, the solution is given as a pareto solution which is presented as a set of non-dominated points. Followings are our conducted method. For technical details, see for (Gen and Cheng 2000).

For the encoding, Integer Permutation Encoding is conducted for decision variables x_{ik} and y_{jk} respectively where locus correspond to index i and j , and it's value corresponds to driver team k. Values of both objective functions are evaluated for every individuals, i.e. pair of chromosomes and plotted. Pareto Ranking Method is conducted to determine rank of every individuals. Tournament Selection is conducted according to rank of each individual where tournament size is 4. One thousand individuals are selected for the next generation. Two-cutpoint crossover is conducted for genetic operation. Subsequence chromosomes of parent generation determined between two randomly selected cut positions are exchanged in offspring generation chromosomes. For mutation operation, an offspring chromosome is generated with that randomly selected value is replaced on randomly selected locus in parent's chromosome. This process is iterated to the Maximum generations.

NUMERICAL EXPERIMENT

We have conducted a series of numerical experiment for the problem by applying proposed model and genetic algorithms. Before applying proposed model, we have conducted multiple correlation analyses to estimate how many driver teams should be placed on each waiting point. See (Kimura et al. 2019). Table 1 and 2 show calculation environment and parameters for genetic algorithms.

Figure 2 and 3 show examples of pareto solution of Model A and B respectively. Horizontal axis corresponds to total travel distance of driver team, i.e. equation (1). Vertical axis corresponds to equation (2a) and (2b) respectively. Note that, difference of values in vertical axis depends on difference of objective function. In the figure, red points show pareto solutions. Blue points show dominated solutions. For both cases, we have enough pareto solutions. For the comparison to the actual operation data, we choose one from the pareto solutions that is the most balanced one, i.e. located centre of distribution of pareto solutions.

Table 1. Calculation Environment.

CPU	Intel Core i5-4590 (3.30 GHz)
Memory	8.00 GB
Operating System	Windows 8.1 Pro

Table 2. Genetic Algorithm Parameters and Conditions

Number of Individuals	1000
The Maximum generations	1000
Tournament size	4

Average calculation time for a run	2.854 sec

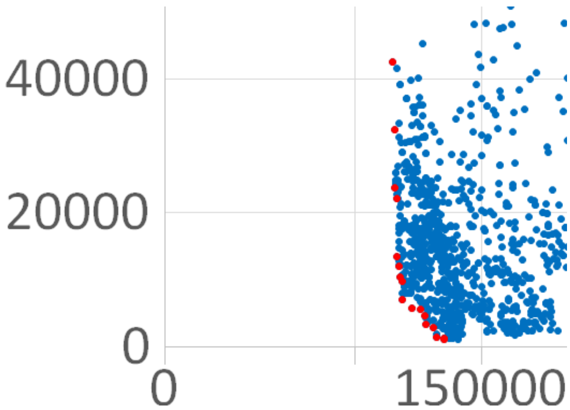

Figure 2. A Pareto solution of Model A.

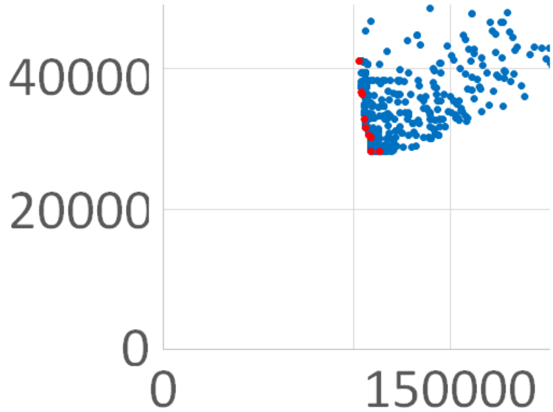

Figure 3. A Pareto solution of Model B.

Table 3. Comparison of distances among models and actual operation [m]

	Actual	Model A	Model B
Jan	1,823,450	1,522,140	1,452,910
Feb	1,431,630	1,588,780	1,171,560
Mar	2,522,040	2,628,880	2,319,540
Apr	1,967,640	2,412,700	2,215,310
May	2,120,830	1,981,930	2,019,320
Jun	2,642,680	2,267,110	1,912,111
Jul	2,508,790	2,467,000	2,510,000
Aug	2,795,830	2,276,580	2,059,610
Sep	2,096,810	2,033,980	2,057,060
Oct	1,616,650	1,584,870	1,629,220
Nov	1,936,190	2,038,125	1,789,830
Dec	2,517,033	2,248,155	2,202,645
Total	25,979,573	25,050,250	23,339,116

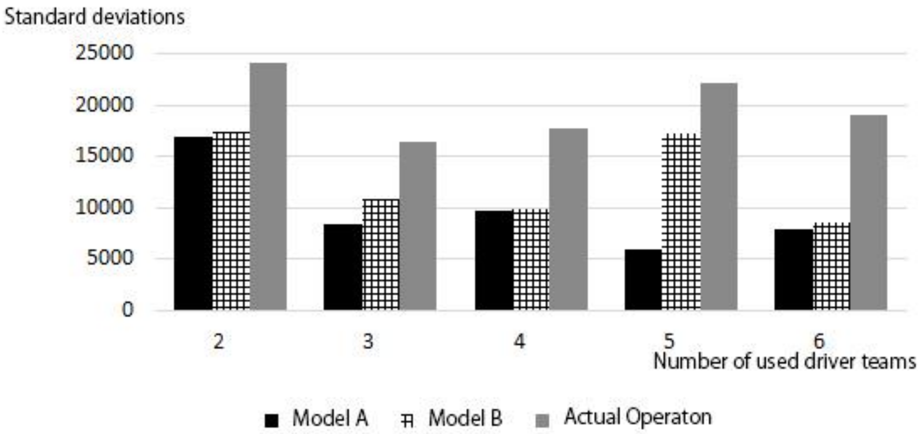

Figure 4. Comparison for workload balance.

Table 3 shows comparison of total distances among proposed models and actual operation. We have reduced about 4% and 10% of total distance of the actual operation with Model A and B respectively. Model A got behind of the actual operation only for 4 months. Model

B got behind of the actual only for 3 months. It is surmised that performance of both Models may depends on characteristics of applied dataset. Note that Model B provide the best solution for most months. However, there is an exception in July. Further analyses are necessary what is the cause of difference among the models. However, calculation time for a run is smaller than 3 seconds. Therefore, we have enough time to apply both method at the same time and choose better one in decision making.

Figure 4 shows comparison of workload balance. Horizontal axis corresponds to number of used driver team. Vertical axis corresponds to standard deviations of travel distance of driver teams. According to the figure, both Model A and B reduce standard deviations comparing to Actual operations. Comparison of Model A and B, Model A obtains smaller variance solutions. However, the difference is not so large.

CONCLUSION

We presented a problem of balance among cost, customer satisfaction and provider's satisfaction in mobility service. We build two Location-Allocation models, and formulations, for replacement driver service. Also we introduced a Genetic Algorithm to solve the models. The models were evaluated series of numerical experiment based on operation record of actual replacement driver service as a case study. Our proposed method reduced 4% to 10% total travel distance compared to actual operation. Also our proposed method reduced variance of travel distance among driver teams. Our proposed method can obtain comparable quality assignment of driver team. However, Model B statistically obtains better assignment compare to Model A. However, sometime the order is reversed. Clarification of this will help to develop more robust method to solve this problem.

It is our next goal that our proposed method is in practical operation in actual replacement driver service company. For the purpose, we are going to build an Information System implemented proposed methodology. Furthermore, we aim to evaluate good effect provided by balanced workloads among driver teams.

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A TRANSFER HUBS LOCATION OPTIMIZATION MODEL FOR ELECTRIC POWER LOGISTIC NETWORKS IN TAIWAN

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1.Introduction

With the rapid development of science and technology, more and more electric equipment was developed for humans to live in a more convenient way. Human can't live without electricity nowadays. Electricity consumption in Taiwan has also increased year by year.
The Taiwan power company is the biggest company to provide electricity in Taiwan. According to the data from Taiwan power company's website, electricity consumptions mainly from the industrial sector, the service sector, and the household sector. For example, in 2017, three sectors accounted for 53.98%, 18.48%, and 18.21%, respectively, of the electricity consumption in that year. However, some power shortage events occurred in Taiwan between 2016 – 2018 dramatically harm for the entire industrial development and the quality of people's livelihood. While any disruption event occurred, a well-designed transportation and distribution network could assist the required maintenance parts delivered to the disruptive point and facilitate the recovery stage. Thus, we start from examining the traditional logistics network of the Taiwan power company, and further developing some network re-engineering strategies.

2.Literature review

Facility location optimization models are usually based on mixed integer linear programming (MILP) with binary location variables. Most reviewed models were single level and the least reviewed models were bi-level. [1]
Chawis Boonmee, Mikiharu Arimura, Takumi Asada(2017) classified location problem into four types, one of the types is deterministic facility location problems. Deterministic facility location problems usually used to select shelters, distribution centers, warehouses, and medical centers by determining location and input parameters such as facility capacity, transportation costs, and fixed costs. Deterministic facility location problems can also be divided into four types by purpose: Minisum facility location problem, Covering problem, P-center problem and Obnoxious facility location problem.
Hub facilities provide switching, sorting or connecting and consolidation functions. [2] In hub networks, goods from the origin point to the destination point will be transported by hub, instead of delivering straight from origin point to the destination point. The aim is to reduce the costs of establishing a network connecting many origin and destination points, and also to consolidate flows at hubs to exploit economies of scale. Hub networks are widely used for many applications such as air transportation, ground freight transportation, postal, express shipment, public transportation networks, and telecommunications. [3]
And O'Kelly is a pioneer researcher of hub location problems. O'Kelly(1987) proposed the first mathematical formulation for a general p-hub median problem. The p–hub median problem aims to minimize total transportation cost from origin point to destination point, but ignores the fixed costs of opening hub facilities. O'Kelly (1992) introduced the single allocation hub location problem with fixed costs, where the number of hubs is a decision

variable. His study has triggered many papers that addressed hub location problems. [4] Ann Melissa Campbell, vTimothy J. Lowe, Li Zhang (2007) [14] lists many literatures which focuses on developing linearization for O'Kelly's model and creating heuristics. Some of the literature focuses on uncapacitated variations, such as in [5,6,7,8], while others consider capacity restrictions on hubs, such as in [9,10,11]. See [12] or [13] for overview of research on hub location problems.

3.Problem and challenge

The power company's existing distribution network is three level. The first level is depot, and there are two depots. The second level are thirty branches. The third level are about 300 business offices which spread all over Taiwan. This study aims to improve the distribution network at the first level to the second one.

After the branches inputs the material demand into the ERP system, the ERP reconciles the materials required, and the materials department of the general management office and its procurement group, depository group, and two depots will coordinate material management.

Materials usually deliver from two depots (the following will call two depots as depot 1 and depot 2) to thirty branches. Although two depots have similar work, depot 1 stores heavy material while the depot 2 stores light material. After getting the order from branches, two depots will deliver material straight to it. Hence, two depots have high opportunity to deliver material to various places in Taiwan. The statistics show that the farthest branches is Taitung branches, which is 488 kilometers away from depot 1, and 381 kilometers away from depot 2. It may be a reason that causes high storage and distribution costs.

In order to improve the system logistics performance (in terms of transportation shipping tons, ton-miles, and costs) of existing electric power logistic networks in Taiwan, the study aims to provide a hub optimization model to assist network re-engineering.

4.Results and analysis

4.1 Model

- Assumptions

(1) The hub does not provide storage space, the only function is transhipment.
(2) Allow partial transhipment.
(3) One-way transportation, no scheduling between same level facilities.
(4) The hub has no capacity limitation.
(5) The setting cost and management cost of each candidate hub are the same.
(6) The demand point has no specific preference for the hub.
(7) The service of the hub for each demand point is homogenous.

The sets and parameters required for the formulations are defined as follows.

- Sets

N	Sets of depots node. $k \in N$.
H	Sets of candidate hub nodes. $j \in H$.
T	Sets of demand nodes. $i \in T$.

- Parameters

P	The number of hub established.
D_{kj}	The shortest travel distance between depot point $k \in N$ and candidate hub point $j \in H$.
D_{ji}	The shortest travel distance between candidate hub point $j \in H$ and demand point $i \in T$.
L_{ki}	The weight of goods that demand points $i \in T$ need and which delivery from depot $k \in N$. (unit: kilogram)
C_{kji}	The freight shipping costs per unit weight. (unit: New Taiwan dollar)

- Decision Variables

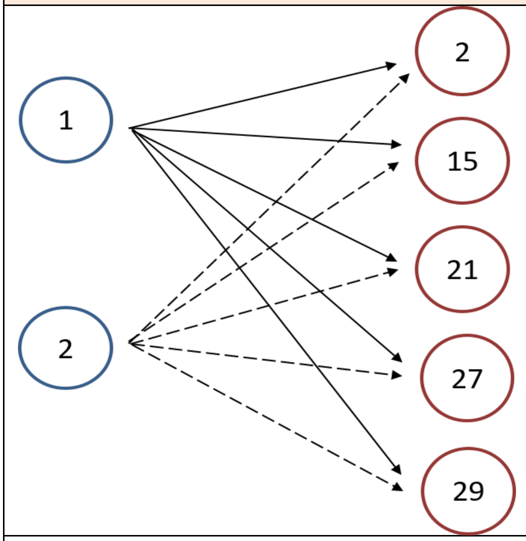
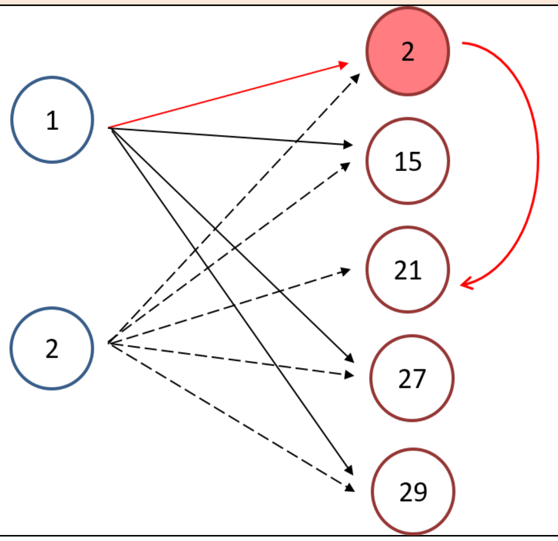
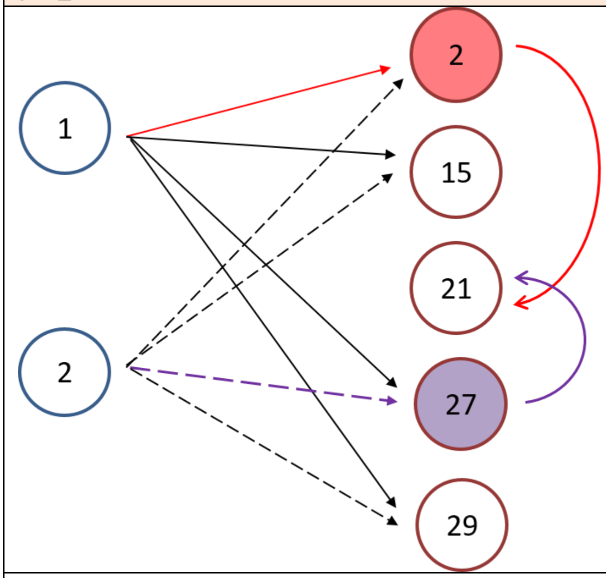
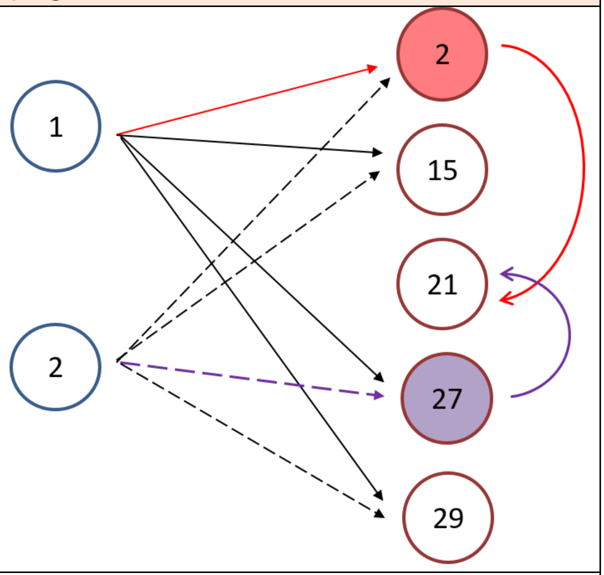
X_j	Equal to 1 if a hub is located at eligible site $j \in H$., and 0 otherwise.

Y_{kji}	Equal to 1 if the goods delivery from depot k∈ N and transfer in hub j∈ H and send to demand point i∈ T, and 0 otherwise.

Minimize $\sum_k \sum_j \sum_i (D_{kj} + D_{ji}) L_{ki} Y_{kji}$ (1)
Subject to : $\sum_j X_j = P$ (2)
$\sum_j Y_{1ji} = 1, \ \forall i$ (3)
$\sum_j Y_{2ji} = 1, \ \forall i$ (4)
$Y_{kji} - X_j \leq 0, \ \forall k, \ \forall i, \ \forall i$ (5)
$Y_{kji} \in \{0,1\}, \ \forall k, \forall i, \forall j$ (6)
$X_j \in \{0,1\}, \ \forall j$ (7)
The objective function (Eq.(1)) minimizes the total ton-kilometer between depots to demand points. Eq.(2) states that there are P hub to be located at site j. Eq.(3) and (4) ensures that each demand point i is assigned to hub j. Eq.(5) set that only if the hub is set, the route from the depot k via the hub j to the demand point i will be established. Eq.(6) and (7) sets binary conditions for the model variables.

Minimize $\sum_c \sum_j \sum_i C_{kji} L_{ki} Y_{kji}$ (8)
Subject to : $\sum_j X_j = P$ (2)
$\sum_j Y_{1ji} = 1, \ \forall i$ (3)
$\sum_j Y_{2ji} = 1, \ \forall i$ (4)
$\sum_j Y_{cji} - X_j \leq 0, \ \forall c, \forall i$ (5)
$Y_{cji} \in \{0,1\}, \ \forall c, \forall i, \forall j$ (6)
$X_j \in \{0,1\}, \ \forall j$ (7)
The objective function (Eq.(8)) minimizes the freight shipping cost between depots to demand points.

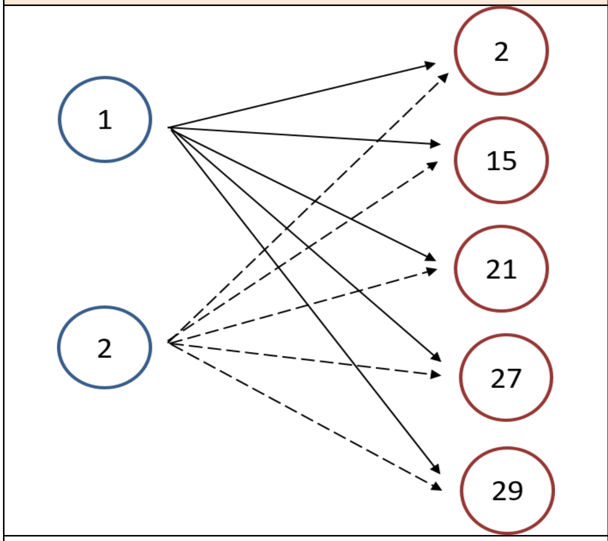
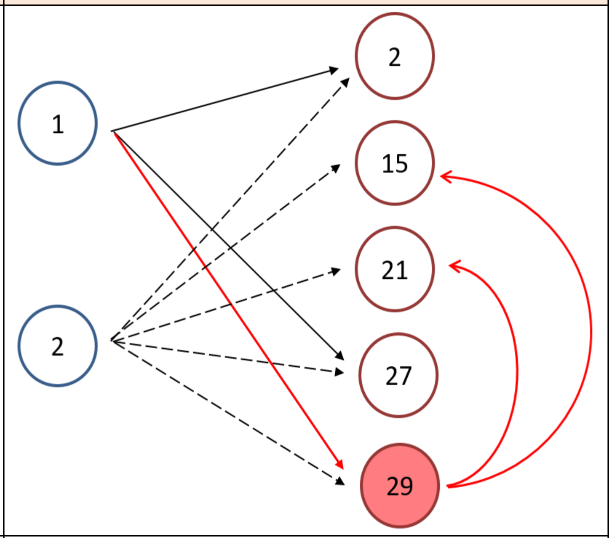
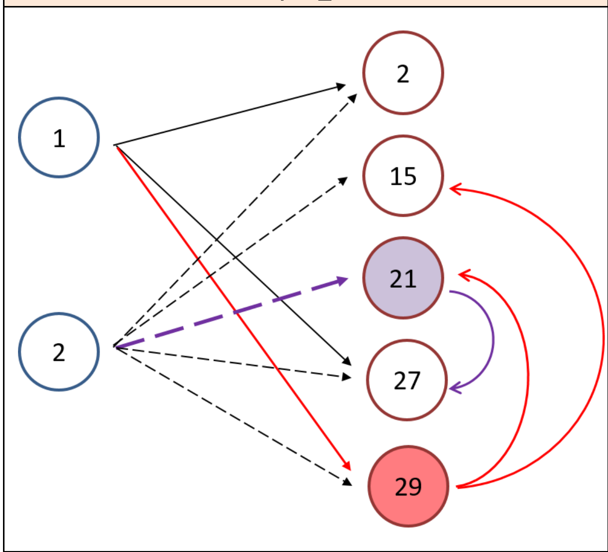
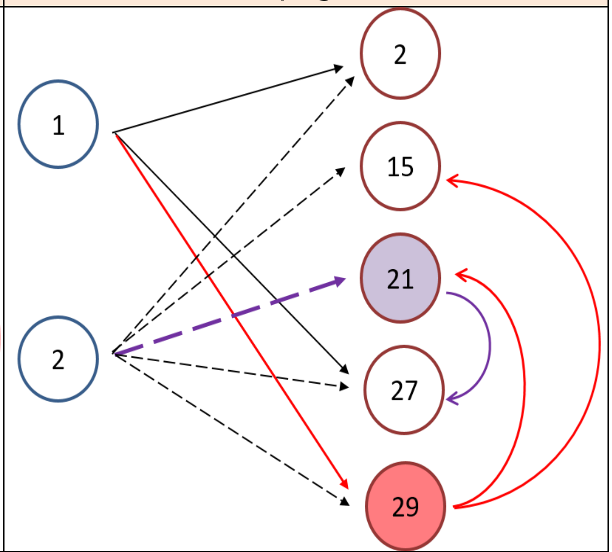
4.2 Results
This chapter follows on from the previous chapter, which use the example to examine the model. Here is the example, there are two depots and five demand points (randomly chosen from 30 branches), so it also means five candidates. Besides, the model is solved by LINGO18.0. And the following shows the result.
4.2.1 Minimizes the total ton-kilometer.

P=0	P=1
	
Objective value equal to 19718.01 ton-kilometer.	Objective value equal to 18730.32 ton-kilometer.
P=2	P=3
	
Objective value equal to 18314.46 ton-kilometer.	Objective value still equal to 18314.46 ton-kilometer.

When P equals to one, point 2 is the hub for depots 1 to point 21. As P equals to 2, there is a new hub added in, point 27 is now a hub for depot 2 to point 21. The result as P equals to three won't be changed.

With the assumption of ignoring hub set up cost and management cost, comparing the four results, it can be seen that the number of hub equals to two can minimize the total ton-kilometer.

4.2.2 Minimizes the freight shipping cost.

P=0	P=1
	
Objective value equal to 52047 New Taiwan Dollars.	Objective value equal to 51114 New Taiwan Dollars.
P=2	P=3
	
Objective value equal to 50845 New Taiwan Dollars.	Objective value still equal to 50845 New Taiwan Dollars.

When P equals to one, point 29 is the hub for depots 1 to point 15 and point 21. As P equals to 2, there is a new hub added in, point 21 is now a hub for depot 2 to point 27. The result as P equals to three won't be changed.

Still with the assumption of ignoring hub set up cost and management cost, comparing the four results, it can be seen that the number of hub equals to two can minimize the freight shipping cost.

Conclusions

From the previous discussion, it can be seen that under the different objective functions, the hub locations are somewhat different. One common finding is that totally two transfer stations would be the best number in the numerical example.

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A STUDY OF COMMUNITY-BASED INSTANT RESPONSE MOTORCYCLE PICK-UP AND DELIVERY SERVICE MODEL UNDER REQUIREMENT OF LONG-TERM CARE

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Abstract
Purpose of this paper
The main purpose of this study is to solve the problem for community-based long-term care demanders by providing instant response service. In Taiwan, similar to other countries in the world, the elderly people and those who are inconvenient going outdoors would require real-time cargo distribution for help. The main purpose of this study is to increase the flexibility of manpower application by sharing the design of manpower, and based on the characteristics of instant response for low frequency demand, using motorcycle as distribution tool to establish a community that meets the needs of future long-term cares. This real-time response logistics pick-and-delivery service model provides services for home care, food delivery, drug delivery or regular delivery.

Design/methodology/approach
This paper proposes an instant response model for manpower assignment and the motorcycle pick-up and delivery service for the community-based long-term care demand. The model of this study is a multi-to-multiple origin and destination vehicle problem, which is a combination optimization issue. This study uses the genetic algorithm to solve the algorithm to obtain the solution of the model.

Findings
This study uses the long-term care needs of the Fengnian community in Beitou District of Taipei City as the test data to demonstrate the results of assigns and routes the distribution personnel through the instant response needs of the long-lived people. The number and size of the packages are assumed as given. After solving the evolutionary generation of the algorithm for 500 rounds, the minimum total path cost can be obtained after the calculation, so as to achieve the assignment of the shared delivery manpower, and the optimal route of picking and delivery, and to meet the motorcycle distribution. The results show this model can improve the efficiency of community-based real-time motorcycle distribution service under long-term demand.

Value
Under the current development of an aging society, the real-time logistics distribution demand reflected by the long-term care demand is important for future community service

work. The real-time response motorcycle logistics distribution service model provide the assignments of shared manpower to meet the logistics distribution service for motorcycle pick-up and delivery service. This model should be a solution of practical long-term care problems.

Keywords: Long-term care policy, motorcycle pick-up-and-delivery service, assignment problem, vehicle routing problem, genetic algorithms

Introduction

According to the Taiwan Statistics Department of the Ministry of Internal Affairs (2018), Taiwan currently has a total population of 23,577,488, of which the elderly population over 65 years old accounts for 14.35% of the total population and regarded as an aging society. In addition, the aging index has also increased to 110.56% in the past decade. This phenomenon indicates that medical progress has prolonged people's lives, but it also increases the possibility of aging disability. However, in the case of insufficient family care resources, the quality of life and dignity of the aged and disabled people become a society issue to address (Li Yijun, 2013). In response to the aging society, the government promoted the long-term care 2.0 policy in 2017 for the elderly, debilitated aged people and people with physical and mental disabilities of any age. Furthermore, the long-term 2.0 service management is divided into A-level: community-integrated service center, B-level: composite day service center, and C-level: day-care station.

The elderly living alone in the home or the elderly who need to be cared for and the caregiver themselves are not easy to go outdoors. The reason may be that the care recipient has physical and mental disabilities and is inconvenient to move. Therefore, it is necessary to distribute the needs to their homes, to satisfy their daily needs. Du Nianci (2016) studied the home and community-based care services, for the elderly in Taiwan. Their study shows that there are four types of government-subsidized private provision, direct government provision, government and private collaboration, and professional integration with hospitals. The food delivery location is divided into two types: fixed-point meal and meal-to-home, but this study does not take all the elderly into account.

For the development of the current community distribution service, the latest way is Online to Offline (O2O). Through the development of Internet technology, consumers can purchase online and obtain services offline. The community O2O is mainly for the purpose of serving residents. According to China's express end service development status and trend report (2017), intelligent locker system, an O2O business model, becomes a new solution. This intelligent locker system can allow consumers to pick up goods anytime, while achieving a non-face-to-face delivery and ensuring consumer privacy. However, smart locker system is limited by the size of the cabinet, unable to deliver larger items and left unattended. The current O2O distribution methods still have some shortcomings in community distribution services for long-term care needs. There is important to response the regular or instant requests from long-term care person to order daily grocery, to access medical care (especially, the emergency drug), and other instant response assistance.

In Taiwan, motorcycles would be the most suitable transportation equipment for community delivery because of small size, convenience, and energy efficiency. The purpose of this study is to design a business model under the community-based planning of the future long-term care policy, to meet the needs of elderly by providing a quick response motorcycle pick-up and delivery services.

Literature Review

The elderly population in Taiwan has been rising, and the long-term care 1.0 policy promoted by the government has not been able to meet the needs of today. Therefore, the long-term care 2.0 policy was developed in 2017. According to Zheng (2007), there are 70% of the respondents believe that it is necessary for the community to provide food for the elderly. Among them, 52% think it should be provided by the government, nearly 80% hope to deliver food to home, and 50% hope the service is an everyday service. Wu,

Zhou, Zhou and Shen (2016) indicated that the service provided by the nutrition and catering service in August 2015 was 1,164 people, accounting for 21.76% of the 5,350 people in the country, far better than the expected 4.3%. There are no restaurants, lunch shops, or food service stands in the township for people to choose. Therefore, the food delivery service is especially important for the local residents. It not only improves the nutrition of the elderly, improves health, but also increases the interaction with the elderly. Lin, Chen and Li (2016) pointed out that the public agreed to set up a joint care organization in the community and to plan a small-scale and multi-functional multi-service model, which is to achieve a close relationship with the familiarity of the elderly and community residents.
Zhang and Sheng (2017) refers to the delivery of the franchise model for the community into the electricity business and communities through profits, the electricity supplier to provide last-mile delivery service to provide facilities for the community by the community owner. Compared with the application of this research in the community-based pick-and-delivery problem of long-term care demand, Guo, Wu, Lan, Zheng and Lin (2007) model a community-based food delivery service for Taiwanese senior citizens. Their model considered the physiological and psychological meal planning concept, most of the food providers provide food delivery services in the form of government-sponsored subsidies. A small number of meals are funded by self-raising, and meals are also available for a small number of meals. It is easy to end because of the small number of cases, so it is mainly based on the service of delivering meals to home. Du (2016) pointed out that elderly people tend to be room service as community care model, emphasizing community-based home services, with the power of social system, combining internal and external resources to establish community welfare services for the elderly community network. In addition, Hewitt, Nowak and Gala (2015) explained that a non-profit organization in the United States provides planning and research on food delivery for the elderly in the community, and issues related to the distribution of the community, including the needs of different locations and the delivery route limited by the capacity of the vehicle. The proposed meal delivery home model and solution will be able to dynamically adjust the number of drivers required with the consumer's ordering requirements to reduce costs or provide additional services.

Due to the development of social economy and the advancement of technology, consumers are paying more and more attention to the timing of goods distribution, resulting in the concept of consumer reverse traction. The results of Joerss, Schröder, Neuhaus, Klink and Mann (2016) showed 25% of consumers are willing to pay a higher fee for the service of the day or for immediate delivery, and the willingness to choose faster delivery when the purchased goods are groceries. You (2017) said that with the cross-industry social logistics team to join the take-out platform, mutual benefit can be realized. On the one hand, the take-out service cooperates with the enterprise, develops the service field and solves the problem of idle logistics and transportation. The mature logistics team can provide logistics distribution and immediate guarantee for the food and beverage delivery platform. For the planning and operation of the model, Han and Xiao (2007) planed the distribution route for the perishable goods with immediate characteristics, and the analysis of the model minimizes the total cost of the delivery route, including the time penalty function and capacity limitation. The mathematical model was established to propose the optimization problem of the immediate distribution route of perishable goods, and the improved genetic algorithm was used to solve the problem.

Wang (2008) as well as Chang and Yen (2012) show that in the urban environment, for the distribution of important documents such as documents, gifts and samples, the car is better maneuverable than the advantage of the locomotive. Accessibility and high efficiency are more suitable for courier services in the city. Zhu, Chen, Gao and Lin (2016) Scholars also said that in fact, the items that really need express delivery are still based on regional business documents and small parcels. Yan, Chen, Li, Peng and Huang (2016) explained the operation mode of GoGoVan Company through the logistics platform of mobile application. In addition, according to the characteristics of Taiwan's market, the

motorcycle with the highest density was selected as the distribution tool. Dablanche et al. (2017) explained the environment in Europe, and the equipment for immediate delivery is 88% suitable for bicycles, 9% for motorcycles and scooters, and other methods. It is 3%. Maes and Vanelslander (2012); Wrighton and Reiter (2016) said that bicycle expresses abroad are common delivery vehicles and have proven to be reliable delivery vehicles. Gruber, Kihm and Lenz (2014) A strategy to address the negative impact of urban freight is to use electric cargo bikes (E-CB) instead of freight cars to enter the city for express delivery.
The model of this study is a community-based instant shared manpower dispatch and motorcycle pick-and-delivery service model under long-term demand. It is a general assignment problem. Traveling Salesman Problem (TSP) is a problem because of the problem of loading capacity and package size of Vehicle Routing Problem (VRP). This study will use the genetic algorithm to find solutions. Clark and Wright (1964) proposed an approach for the VRP problem, later modified by Gaskel (1967); Yellow (1970) and Nelson, Nygard, Griffin and Shreve (1985) to solve the unequal demand vehicle journey. The approach is more suitable for practical use. Furthermore, Lu, Feng and Li (2005); Alvarenga and Mateus (2005) both use the heuristic method of genetic algorithm to solve the problem of vehicle dispatching after customer grouping and then solve the shortest total path with the set segmentation method.

Research Methodology
In this study, the proposed model designs the logistics distribution system are based on following conditions. First, the distribution manpower is planned and assigned by the shared delivery personnel. Under this condition, the delivery personnel may not start from the same position. Therefore, the instant response needs of each long-term care person may be served by multiple delivery personnel. Because the size of the motorcycle is small, and the goods being transported are in response to the demand for instant response, there is a limitation of the loading capacity on the delivery, and the scope is limited, the loading capacity is limited, and the distribution distance is a certain range. The characteristics of the instant response, therefore, the delivery method is that one motorcycle can receive multiple orders, each order is represented as a package, in which the package is counted with a variety of different capacities, and each order will load capacity on one locomotive. Within the allowable range, then plan the location of each parcel and the route to the destination. The objective of this model is to minimize the total travel cost by solving the assignment and route planning and distribution personnel.

The following is an explanation of each symbol:

c_{ij} ： the distance cost of the arc (i, j)；

x_{ijklm} ： a [0,1] variable, which is expressed as the flow of the mth order of the package of the kth delivery personnel that is taken by the arc (i,j) belonging to the l type of goods then its value is 1, otherwise it is 0.；

a_k ： the parcel capacity carried by the kth delivery personnel;

$\bar{a}_k$ ： the upper limit of the parcel capacity that can be carried by the kth delivery staff；

ρ_l ： the equivalent of the conversion of the i package capacity；

Q_i ： the total package capacity of each node i；

QC ： the sum of the package capacity；

L ： the collection of all package types

M ： the number of orders；

K ： the number of all delivery personnel；

N ： the collection of all nodes

The following is a mathematical formula for the community-type real-time response motorcycle pick-up and delivery service model established under the long-term demand established by the study. Equation (1) is the target model of the model, and (2) to (9) are constraints:

$$\min Z = \sum_{i \in N} \sum_{j \in N} \sum_{k \in X} \sum_{l \in L} \sum_{m \in M} c_{ij} \cdot x_{ijklm} \tag{1}$$

Equation (1) is the goal of pursuing the minimum total path cost.

$$\sum_{i \in N} x_{ijklm} \leq 1 \qquad \forall j \in N,\ \ \forall k \in K,\ \ \forall l \in L,\ \ \forall m \in M \tag{2}$$

Equation (2) is a limit for each delivery person to start from different positions and is not necessarily assigned. That means that for these delivery person the starting position may not be the same.

$$\sum_{k \in K} x_{ijklm} \leq K \qquad \forall i, j \in N,\ \ \forall l \in L,\ \ \forall m \in M \tag{3}$$

Equation (3) is the limit of the assigned delivery personnel should be less than the limit of all the distribution personnel of the shared manpower.

$$\sum_{j \in N} x_{ijklm} - \sum_{i \in N} x_{ijklm} = \begin{cases} 1 \\ 0 \\ -1 \end{cases} \qquad \forall k \in K,\ \ \forall l \in L,\ \ \forall m \in M \tag{4}$$

Equation (4) is a restriction type for the delivery of each pick-up point and the delivery point. The former indicates x_{ijklm} that there is no delivery person on the route of the delivery point j, and the latter x_{ijklm} is indicated as entering the pickup that there is no delivery personnel on the path of node i.

$$\sum_{l \in L} \sum_{m \in M} \rho_l \cdot x_{ijklm} = QC \qquad \forall i, j \in N,\ \ \forall k \in K \tag{5}$$

Equation (5) is the limit of the total package capacity of each package to be equal to the total package capacity to be delivered.

$$\sum_{i \in N} \sum_{l \in L} \sum_{m \in M} \rho_l \cdot x_{ijklm} = Q_i \qquad \forall j \in N,\ \ \forall k \in K \tag{6}$$

Equation (6) The sum of the parcel capacity of each order for each pick-up point will be equal to the limit of the total parcel capacity at each pick-up point.

$$\sum_{j \in N} \sum_{l \in L} \rho_l \cdot x_{ijklm} - \sum_{i \in N} \sum_{l \in L} \rho_l \cdot x_{ijklm} = a_k \qquad \forall k \in K,\ \ \forall m \in M \tag{7}$$

Equation (7) is a limit of the total capacity taken by each delivery personnel at the pick-up point.

$$a_k \leq \bar{a}_k \tag{8}$$

(8) The total capacity of the parcels carried by each delivery personnel shall not exceed the limit of the capacity limit that each delivery personnel can carry.

$$\forall x_{ijklm} \in \{0,1\} \tag{9}$$

Equation (9) is the limit of all 0-1 variables

This study uses Genetic algorithms to solve the problem. First, to select the fitness function for the problem, and then use this fitness function as an ability indicator to adapt to the environment, and set the control parameters. Secondly, the system configuration is organized into a set of gene codes through permutation coding technology, and then a set of initial parental groups is generated. At this time, the evolution process of alternation and natural selection is completed by three genetic algorithms. The first step is the selection problem. In this study, the competition method is used. After sorting the fitness values, the better genes are put into the mating pool for mating. The step is the mating problem. This study uses the fitness value to identify the better chromosomes to first perform the mating of the genes, while the mating process uses random single-point mating to produce better progeny chromosomes. The third step is the mutation problem. In order to solve the research problem, the design of the mutation is calculated in each generation by a single point of substitution. The mutation will make the recombination solution more change to prevent premature convergence to the local best. Solution, but cannot get the overall best solution. Finally, the program of the above generation operation is repeated until the number of generation operations reaches the limit value or the fitness function value converges to a certain extreme value, that is, the operation is stopped and the path planning scheme corresponding to each assigned delivery person is solved.

Results

This study takes the long-term care demand of the Fengnian community in Beitou District of Taipei City as an example, and designs a large test road network with a total of 14,000 arcs among 180 nodes through Google Map. There are 80 parcels in the goods list that need to be delivered to each dependent point of origin, with a total capacity of 50. The parcels are divided into three types of restrictions. The bulk parcel capacity is 1 for 30, and the middle package has 0.5 for 25. The parcel capacity of the small and small pieces is 0.3 and there are 25 calculations. Furthermore, the use of shared manpower is regarded as an environment but there are at least 80 delivery personnel, and there are 50 households with the delivery point. The objective is to minimum total travel cost.
The results show that there are total of 51 pick-up and delivery combinations, and the total minimum cost (in distance) is 78.781 km. The 500-round iteration convergence state of the path cost of the network, as shown in Figure 1. It reaches the minimum total path cost at the 480th time. Among them, the sum of the parcel capacity is consistent with the total capacity of the basic data, and it is considered that the limitation of this model is that each parcel is picked up and the delivery is completed. Furthermore, the maximum size of each motorcycle can be loaded into a large package, two middle packages, three small packages or a combination of middle and small packages.

If the total capacity of the parcels received by each delivery personnel is 1, the number of parcels taken by the delivery personnel indicating the route is three. One is to take a large parcel from a pick-up node and then deliver it to the dependent long photo. The location of the demander's origin, the second is to enter a pick-up node to take two middle-packages and then respectively distributed to the dependent point of the long-term demand, and the third is to enter the two pick-up nodes. The parcels are then separately distributed to the origin of the dependent long-light demanders, which is regarded as the end of the service of the combination of pick-up and delivery; if the total capacity of the parcels received by the dispatcher is 0.9, the delivery personnel indicating the route should be picked up three small parcels and delivered to the origin of the dependent long-term care demand. In addition, in the case of the 80-person shared manpower designed by the model, the solution results show that only 51 delivery personnel are required to complete whole mission.

Through the results of 10 rounds of 500 rounds of iterations, the overall analysis and comparison are performed as shown in Figure 2. The maximum total cost fluctuations of each time are not normal, but after the iterative operation by the model of this study, an approximate optimal solution can be obtained, therefore, the reliability and stability of the model of this study can be proved.

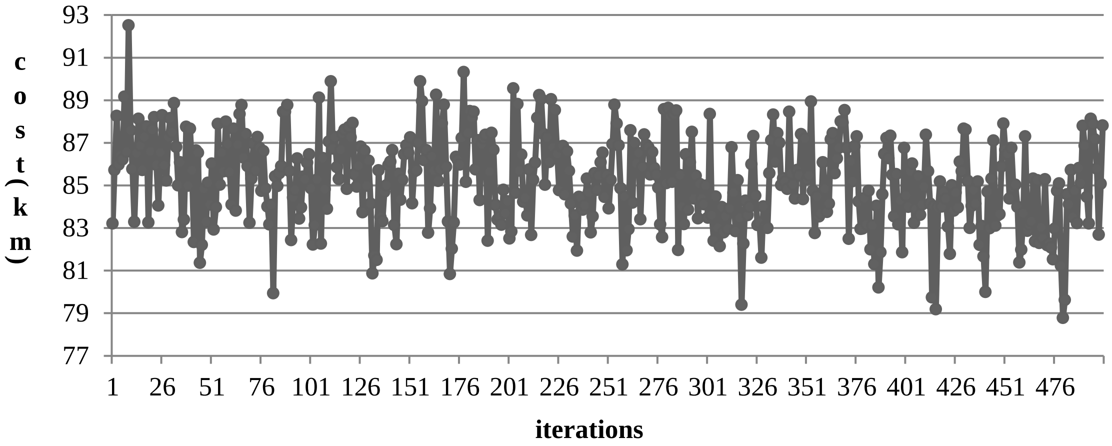

Figure 1. The 500-round iteration convergence process

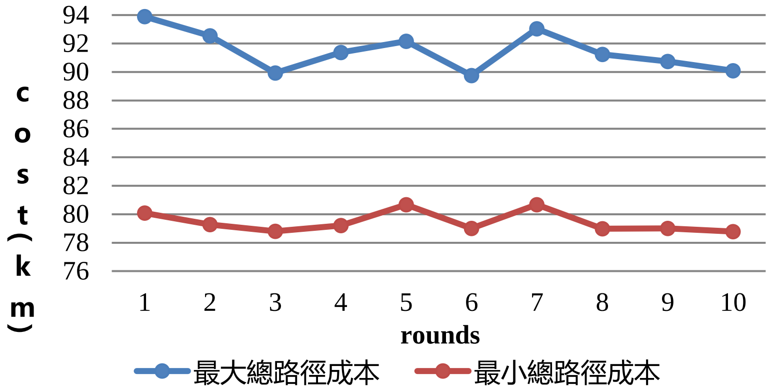

Figure 2 Results of 10 rounds of 500 rounds of iterations

Table 1. Comparision of Results of 10 rounds of 500 rounds of iterations

Round	Max cost (km)	Min cost (km)	Difference ratio between the times (%)	Computing time(Sec)
1	93.894	80.087	0.735	1.781
2	92.549	79.272	1.771	1.86
3	89.927	78.790	2.394	1.875
4	91.375	79.210	1.851	1.922
5	92.171	80.672	0.005	1.657
6	89.758	79.010	2.109	1.875
7	93.046	**80.676**	0	1.906
8	91.233	78.972	2.158	1.89
9	90.750	79.006	2.114	1.687
10	90.082	**78.781**	2.405	1.485

In addition, through the 10 times of 500 rounds of iterative information of the large test path cost of Table 1, the model solve time is an average of 1.79 seconds of iterative operation to find the minimum total path cost, which means that the calculation of this study is efficient. And in the 10 operations, the difference between the minimum total costs is found to be small. Furthermore, in Table 1, the difference between the maximum value of the minimum total path cost and the cost of each path is used to calculate the model. As a result, the difference ratio between the times is in the range of 0% to 2.4%.

Discussion and Conclusions

The main purpose of this study is to explore the real-time logistics and manpower assignment planning for the needs of community-based long-lit people under the long-term demand, in order to solve the real-time logistics pick-up and delivery services for long-haired people to the government. For the community-type environment and the demand characteristics of real-time response, it is considered that the number of parcels is small, the distance is not far and must be received by itself. Therefore, the motorcycle is used as the transportation and transportation tool for the distribution of the research, and the mobility of the motorcycle is high and the parking is convenient.

This study establishes an optimization model, considers the assignment of distribution personnel, the loading capacity of the motorcycle and the limitation of the package capacity in the form of integer programming, and establishes the community-type instant response motorcycle pick-up and delivery under the long-term demand. This study achieves the following conclusions:

1. This study is based on the needs of long-term care people (elderly) for community-based real-time motorcycle distribution services, and the needs of each person are different, reflecting that the package size could be different for each pick-up service.
2. This model deal with heterogeneous demand for each pick-up node. The load capacity of the motorcycle and the size of the package are considered.
3. In this study, the current motorcycle pick-up and delivery service is based on the characteristics of the community-based environment. This feature is considered as a short distance and the randomness of the demand generates a small amount of parcels. Therefore, the regional-based environment is achieved in a short distance.

The concept of real-time response to pick-and-delivery is closer to the actual application. In the future, it can be included in the time window and limited to the research. The dynamic planning method is used to solve and improve the shortcomings of the model.

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ENVIRONMENTAL SUSTAINABILITY OF LOGISTICS SERVICE PROVIDERS: A SYSTEMATIC LITERATURE REVIEW ON INDICATORS FOR CITY LOGISTICS

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Purpose: United Nations reported that currently in Europe, 70% of the population lives in urban and metropolitan areas, this number is expected to reach 85% by 2050 (Russo and Comi, 2016). The increasing logistics and transport activities in the city significantly impact on the environment we live in. Provision of green and sustainable logistics services is on the top of logistics service providers' (LSPs) agendas and can also become a competitive edge to their customers (Piecyk and Björklund, 2015). Both academics and industry have shown increasing attention to measure the logistics sustainability in the recent decade, yet limited research has been developed comprehensively (Evangelista et al., 2018). Thus, LSPs' sustainability performance measurement methods and relevant indicators need to be assessed and updated particularly in the context of city logistics. To fill this gap, this paper aims to identify and evaluate the current frameworks and indicators that reflect the performance of LSPs' environmental sustainability in academic publications, and further propose a practical set of sustainability indicators to assess the city logistics 'greenness' and environmental sustainability in LSPs' operations.

Design/methodology/approach: To achieve this aim, a systematic literature review was carried out to map out the existing measurement indicators of environmental sustainability that apply in city logistics and LSPs domains. The academic database - Scopus was primarily used, and key references were added as supplement through cross reference. A total of 56 papers dating from 2010 - 2018 were selected and analysed in detail to investigate how the different environmental sustainability measurement frameworks/methods are used by different industries for their logistics operations, and what indicators are applied.

Findings: Despite the increasing numbers of published papers on environmental sustainability measurement since 2010, few studies have focused on city logistics and freight transport sector. Among various frameworks identified, the Triple Bottom Line (TBL) and the Global Reporting Initiative (GRI) are the two major frameworks adopted by scholars when assessing sustainability. However, the research in city logistics has yet to embrace the GRI framework in the environmental sustainability evaluation.

Value: This study attempts to fill the research gap of current studies by providing a comprehensive review of the indicators to assess the environmental sustainability of LSPs in the city logistics context. A framework embedded with GRI framework was developed to provide a set of updated indicators. Future research directions are also highlighted.

Research limitations/implications: The literature reviewed only included academic articles at this stage, industry and government reports shall be considered in future research to comprise an exhaustive review.

Practical Contribution: This paper provides a basis for future research to develop a comprehensive taxonomy of sustainability for city logistics to select the suitable environmental sustainability indicators and measure LSPs' sustainability performance, which will enable LSPs to benchmark the status-quo of their 'greenness', and identify the

hurdles to fulfil environmental sustainability requirements and adopting realistic and practical practices for improvement

1. INTRODUCTION

The digital era has a definite emphasis on 'timeliness' for the modern supply chain. Both the volume and the distance of cargo travelling around the world has grown exponentially. Cities and urban areas with large populations and extensive commercial establishments have served as significant nodes for trade, merchandising, wholesale and retail distribution activities (Hesse, 2016, p.13). The high demand of just-in-time deliveries and asymmetrical patterns of trade has led to increasing demand for urban freight transport services - trucks on the road are running empty or below capacity (Goldman and Gorham, 2006).

Inevitably, the level of carbon dioxide (CO_2) has risen significantly over the years. McKinnon (2018) pointed out that logistics activities generates about 9-10% of global CO2 emissions and it is considered as the most difficult sectors to decarbonise. Road-intensive logistics activities in the city has posed a series of social, environmental and economic impacts in the urban areas, such as traffic congestion, greenhouse gas emissions, air pollution, noise pollution, and the consequences of traffic accidents (Browne *et al.*,2012).

Logistics service providers (LSPs) has played a pivotal role in long-distance global shipping and last-mile city deliveries. In the past, improving environmental sustainability has been treated as an extra cost for LSPs, due to the low profit margins in the freight transport industry (Piecyk and Björklund, 2015). Under the sustainable development request, new requirements will be addressed to logistics service providers –'environmental sustainability' is now becoming a supplier selection criterion (Wolf and Seuring, 2010; Björklund and Forslund, 2013) and a competitive edge for LSPs (Piecyk and Björklund, 2015) and even an expected dimension of modern logistics service offering (Evangelista *et.al*, 2018). However, because there are multiple organisations involved in the supply chain, it is very difficult for LSPs to gain visibility and measure their environmental sustainability as a focal organization (Piecyk *et al*., 2015).

Over the past decades, the concept of sustainability has been embodied into government, industries and corporations' policies through 'standards, conformity assessment, and metrology' (Brand *et al.*,2016). A variety of governmental initiatives, trails and pilot projects have been carried out to improve the sustainability of city logistics (Browne *et al.*,2012). Sustainable city logistics can reduce logistics cost, improve transport efficiency and economic vitality, and ultimately, lead to a harmonious and sustainable development of the economy, the environment and society (Carlucci *et al*.,2018).

From an academic perspective, Evangelista *et al.* (2018) conducted a systematic literature review on the environmental sustainability of third-party logistics service providers. Their study highlighted that the current research on LSP's environmental performance measurement is absent and inadequate. In addition, Tundys and Wiśniewski (2018) also carried out an extensive literature review on green and sustainable supply chain measurement methods. Their research study suggests that the various existing measurement instruments, tools, and methods may mislead and lack comparability for different entities, and that clearly defined key performance indicators are needed to assess sustainable performance in logistics.

From an industry perspective, a few global sustainability indexes are identified, such as the Global Reporting Initiative (GRI), the Green City Index developed by Siemens, the Climate Change Performance Index (CCPI) by GermanWatch, Dow Jones sustainability index (DJSI); FTSE4Good Index; MSCI Environmental, social and governance (ESG) Index. Some of these indexes focus on the city or country's environmental sustainability as a whole, while some are designed for the corporate social responsibility (CSR) reporting purpose of large and listed companies. Buldeo Rai. *et al.*(2018)'s study highlighted that freight transport and logistics related activities are underrepresented in these established frameworks and there is no current available globally agreed set of city logistics-related indicators to measure the environmental sustainability performance of LSPs' operations. Among the above-mentioned frameworks, the GRI framework was developed for organizations to report their sustainability performance from economic, environmental, and social aspects (Piecyk and Björklund, 2015) and a supplement set of indicators was developed in 2006 for the logistics and transport sectors. The Global Reporting Initiative (GRI) framework was not included in Buldeo Rai *et al.* (2018)'s research.

To address this gap, this paper carried out a systematic literature review to answer two research questions:

RQ1: What environmental sustainability measurement frameworks and indicators are currently used by different industries for their logistics operations?

RQ2: Which of those indicators are the most appropriate to measure the environmental sustainability of city logistics?

This study fills the gap of current studies in logistics sustainability by providing a comprehensive review of the practical indicators dedicated for city logistics, to assess the environmental sustainability of LSPs. The findings of this paper discovered important variables and indicators related to measure environmental sustainability in logistics activities. On this basis, an indicator framework was proposed to relate new findings to previous research.

The remainder of this paper is organised as follows: Section 2 presents the methodology employed to answer the research questions of this study and a brief descriptive analysis of the selected literatures. Section 3 presents the existing measurement frameworks and their applications through content analysis. Section 4 proposes a conceptual framework with a shortlist of indicators dedicatedly to measure city logistics environmental sustainability. At last, Section 5 discusses the implications of this study and future research agendas.

2. METHODOLOGY

Different from the literature review in traditional sense, the systematic literature review (SLR) is a 'self-contained' research project (Denyer and Tranfield, 2009). A SLR provides a rigorous and transparent 'evidence-informed approach', which helps researchers to explore a specific research query by capturing existing studies across disciplines, analysing and synthesizing literatures, and evaluating research findings (Denyer and Tranfield, 2009; Tranfield, Denyer, and Smart, 2003).

This study attempts to address the pressing need to make clear sense of the existing literatures surrounding the topic of logistics sustainability measurement and have a collective overview of what measurement frameworks and indicators of environmental sustainability have been discussed and used in academic research. Thus, a systematic literature review has been conducted in this study in order to map out and assess the relevant literatures to answer the two abovementioned research questions, and further develop the knowledge base and inform future research agendas.

2.1 Selection of literatures

Cooper (1984, cited in Randolph, 2009) and Denyer & Tranfield (2009) suggested that a SLR comprises the process of research question formation, selection of data (i.e. literatures), data evaluation, data analysis and report of the research findings. In this study, following this theoretical logic, the systematic review approach in also incorporate the processes from two recent SLR studies on the logistics sustainability topic - Evangelista *et al.* (2018) and Centobelli *et al.*(2017), the main steps were illustrated in Figure 1 below.

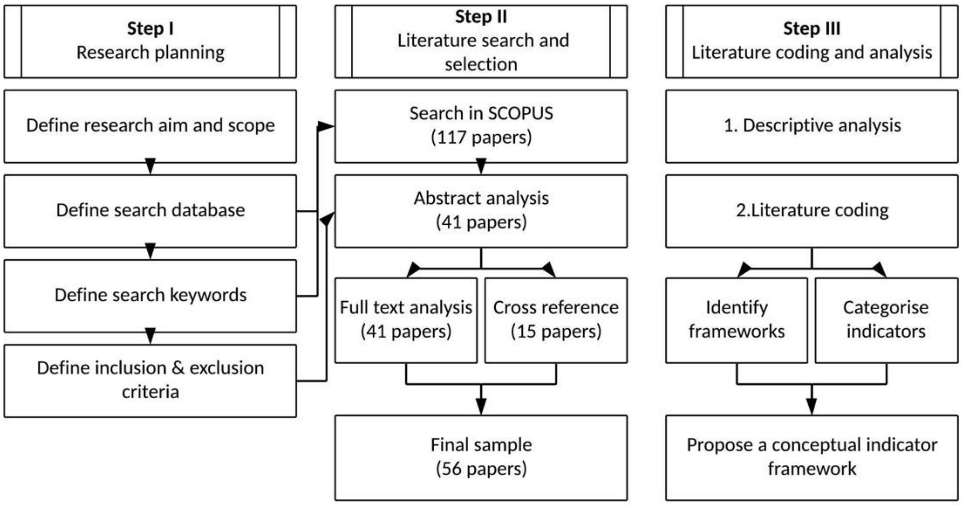

Figure 1: Research Method (Adopted from Evangelista *et al.*, 2018)

Firstly, research planning aimed to determine the research scopes and define keyword search strings. The academic database Scopus was primarily used as it includes extensive peer-reviewed international journals in science, technology, and management among others, and it is also used by many other published systematic literature review studies (Evangelista *et al*.,2018, Centobelli *et al*., 2017) in the topic of third-party logistics sustainability.

Secondly, with an aim to align the literature search tightly with the research questions (Denyer & Tranfield, 2009), the keywords search was conducted using the keywords indicating environmental sustainability measurement and logistics service. The searched keywords string embedded with Boolean logic (Denyer & Tranfield, 2009) included *logistics, sustainability (or sustainable), environment (or environmental), measurement, indicator.* The articles that have matching phases in the article title, abstract, or author-supplied keywords were identified. We included peer-reviewed journal articles written in English language only.

The initial search resulted in 117 articles (status on 09 Jan 2019). Thereafter, the articles identified by the search were screened by reading the abstracts to exclude the unrelated articles that do not concentrate on the 'logistics sustainability' issues. This reduced the sample of literatures to 41 articles. A full text analysis was then carried out and an additional of 15 highly relevant cross-reference articles (including 5 conference proceedings) were found and included in the final sample. The final sample included 56 articles with relevance to the measurement of logistics environmental sustainability.

Thirdly, descriptive analysis was conducted to present the research trends throughout the recent years and across various academic fields. Content analysis were also carried out to capture the research trends, and identify key frameworks and indicators used in logistics environmental sustainability measurement to further develop the measurement index for city logistics.

2.2 Descriptive analysis of literatures

The total 56 articles were reviewed and outlined from the publishing time and sustainability assessment frameworks used. We also extracted and coded the environmental sustainability measurement indicators identified from the literatures.

Figure 2 below shows the number of the related articles from the year 2010 to 2019. In the initial search, we did not limit the time range. We can easily observe that increasing number of research goes to the measurement of logistics environmental sustainability issues in the recent decade. Evangelista *et al.*, (2018) observed that the formal implementation of the Kyoto Protocol in 2015 has a great influence on the increasing research interest on the issues of environmental sustainability in logistics operation. In our observation, the amount of research has enjoyed a rapid growth after 2015 as well. The year 2015 also marked a milestone in global sustainability development - the 2015 United Nations Climate Change Conference (known as COP 21 or CMP 11) was held in Paris, and in the same year United Nations also set the 17 Sustainable Development Goals (SDGs) to tackle human well-being, clean energy, environmental issue etc. These governmental initiatives may have to some degree stimulated the related research interests in freight transport sustainability and especially, how to measure the sustainable performance.

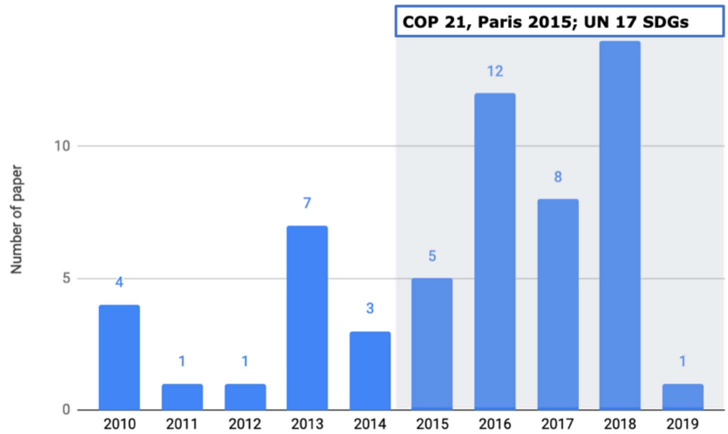

Figure 2: Number of Related Articles (2010-2019)

Note:COP21 is short for the 2015 United Nations Climate Change Conference; SDGs is short for Sustainable Development Goals.

The selected 56 papers have been published in total 35 international journals and conference proceedings. The journal coverage ranges from transportation research to energy, environment, urbanism, and benchmarking studies. A total of 17 (about one-third) out of 56 papers were identified in transportation and logistics-related journals and proceedings. This generally supports that the research of freight transport sustainability has grown as a cross-discipline area of transportation, energy and environment.

3. CONTENT ANALYSIS – MEASUREMENT FRAMEWORKS FOR LOGISTICS ENVIRONMENTAL SUSTAINABILITY

3.1 Logistics environmental sustainability measurement frameworks

Identifying the existing measurement frameworks and metrics for logistics environmental sustainability serves as a theoretical basis for this research to further develop a set of indicators to measure city logistics environmental sustainability. To achieve this goal, we categorized and analysed the sustainability measurement frameworks identified in the literature.

The overall usage of measurement frameworks (shown in Figure 3) indicated that 60.8% of the papers have applied or adopted measurement frameworks to measure logistics sustainability. Among them, the Triple Bottom Line (TBL) and the Global Reporting Initiative (GRI) are the two major frameworks adopted by scholars, about 42.9% of the papers are measuring sustainability from the triple bottom line approach - economic, environmental and social aspects.

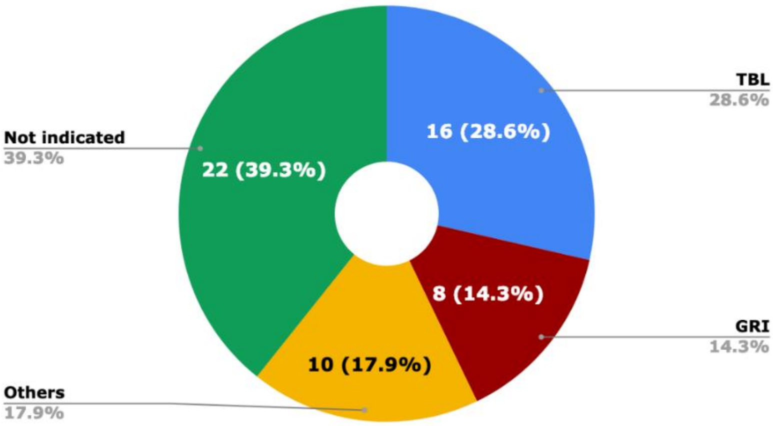

Figure 3: TBL and GRI Frameworks Usage Identified in the Literature

Note: TBL is short for Triple Bottom Line; GRI is short for Global Reporting Initiative

The Triple Bottom Line (TBL) Framework

The triple bottom line (TBL) concept, was developed by Elkington (1998;2004, cited in Carter and Rogers, 2008). TBL is a fundamental framework, which provides three pillars to assess sustainability performance, namely economy (profit), environment (planet), and social (people), and is frequently used in sustainability research (Buldeo Rai *et al.*, 2018).

In our literature review, it is noted that scholars sometimes refined the TBL framework to fit their research context. For instance, Carter and Rogers (2008) expanded the conceptualization of sustainability by adding supporting indicators (i.e. risk management, transparency, strategy and culture) beyond the triple bottom line to assess sustainable supply chain practices. Policy, as an additional dimension of sustainability, also has been added in the study by Buldeo Rai *et al.*, (2018) with the aim to use urban transport (including both passenger and freight) sustainability indicators to support policy making.

The Global Reporting Initiative (GRI) Framework

The Global Reporting Initiative (GRI) framework was firstly launched in 1997 as a joint initiative of the U.S. non-governmental organization - Coalition for Environmentally Responsible Economies (CERES), and the United Nations Environment Programme with the goal to enhance sustainability reporting (Gallego-Álvarez and Vicente-Villardón, 2012). The GRI framework is deeply grounded within the triple bottom line (TBL) principle with economic, environmental and social pillars (Maditati *et al.*, 2018), and it is internationally recognised and considered as the most comprehensive sustainability evaluation framework for an organization to report their economic, environmental, and social performance (Piecyk and Björklund, 2015). The GRI can be considered as an advanced or detailed version of the TBL framework.

In 2006, the GRI has proposed a number of supplement indicators dedicated for the logistics and transport sector to make reporting more relevant and tailored to the sector's specific needs (Piecyk and Björklund, 2015). Beside economic and social indicators, nine categories of environmental indicators - energy, urban air pollution, fleet compositions, noise/vibration, congestion, policy and transport infrastructure development are proposed in GRI Logistics and Transportation Sector Supplement Pilot Version 1.0 (2006).

Other frameworks

Ten studies (17.9% of the sample of this research) use other theories and frameworks to investigate their specific research context. For example Lirn *et al.(*2019) apply institutional and stakeholder theory to identify green assessment criteria for shipping operators in Taiwan; Lam and Dai (2015) use analytical network process (ANP) with quality function deployment (QFD) techniques to evaluate the environmental sustainability of LSPs; Nathanail *et al.* (2017) adopt life cycle analysis for city logistics and proposed a supply/demand logistics sustainability index based on city logistics context.

No frameworks indicated/applied

Among the total 56 sample papers, 22 papers (39.3%) did not indicate the use of any established framework. These studies are only partially related to the measurement of logistics sustainability. They address a wide spectrum of research topics related to logistics environmental sustainability, ranging from port city sustainability (Nathanail *et al.*, 2016; Carlucci *et al.*, 2018), the role of environmental sustainability in LSPs operations (Björklund and Forslund, 2013; Bask *et al.*, 2016), and the systematic literature reviews on logistics environmental sustainability in LSPs (Centobelli *et al.*, 2017; Evangelista *et al.*, 2018).

However, these studies are equally important, because they not only helped us to map out the current research gaps in this area, but also supported our research to develop a well-round set of indicators to capture the environmental sustainability performance of LSPs in city logistics context.

3.2 Framework usage by industry

As the Triple Bottom Line (TBL) and the Global Reporting Initiative (GRI) are identified in 34 papers (i.e. 24 papers using only TBL or GRI, and 10 papers which are using other frameworks in addition to TBL and/or GRI), we further investigate these literatures to identify the research context that those measurement frameworks are applied. The aim of this step is to identify and validate the current research gap, and also to identify key literatures in our research area – city logistics/urban transport to extract environmental indicators.

In the content analysis, we coded and ranked the total of 56 papers by the number of papers that are focused in each industry sectors. Table 2 presents the distribution of major frameworks among the 34 papers which applied established frameworks. It is noted that we only listed the top 7 sectors based on the number of papers identified.

Table 2: Major Frameworks Identified in Different Industries

Industry	No.	TBL	GRI	Other Frameworks
City logistics	14	(Buldeo Rai et al., 2018) (Cheba and Saniuk, 2016) (Morana and Gonzalez-Feliu, 2015) (Garcia et al., 2015) (Tadić et al., 2018)	*Research Gap*	(Chen et al., 2010) (Giret et al., 2018) (Nathanail et al., 2017)
Freight transport	12	(Havenga and Simpson, 2018) (He et al., 2017) (Furtado and Frayret, 2015)	*Research Gap*	(Kim and Han, 2011) (Lai et al., 2013) (Kumar and Anbanandam, 2019) (Lirn et al., 2019)
Logistics service providers (LSPs)	7	(Klumpp, 2017)	(Piecyk and Björklund, 2015)	(Lam and Dai, 2015)
Energy	5	(Ngan et al., 2018) (Manara and Zabaniotou, 2014)		(Brandi et al.,2016) (Dos Santos and Brandi, 2016)
Reverse logistics	4	(Govindan et al., 2016) (Dhib et al., 2013) (Sarkis et al., 2010)	(Nikolaou et al., 2013)	
Retail logistics	4	(Papoutsis et al., 2018) (Matopoulos and Bourlakis, 2010)	(Andersson and Forslund, 2018) (Björklund et al., 2016)	
Manufacturing	4		(Ferreira et al., 2016) (Xu et al., 2016)	

*Note: *TBL is short for Triple Bottom Line; GRI is short for Global Reporting Initiative ** Not all 56 papers listed in the table, full list can be provided upon request.*

City logistics and urban transport rank the highest with 14 papers focused in this area; following by the freight transport sector with 12 papers, in which the research focus covers different transport modes; 7 papers purely focused on the LSP's side, therefore we separated these papers from those which are focused on freight transport.

By categorising the frameworks by sectors, we validated the research gap in city logistics environmental sustainability performance measurement. The analysis clearly shows that city logistics environmental performance measurement is underrepresented in these established frameworks, and that there is a lack of industry-standarised measurement framework for logistics service providers to track their own sustainable performance (Piecyk and Björklund, 2015). In addition, the GRI framework tends to be perceived and adopted widely by LSPs in retail, manufacturing, and reverse logistics sectors, which might be due to the higher customer's demand for sustainability reporting and corporate social responsibility. However, the research in city logistics has yet to adopt the GRI framework.

4. DEVELOPING INDICATORS FOR CITY LOGISTICS ENVIRONMENTAL SUSTAINABILITY

4.1 Indicator selection process

Inspired by Buldeo Rai *et al.* (2018)'s hierarchical design of an indicator framework, this study takes a stepwise approach to narrow down the scope and propose a set of practical indicators based the GRI frameworks. The GRI framework, aligning with the TBL framework, is well accepted in academia and is also coherent with indicator sets proposed by other organizations and institutions, such as OECD (Stindt, 2017).

In this study, firstly, we adopted the GRI Logistics and Transport Sector supplement framework which published in 2006 as a basis to build upon and finetune the indicator sets. Secondly, the systematic literature review has yielded more than 100 relevant indicators on environmental sustainability and assessment criteria for green transport. These indicators were extracted and coded into the GRI framework and its sub-categories. Thirdly, to further narrow down the indicator selection to city logistics context, four key articles (as shown in Figure 4 note) on city logistics environmental sustainability have been used to finetune the indicators.

4.2 Proposing a set of indicators for city logistics

With a focus on the environmental aspect, this research looked into the environmental sub-categories from GRI Logistics & Transport Sector supplement. We categorized the identified environmental indicators from the four key references with a dedicate focus on city logistics into the GRI sub-categories. The sub-category 'Material use' from the GRI framework has not been identified any related indicators in the four city logistics literatures, therefore we have excluded it in the proposed framework.

Using this GRI framework as the evaluation basis, a total of 15 new indicators dedicate for city logistics have been identified from literatures as shown in Figure 4. These new indicators for city logistics embedded with the GRI framework have provided a new update for the GRI logistics and transport sector guideline.

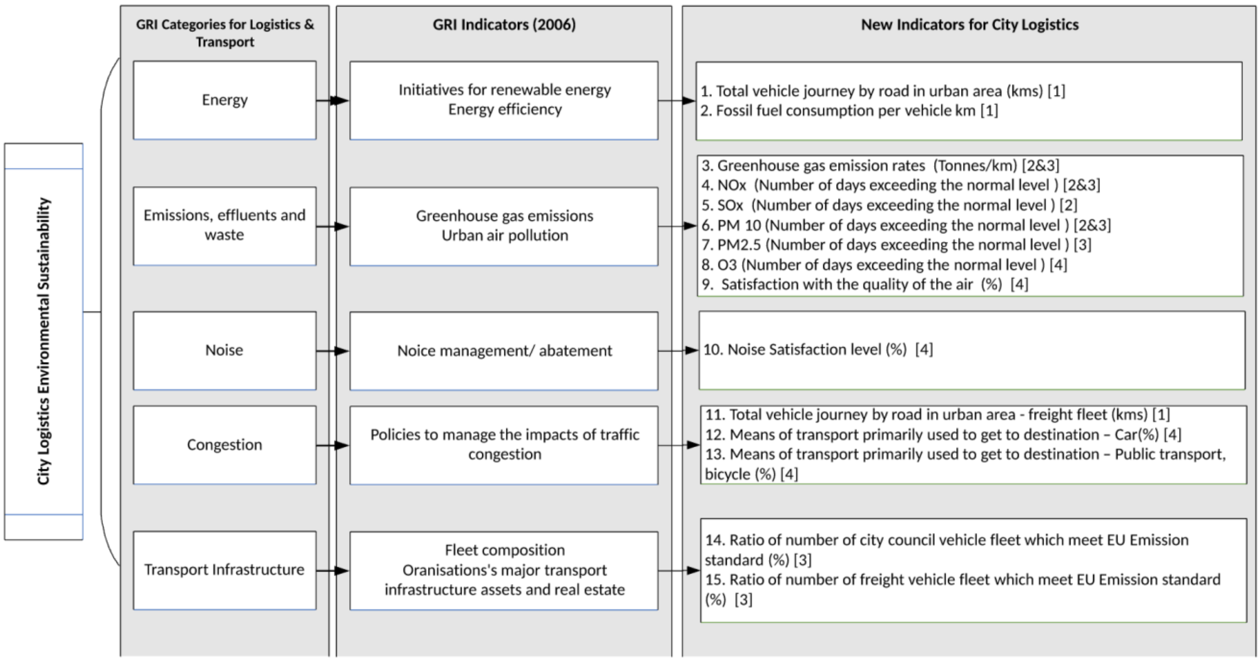

Figure 4: Environmental Sustainability Indicator Framework for City Logistics
Note: Reference list for the new indicators for city logistics are as follows: [1] Browne, M et al., 2012; [2] Morana and Gonzalez-Feliu, 2015; [3] Rai et al., 2018 [4] Cheba and Saniuk, 2016

5. CONCLUSION, IMPLICATIONS AND FUTURE RESEARCH AGENDA

This paper presented the content analysis of 56 papers on logistics environmental sustainability measurement. The existing two major frameworks – Triple Bottom Line (TBL) and Global Reporting Initiative (GRI) applications in logistics sector and the relevant indicators on city logistics environmental sustainability are reviewed. Moreover, linking various sustainable indicators with various city logistics practices, a conceptual framework and a shortlist of practical indicators dedicatedly to measure the city logistics environmental sustainability was proposed and provided a timely update to the GRI framework.

This paper provides a conceptual basis to develop a set of composite indicators for city logistics sustainability measurement. A robust set of indicators need to fulfil certain criteria, namely "dynamic, communicative, comprehensive, feasible, interpretable and relevant" (Buldeo Rai et al., 2018). Future research needs to validate and finetune the selected indicators. Thus, inspired by Huovila *et al.*(2019) 's taxonomy research on smart cities, a comprehensive taxonomy of sustainability for city logistics can be developed to further evaluate all the selected indicators on the basis of "empirically observable" and "measurable characteristics" (Smith, 2002). Furthermore, the sets of indicators can be potentially aggregated into an index or dashboard to measure the logistics performance of the city, therefore to fulfil strategic and practical needs, such as to assist the industry to pinpoint the hurdles for LSPs and monitor their progress on decarbonising in freight transport operations, and support government in policy making for decarbonisation.

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Session 4: Food and Cold Chain Supply Chain Management

OPTIMAL RESOURCE ALLOCATIONS AND PRICES NEGOTIATIONS IN COLD CHAIN CHANNELS

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1.RESEARCH MOTIVATION AND PURPOSE

This study aims to develop a price negotiation mechanism and channel resource allocation methods to assist the ice cream brand marketer determining the appropriate channel management strategies. Ice cream is attributed to the so-called 'cold-chain' product with perishable shelf-life characteristics and usually faces the product shortage issues among channels during the summer peak season. In addition, the interactions among the supplier's yearly promotion plan with various channel partners' promotion schedules during the relatively off-peak periods are also examined in this study.

2.METHODOLOGY RESEARCH

Instead of arbitrarily determining the channel sale prices, a simulation-based model is developed for analysing different price negotiation scenarios, to find out the optimal prices between the brand marketer and various channel partners. Moreover, the existing resource allocation rules are examined, and the potential impacts of these rules are also discussed in this study.

3.RESEARCH STRUCTURE

The remaining sections are listed as follows. Section 4 addresses the previous studies related to this study. Section 5 illustrates the simulation processes of price negotiations and channel resource inventory management.

4.LITERATURE REVIEW

4.1 Perishable Product and Cold-Chain Property

Perishable product means the products which are easily deteriorate quality due to time, environment or temperature. For example, meat and meat processed products, diary product, fresh vegetables and seafood, flower and pharmaceuticals.

Writer get the detail information of published of Industrial Technology Research Institute of Taiwan of "Cold-Chain Quality Collaborative Management Model and International Trend Response" report, Cold-Chain means holding and transportation perishable goods in appropriate temperature range to reduce goods deteriorate. Cold-Chain technology need to implement "Information Integration" and "Strengthening Partnership", it means the regulations and standards of Cold-Chain are strict than general supply chain. Each node has to highly control, that is the information flow of supply chain need to timely and transparent.

4.2 Bargaining Power Between Supplier and Channel Partners

Bargaining Power nor only talk about purchasing and selling price but also the contract conditions power. Recent years, channel films are stronger and stronger, just like Walmart, those Bigger Physical Retailers pressed the profit of upstream supplier, especially small supplier.

Common factors influenced the bargaining power in this research field could classify into quantitative factors and qualitative factors. Quantitative factors: proportion of profit, order volume and market shares. Qualitative factors: whether control key resource or skill?

Whether has other options? In addition, in the one to multiple or multiple to one condition, the sequence of negotiation also influence bargaining power.

4.3Resource Allocation

Resource general means final product or unfinished components, in logistics field, resource usually represent the car, staff or DC assembly line. This study we only focus on the allocation of final product.
There are two cases of resource allocation, one is supplier consider retailer's order quantity and investing cost to make whole manufacturing product capacity plan then allocate. The other is that supplier has a fixed resource quantity and then allocate the limited resource to every retailers or channels. Two cases all indicate that the precondition resource allocation is limited resources.
Two aspects status describe the reason why resource is limited, according to Zhixin Lin(2012). From demand side, seasons, festivals and promotions makes customer demand become unpredictable and floating. From supply side, suppliers sometimes will strategically limit capacity to stimulate the competition among channel firms. Supplier not usual to adjust product price to control demand floating, Zhixin Lin(2012) explained that the change of price easily causes worse competition between suppliers (especially similar firms).
Simulation is often used to assist in uncertain environments. Simulation be applied in rich of field, such as commercial, medical and public construction.
Last year, successively research simulation of multiple channel resource allocation such as Benyong Hu et al. (2018) and Tzu-Yin Lin (2018).

5.RESEARCH MODEL- SIMULATION SYSTEM DESIGN

5.1 Simulation of Negotiation Model Background

There are 5 degrees of channel bargaining power to supplier in simulation of annual negotiation are respectively powerful, slightly powerful, balance, slightly weak, weak. These degrees would present by different bargaining rules in simulation system, as shown in Figure 1.

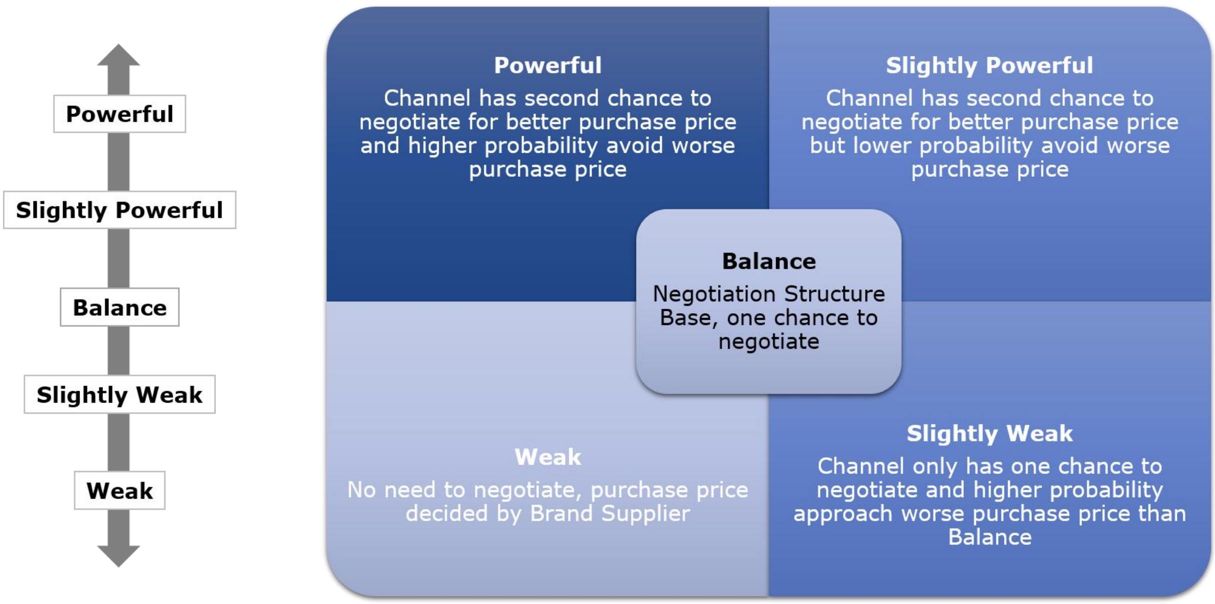

Figure 9 Degrees of channel bargaining power to the supplier

After negotiation done, channel plus the profit scale (channel based on their own cost structure to decide) on purchase price then get a price that sell to final customer, the following called actual selling price. In other side, supplier will define a price in the market which is the highest price (absolute bigger or equal to actual selling price) and the highest price that final customer can accept, the following called nominal price.

5.2 Simulation of Negotiation Model Structure

We build a simulation of negotiation perspective of suppliers, and design a general practice flow chart for reality industries to refer, as shown in Figure 2.

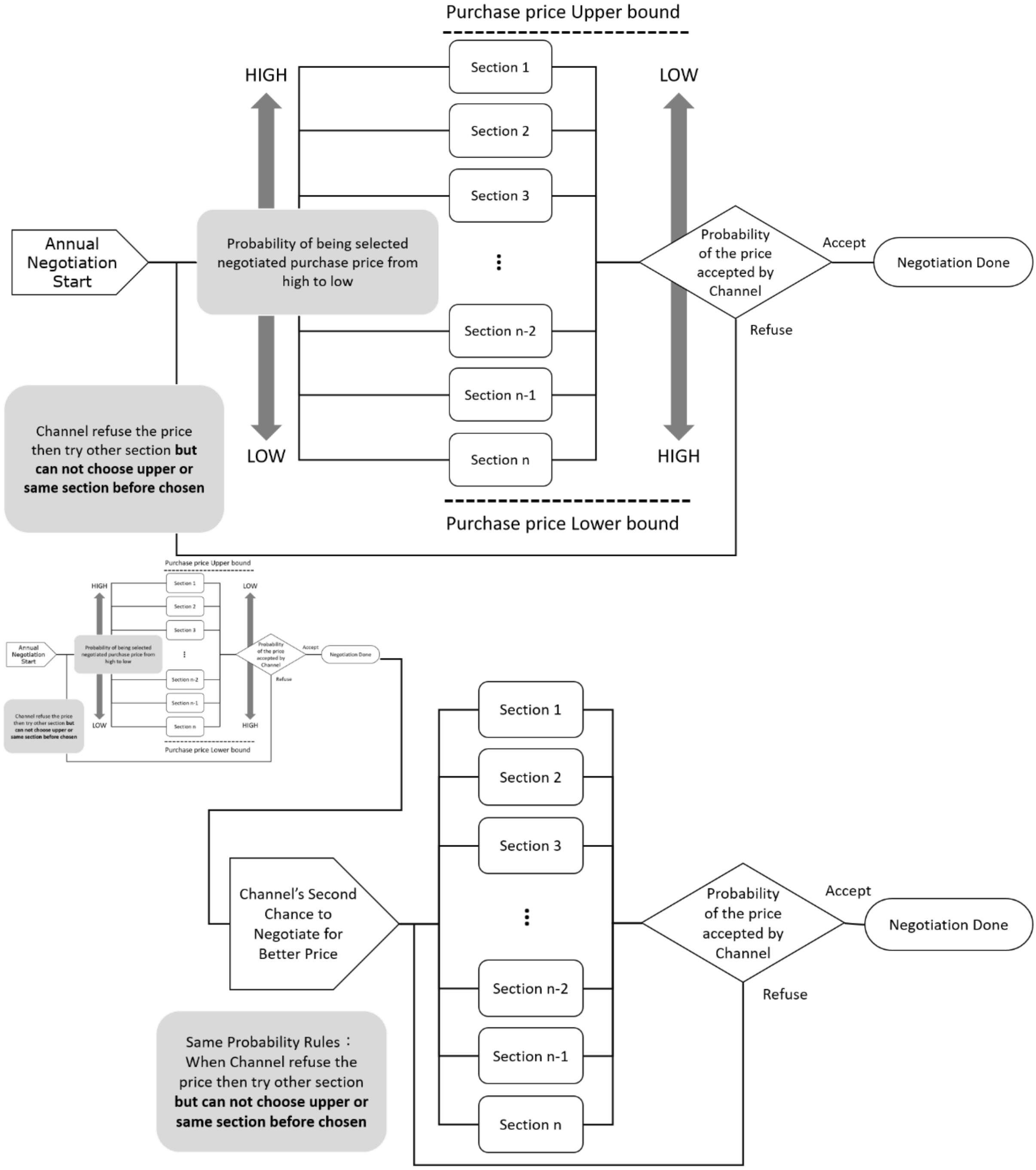

Figure 2 Detailed simulation processes

5.3 Simulation of Negotiation Model Assumption and Parameters Setting
Model Assumption:

1. Supplier won't negotiate with multiple channel firms at the same time.
2. Supplier and channel have no choice to quit the negotiation game.
3. The upper and lower bound of purchase price is decided by supplier, channel could only bargain a satisfied price between upper and lower price.

Model Parameters:

Set	Description
S	The set of purchase price section, $s \in S$
Parameter	**Description**
n	Total section quantity
P_s	The probability of chose of section s
S_s	The probability of success of section s

We try to test the simulation of negotiation, then input intuitive and reasonable reality parameter value. The system generates 10,000 iterations then records these result to find out each sections output probability.
About the parameter values, reality industries could fine adjust the values by their working experience or company data in future practice. As Shown in Table 1:

Table 1 Parameter Settings

Setting	Value
S	$s = \{1,2,3 \ldots ,10\}$
n	$n = 10$
P_s	$P_1 = 19\%$, $P_2 = 17\%$, $P_3 = 15\%$, $P_4 = 13\%$, $P_5 = 11\%$, $P_6 = 9\%$, $P_7 = 7\%$, $P_8 = 5\%$, $P_9 = 3\%$, $P_{10} = 1\%$
S_s	$S_1 = 10\%$, $S_2 = 20\%$, $S_3 = 30\%$, $S_4 = 40\%$, $S_5 = 50\%$, $S_6 = 60\%$, $S_7 = 70\%$, $S_8 = 80\%$, $S_9 = 90\%$, $S_{10} = 100\%$

Table 2 Simulation results under different channel bargaining power scenarios

Section/ Channel bargaining power	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Powerful	0.11 %	0.90 %	2.17 %	5.01 %	8.11 %	12.44 %	16.97 %	21.03 %	20.68 %	12.59 %
Slightly Powerful	0.20 %	1.11 %	2.58 %	5.60 %	9.21 %	14.08 %	18.78 %	21.56 %	19.82 %	7.05 %
Balance	1.69 %	4.19 %	6.10 %	9.89 %	11.80 %	13.91 %	15.60 %	16.07 %	13.81 %	6.95 %
Slightly Weak	2.32 %	4.79 %	7.56 %	11.19 %	13.65 %	15.30 %	16.30 %	14.09 %	10.82 %	3.99 %
Weak	-	-	-	-	-	-	-	-	-	-

Following the result that we found powerful channel high probability falls in 8-9 section; slightly powerful channel also falls in 8-9 section but the section 8 is a little higher than powerful channel; in condition of balance falls in 7-8 section; slightly weak channel will fall in 6-7 section; needless to say, weak channel will not participate negotiate for purchase price.

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A SYSTEMATIC REVIEW OF FOOD LOSS AND WASTE FOR THE CIRCULAR ECONOMY

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Purpose of this paper:

Food waste is recognised as the top priority area in the context of transitions towards circular economy under an EU Action Plan for the Circular Economy (EC, 2015) and in the achievement of the Sustainable Development Goal (SDG) 12.3 set by the United Nations (UN, 2015). Circular Economy (CE) aims to replace the traditional "take-make-dispose" linear pattern of production and consumption (Ness, 2008) to decouple resource use from economic growth and contribute to more sustainable development in the period of resource depletion (EC, 2015; Ghisellini, Cialani and Ulgiati, 2016; Geissdoerfer *et al.*, 2017). It offers a new business model to drive sustainable development and a harmonious society (Naustdalslid, 2014). While there are many papers looking at wastes in the food supply chain, the research on recirculating food wastes under the CE landscape is relatively new. The purpose of this study is to present a structural analysis of extant literature in a systematic manner on the topic of FW management under CE context.

Design/methodology/approach:

A systematic literature review of 76 papers collected from two most dominant databases, Scopus and Web of Science, was carried out using structural dimensions and analytical category approach to provide content analysis and highlight the main research themes relevant to the food supply chain under the CE perspective.

Findings:

The article provides a framework for classification of the literature review using structural dimensions and analytical category. The earliest article was recorded in 2009 but it is not until 2014, CE gained popularity in FW studies; and Journal of Cleaner Production remains its leadership in this field. Despite no author in the record having more than five publications, the EU and China are two geographical focuses of the studies, which are aligned with policy implementation. Most studies employed case study and quantitative approach using life-cycle assessment and material flow analysis. Key themes emerged from the list of keywords including environmental assessment, anaerobic digestion for nutrient recycling, and new business model with refinery and industrial symbiosis. Food waste at retail and consumption stage, particularly urban solid waste, attracted the largest attention in the literature, followed by AGRO residues. In term of waste management options, nutrient recycling and energy recovery via anaerobic digestion are dominant. There is a limited attention on food prevention or food valorisation via cascading bio-refinery to generate high value product. In term of three-pillar sustainability, interests are primarily paid on environmental and economic pillars. Social indicators or benefits are rarely mentioned. Although CE requires a system thinking approach, studies on micro level at consumers and firms' levels towards CE implementation are insufficient. Finally, key aspects of FW as per guidance in EU Action Plan for the CE including FW quantification, FW re-distribution and consumers' label understanding are rarely discussed in literature.

Value:

A first holistic review of the circular food economy in food waste prevention and management

1. Introduction

Although there are different approaches towards the definitions of food waste (FW) (Corrado and Sala, 2018), FW generally refers to foods that "are removed from (lost to or diverted from) the food supply chain (FSC)"(Östergren *et al.*, 2014), which covers both food loss and food waste, as well as inedible fraction and edible fraction of foods. It is estimated that about a third of the food produced globally is wasted or lost along the FSC (~1.3 billion tons per year) (Gustavsson *et al.*, 2011), causing substantial repercussions in economic, social, nutritional and environmental dimensions (FAO, 2013; Grizzetti *et al.*, 2013; Halloran *et al.*, 2014; Papargyropoulou *et al.*, 2014). In the Europe, in 2012 alone, around 88 million tons of food with an associated cost of around 143 billion euros were wasted by 28 Member States (FUSIONS, 2016, p. 5)[9]. It is amount to 173kgs of food waste (FW) per person or 20% of total food produced in Europe (FUSIONS, 2016, p. 5). If no additional prevention policy or activities are taken, the number is expected to rise to about 126 million tons by 2020, which is enough to feed all hungry people in the world two times (Monier *et al.*, 2010). The trend is opposite with an ambitious goal set by the United Nations (UN) on Sustainable Development Goal (SDG) 12.3 to "*by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses*"(UN General Assembly, 2015, p. 27).

In order to achieve SDG 12.3 by the UN, an emerging concept of Circular Economy (CE) has been adopted to by the European Commission (EC) as a tool to enhance the sustainability of the food system. CE aims at replacing conventional take-make-dispose linear path of production and consumption by proposing a circular system where value of products, materials and resources are maintained as long as possible (Ellen MacArthur Foundation, 2013; Geissdoerfer *et al.*, 2017). FW prevention and management are identified as an integral part and top priority task of the European Commission's new CE Package to facilitate Europe's transition towards a CE (EC, 2015; Vilariño, Franco and Quarrington, 2017). CE in the food system emphasises on lowering the amount of wastes generated along the FSC, re-use of food surplus, utilization of FW and its by-products, recycling of nutrients, and changes eating diets toward a diverse and efficient pattern (Jurgilevich *et al.*, 2016). CE is believed to enhance global competitiveness, foster sustainable growth and create new job opportunities (EC, 2015). It is estimated that by from keeping the organic waste out of landfill under CE landscape, the UK could save an annual landfill cost of 1.1 billion pounds, and generate up to 2GWh worth of electricity as well as produce high value-added products e.g. fertilisers/composts for soil or special chemicals. The combined effects ultimately leads to a reduction of 7.4 million tonnes of methane or GHG emissions (Ellen MacArthur Foundation, 2013).

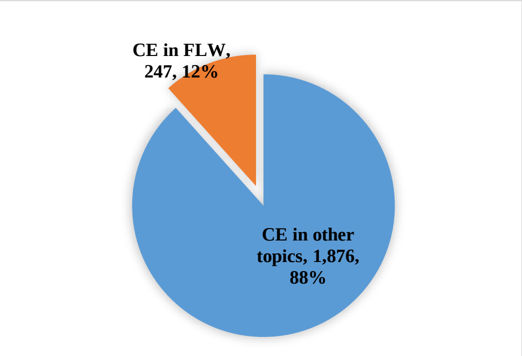


Figure 28: Proportion of circular economy in food loss wastes and in other topics

Despite benefits of adopting CE in the FW management, literatures showed limited interests in this topic compared to other topics in CE (such as waste management/recycling in manufacturing industry or eco-design). Figure 1 provides a quick look at the number of literatures found in the topic of generic CE and of CE in waste management in FSC. The finding suggests there is an ample room for the future research in this area.

This study has a main goal to provide a comprehensive review of research topics and

[9] *53% from family, 12% from food service, 5% from wholesale and retailers, 19% from processing and 11% from production*

approaches linking between the concept of CE and of FLW management. It is to provide a better picture of how literature approaches FLW under CE landscape, highlight trends and gaps, and act as a baseline for the identification of research trends on the topic.

2. Research objectives, questions and methodology

Several studies conducted literature review on CE in food waste management (table 1). Majority of these papers focused on FW recycling or recovery options to generate energy, heats or high value products from FWs (Mirabella, Castellani and Sala, 2014; Maina, Kachrimanidou and Koutinas, 2017; Nizami *et al.*, 2017). Some of them reviewed publications on recycling options for a particular type of FW, e.g. olive oil in (Berbel and Posadillo, 2018) or spent ground coffee (SGC) in (Imbert, 2017). Other reviews focused on comparing different results from various life cycle assessment (LCA) models for FW treatment options (Ingrao *et al.*, 2018) or reviewing several quantification approaches to measure waste stream (Corrado and Sala, 2018). However, waste recycling options or environmental impact assessment of these options are just parts of CE thinking. Scope of CE is much broader than that. None of these papers has adopted a holistic approach from circular economy thinking in FW management. This paper aims at providing a comprehensive review of CE in the research of food loss and wastes to identify the research gaps and underline topics for future research.

Table 10: Summarise of extant literature review papers on FLW under CE

No	References	Main focus
1	Mirabella et al., (2014)	Options to valorise food processing residues (111 papers)
2	(Capson-Tojo *et al.*, 2016)	Comparison of various technologies for anaerobic digestion (AD) plants
3	(Imbert, 2017)	Options to valorise SGC from CE viewpoint.
4	(Vilariño, Franco and Quarrington, 2017)	FLW as an integral part of CE from technological, social and environmental viewpoints
5	Nizami *et al.*, (Nizami *et al.*, 2017)	Options for valorising wastes in developing countries (including food wastes).
6	Maina *et al.,* (2017)	Options to transform wastes into high value-added products.
7	(Ingrao *et al.*, 2018)	Different life-cycle-assessment (LCA) results for AD technologies.
8	(Corrado and Sala, 2018)	Food waste accounting methodologies and results in the EU.
9	(Berbel and Posadillo, 2018)	Options for valorising olive oil by-products
10	(Peng and Pivato, 2019)	Options for digestate management under the CE landscape.

Based on research objectives, research questions are formulated as follow: what is the distribution pattern of the literature over time, journals, authors and geographic focus? Which methods have been most employed? How many dominant key word clusters emerge to identify research themes? What types of food wastes are widely addressed? Which reduce, reuse, recycle and recovery is most addressed? What sustainable pillars are most explored in academia? Which level of analysis in system thinking is most investigated? What are the current and future research themes?

3. Research methods

Conceptually, a literature review is defined as "*a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded documents*"(Fink, 2019, p. 6). It generally serves two purposes, first is to identify patterns, themes and issues of extant literatures; and second is to identify the conceptual content of the field, and possibly, contribute to theory development (Meredith, 1993).

Methodologically, the literature review is considered as a content analysis employing a mixed approach integrating both qualitative and quantitative method to explore a specific topic (Brewerton and Millward, 2001). Several methodological frameworks for systematic and reliable literature reviews have been proposed in literature. In this paper, we employed a four-step framework which has been adopted from the studies of Denyer and Tranfield (2009), Mayrring (2002) and Tranfield*, et al.,* (2003) (figure 2).

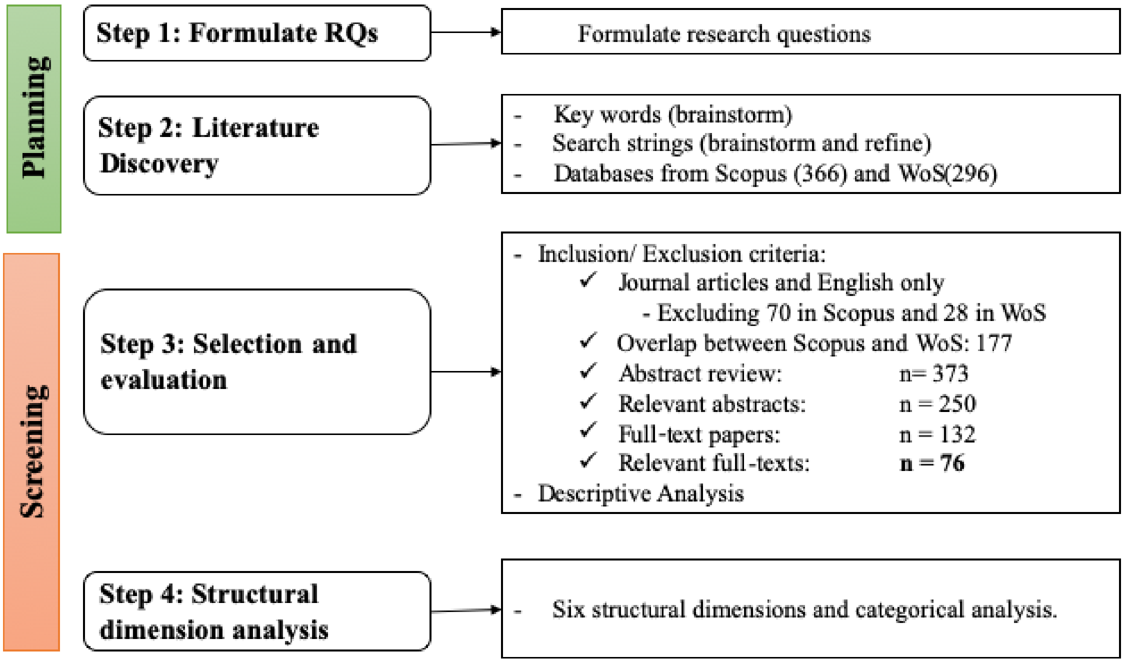


Figure 29: Four step framework

The formulation of research questions is considered as the first and critical step to scope the research as suggested by Denyer and Tranfield (2009). A list of research questions is provided in the section 2. The second step is literature discovery using keywords, search string and database search (section 4). The next step is paper selection and evaluation to select and analyse the "relevant papers" (hereinafter referred as review sample) for further content analysis using several inclusions and exclusion criteria (section 5). In this step, distribution and evolution of papers over time, sources, authors and geographic focus are explored. The final step is to evaluate the review sample using structural dimension analysis as proposed by Mayrring (2002) and Tranfield*, et al.,* (2003). Structural dimension analysis helps to categorise the review sample and establish the main research streams. The data were broken down and codified in an encrypted format with the support of NVIVO. Content was then analysed and summarised to enable analysis with respect to research questions. The findings are presented in the section 6.

4. Literature discovery

Based on the research objectives and research questions, the following key words are brainstormed and selected. For the topic of food loss and waste, keywords include "food loss", "food waste", "waste" OR "loss" in "food", "agri" OR "agro" OR "agriculture". For the topic of circular economy, possible keywords include "circular economy", "circular bioeconomy", "circularity", "industrial symbiosis". The selection of these keywords is to avoid missing of relevant papers or too wide coverage of irrelevant papers in the topic. The keywords are then combined to create a series of strings to be put on the databases. Given the focus of the study is on FLW management in CE landscape, the strings are designed to extract relevant studies for the overlap between food waste and circular economy. These search strings were brainstormed and iteratively refined until obtaining a sufficient list of terms.

The next step is to apply search strings in Web of Science (WoS) and Scopus databases, which are the most extensive databases for the academic literature searches. From 1960s to 2004, WoS, also known as the Institute for Scientific Information (ISI)[10], was used as the only tool to locate and conduct citation analysis (Kulkarni *et al.*, 2009). The release of Scopus in 2004 by Elsevier Science offered an alternative and quickly become a rival to challenge WoS. There is an intense competition between two databases (Aghaei Chadegani *et al.*, 2013). Compared to WoS, Scopus offered a wider journal range and 20% more coverage, but limited to recently published articles (Falagas *et al.*, 2008). Main disadvantage of Scopus is that it is not as clean as WoS It is therefore suggested that the use of both Scopus and WoS offer a more comprehensive picture for literature search (Meho and Yang, 2007).

Table 11: Results from applying different search strings on databases

Search string	Scopus [11]	WoS [12]
("food waste" OR "food loss") AND "circular economy"	116	97
(loss OR waste) AND food AND "circular economy"	231	214
(loss OR waste) AND (food OR agri OR agro OR agriculture) AND "circular economy"	310	253
(loss OR waste) AND (food OR agri OR agro OR agriculture) AND ("circular economy" OR "circularity" OR "circular bioeconomy" OR "industrial symbiosis")	366	295

Table 2 illustrated the process of refining and applying search strings on the topic of research in WoS and Scopus. The last search string allowed us to locate a sufficient number of studies and avoid missing relevant papers.

5. Selection and evaluation

5.1. Selection of the articles

This step is to select only the relevant papers for further analysis from search results in two databases in section 4. It started with applying inclusion and exclusion criteria to remove papers which does not satisfy following criteria.

(i) Including only papers written in the English language and published by journals articles
   - Excluding 70 papers in Scopus and 28 papers in WoS

(ii) Overlap between WoS and Scopus is 175 (figure 3)
   - ⇨ The result indicated Scopus has wider coverage compared to WoS in this topic; 61.4% of Scopus records were covered by WoS whereas 66.5% of WoS records were covered by Scopus.

(iii) Screening abstract for relevant papers: excluding 123
   - ⇨ Relevant Abstract screening: 250

(iv) Only papers with full-texts can be able to retrieved: 105 papers

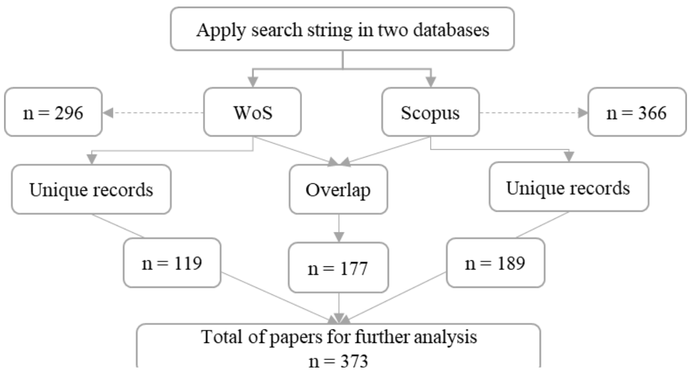


Figure 30: Overlap between WoS and Scopus

[10] ISI is now a part of Thomson Reuters
[11] Search with title, abstract, keywords
[12] Topic search

(v) Only papers with description of circular economy in the content: 76 papers

The final sample size for further analysis is **76**, which had been published in the period from 2009 until May-2019.

5.2. Evaluation of the articles

The distributions of papers over time, sources, authors, and geographical dispersions are reviewed in this section. Figure 4 illustrated a rapid growth of CE topic over the last couple of years. The first were recorded in Zhao *et al.,* (2009) who investigated a circular production system for paddy rice using agricultural residues like straw. It is however not until 2014, CE gains momentum in the literature research. In fact, over 90% of the publications were published over the last four years (2016 until mid-2019).

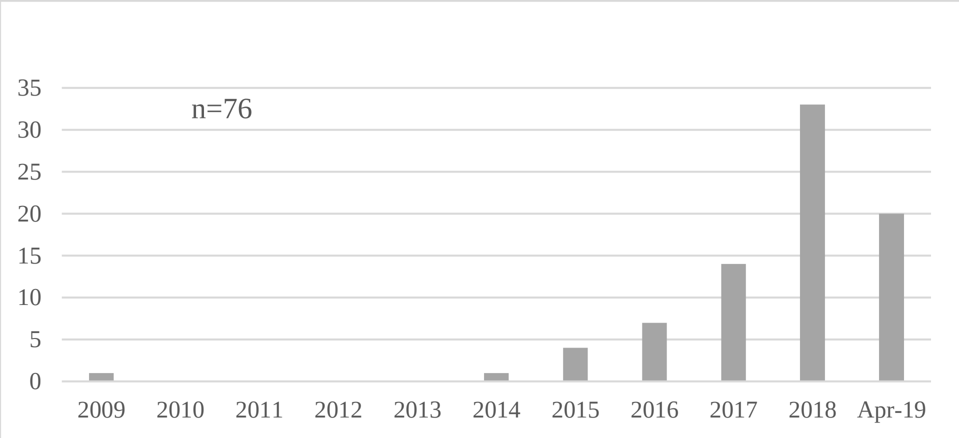
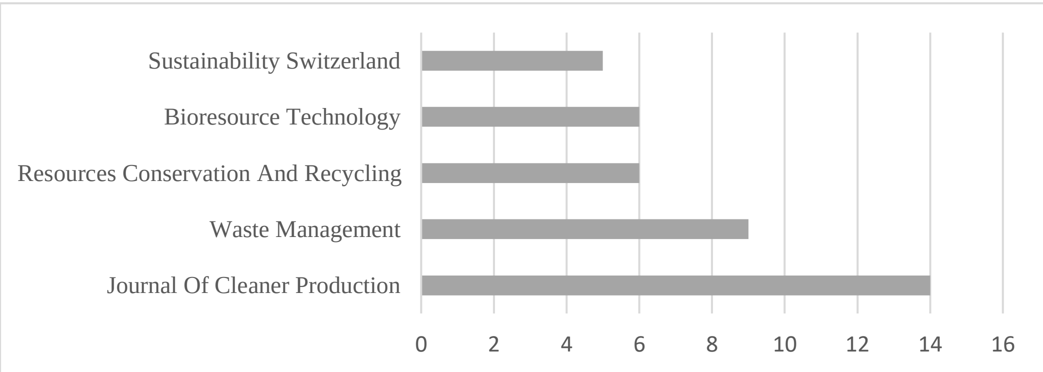


Figure 31: Distribution of publications over time (2014 to May 2019)

Figure 5 presented top five journals with the highest number of publications. The top rank is Journal of Cleaner Production, followed by Waste Management, Conservation and Recycling, Bioresource Technology and Sustainability. The top 5 journals contributed to 50% of the total publications. Journal of Cleaner Production remains leadership overtime with increasing publications from 2014. Waste Management and Conversation and Recycling have emerged as the popular journals since 2017. It is noted that the articles are mainly in the journals on environmental and sustainable issue.



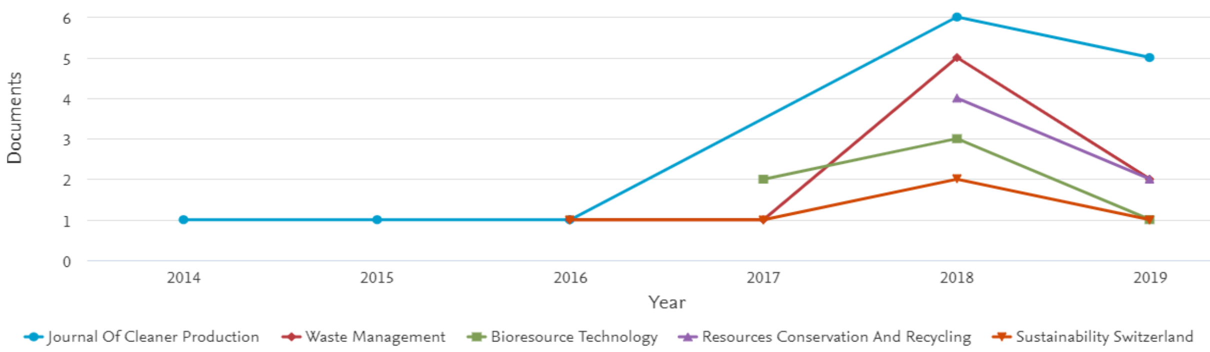


Figure 32: Top five journals with highest number of publications (more than 6 articles)

Regarding to the author analysis, 72% of authors in the sample has no more than one publication and no authors having more than 5 publications (figure 6). It indicates no lead authors in research topic. Interestingly, co-authorship is high among authors with multiple publications. For instance, Aldaco, R; Laso, J; Irabien, A; Fullana, P; Margallo, M shared four publications in the case of anchovy supply chain. Along with the maturity of CE topic in the future, more authors with multiple publications are expected.

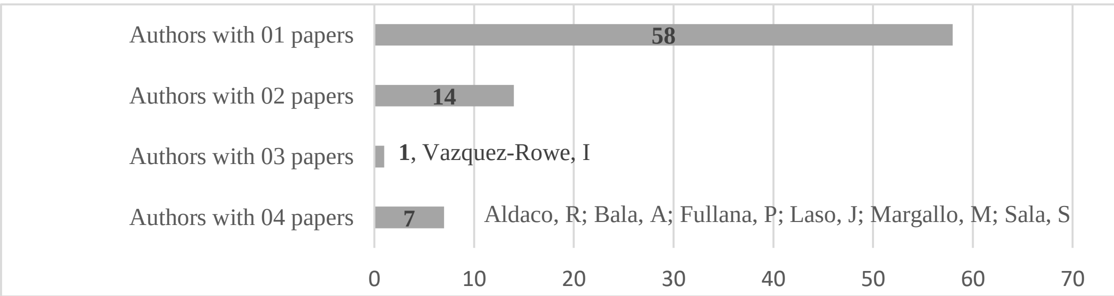


Figure 33: Number of authors with one, two, three, four articles

Figure 7 showed the country affiliated with high number of publications. The EU and China emerged as the top geographical focus where CE has been actively fostered as guiding disciplines, despite the differences in the adaptation approaches (Ghisellini, Cialani and Ulgiati, 2016). Chinese government adopted a top-down approach to incorporate CE in its legislation via Chinese CE Promotion Law enforced in 2009 (The Standing Committee of the National People's Congress China, 2008). On the other hand, the EU recently adopted a bottom-up approach via a comprehensive CE action plan package at supranational level (EC, 2015). The result also indicated that academia aims to provide policy-makers tools and guidelines for the implementations of CE in the food system. Interestingly, the number of China-linked documents is less than those of European countries. It is opposite with findings in the study of Merli *et al.,* (2018) on the topic of generic circular economy in which China is a dominant country. It highlighted the issues of food loss and wastes attracted more attention in developed countries compared to developing countries.

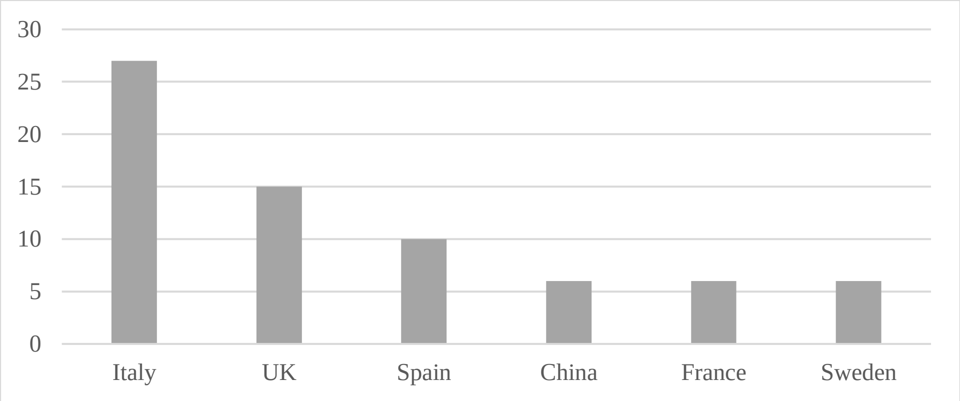


Figure 34: Top countries with the high number of affiliated publications

6. Structural analysis

To analyse the topic with respect to research questions, six structural dimensions were selected to analyse the literature on FLW management under circular economy perspective (table 3). The first three dimensions are for general analysis while the last three are those belonging to CE adopted from the study of Kirchhherr *et al.,* (2017). In their study, three dimensions of CE were identified from literature review include: waste management options, sustainable aims, and system thinking.

Table 12: Structural dimension and analytical categories

Structural dimensions	Analytical Categories
4.1. Research methods	- Modelling/ quantitative - Experimental/ case studies - Theoretical/conceptual model - Survey/questionnaires/ interviews - Literature reviews.
4.2. Key words	- Cluster analysis
4.3. Types of food wastes	- Agricultural and processing residues - FW at consumption stage - Food-related package wastes
4.4. Waste management options	- Prevention - Recycle and recovery
4.5. Sustainability	- Economic - Environmental - Social
4.6. System thinking	- Macro level - Meso level - Micro level

6.1. Research methods

Five research methodologies were differentiated: (1) quantitative methods; (2) experimental/ case studies; (3) theoretical/conceptual models (4) survey/questionnaires/ interviews; and (5) literature reviews. Figure 8 shows the allocations of the papers over five research methodologies. Nearly 35% of the researches use modelling and quantitative tools for decision making. Models and tools are necessary to assist decision-makers (at both company and government levels) in food supply chain in the transition towards CE. From the analysis, LCA and related tools are widely used and discussed to assess sustainability performance of different waste treatment options. It is a bottom up approach. Material flow analysis (MFA) or input and output analysis is another approach (top-down) to quantify the flow of wastes. MFA is adopted in the several studies (e.g. (Pagotto and Halog, 2016; Sadhukhan *et al.*, 2018; Tanzer *et al.*, 2018; Zeller *et al.*, 2019)). Some other qualitative tools or models include cost-benefit analysis, economic analysis or statistical analysis.

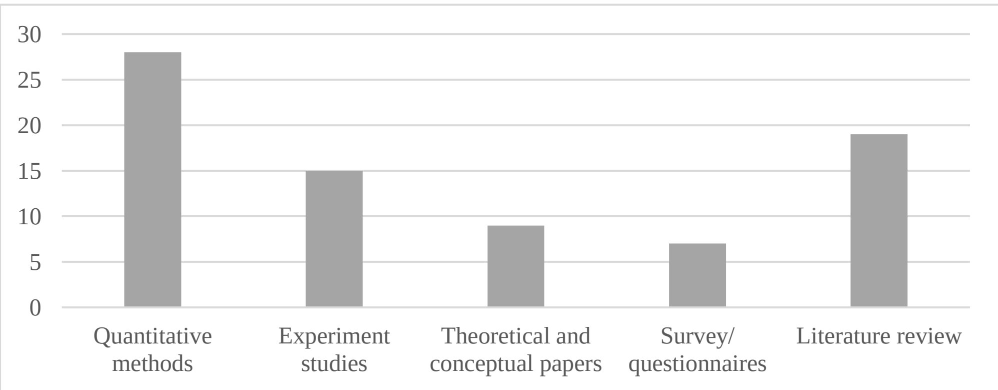


Figure 35: Distribution of research types

Literature review is the second popular research method. Review articles were presented in the table 1 in section 2. Twenty percentage of review papers is concerned with experiment studies, such as experiments to demonstrate technologies or to monitor/control customers' behaviours. Twelve percent of the studies focus on constructing theoretical or conceptual framework. The remaining (nine percent) used survey or questionnaire approach to explore firm's perception (L. Chen *et al.*, 2017) or consumer's behaviours (Borrello *et al.*, 2017). It can be said that survey is an underexplored method, which should be further developed to understand perception of firms and consumers, and of identifying enabling measures to disseminate CE practices.

6.2. Keyword co-occurrence analysis

Using VOS Viewer tool to create a map of co-occurrence network of keywords across the review sample. These keywords are then grouped into three clusters with three different colours in the map (figure 9). The first cluster is about applying environmental impact assessment (EIA) and Life cycle assessment (LCA) tools to assist decision making process to select the most environmental sound options. The second cluster is all about nutrient recycling from organic municipal wastes or agricultural residues via Anaerobic Digestion (AD) to generate biogas and fertilisers (compost). The third cluster is about new business models, bio-refinery, industrial symbiosis, economic and environmental impact assessment.

Cluster 1 (Red) Environmental assessment	**Cluster 2 (green) Nutrient recycling via AD**	**Cluster 3 (blue) Biorefinery**
EIA	Circular economy	Bio-refinery
LCA	AD	Economic analysis
Greenhouse effect	Recycling	EIA
Incineration/ landfill/ energy recovery	Nutrients	Industrial symbiosis
	Compost	Sustainability
Organic wastes Agricultural wastes	Biogas	
	biomass	
	Fertilisers	

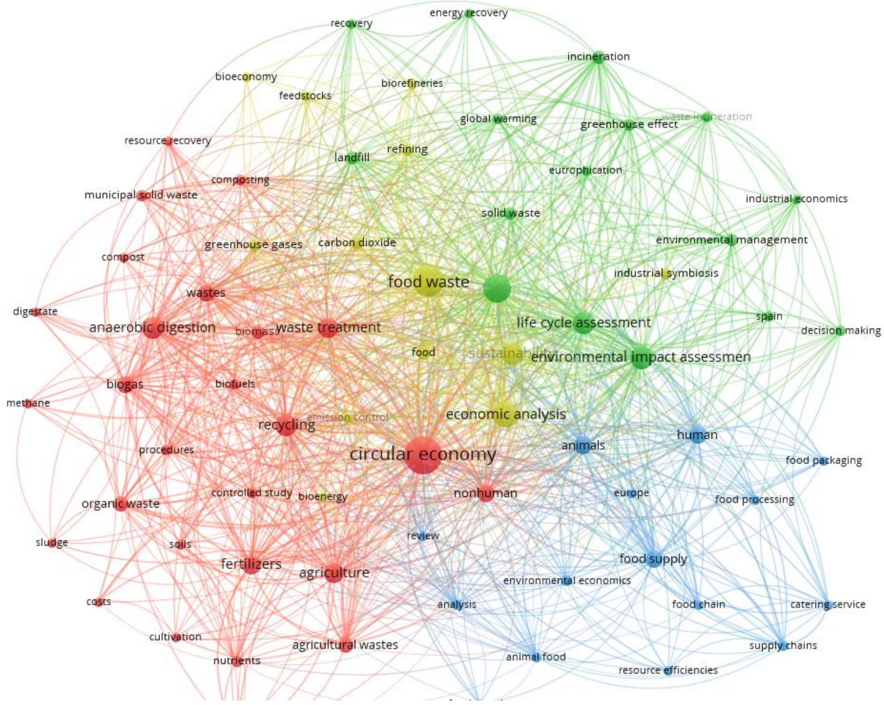


Figure 36: Keyword co-occurrence analysis

Co-occurrence and clustering of key words highlighted the main interests of literature sample on using LCA tool for environmental assessment, anaerobic digestion technology to close nutrient loops of food supply chain, and bio-refinery as well as industrial symbiosis.

6.3. Type of food wastes

Under CE, FW is recognised as **"resource"** to be diverted from landfilling (Maina, Kachrimanidou and Koutinas, 2017; Ingrao *et al.*, 2018)**.** There are three main types that have been investigated in the literature, (i) FW at retail/consumption stage (ii) residues from agricultural and processing industry (iii) food-related package wastes.

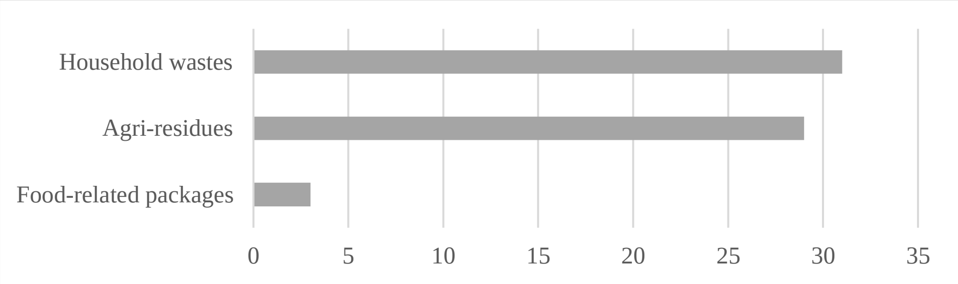


Figure 37: Number of articles on different types of food wastes

Figure 10 and table 4 show that FW from retail/consumption stage in the literature attracted the largest attention in the literature. This waste stream can be broken down into three types, urban food waste (also called as OFMSW[13]) (e.g. Al-Addous *et al.,* 2019); household food waste (e.g. Slorach *et al.*, 2019); and organic waste from retail/catering services (e.g. Yeo *et al.,* 2019). This type of waste is heterogeneous in nature which cause difficulty to quantify the amount for each type of food, composition of major macromolecules and minor constituents (Rathore *et al.*, 2016) and encounters the issue associated with logistical challenges from collection and transportation process (Kokossis and Koutinas, 2012)

The second popular type of waste in literature is agricultural and processing residue. This waste stream offers a huge pool of untapped biomass resources used as feedstock for bio-economy (Santagata *et al.,* 2017; Gontard *et al.,* 2018) and is typically informed as causing much lower overall environmental impacts than their land-dependant biomass (Tonini, Hamelin and Astrup, 2016). Compared to the first type, this type is more homogeneous in nature; but it is characterised by seasonality, regional and complexity factors (Gontard *et al.*, 2018).

Unlike the first two types of wastes, only three papers found investigated aspects of food-related package wastes (table 4). While de la Caba *et al.,* (2019) explored novel package materials made from seafood waste, Kaur *et al.,* (2018) and Gueeke *et al.,* (2018) discussed chemical safety of food packaging with the focus on degradable plastics.

Table 13: List of articles on different types of food wastes

Types of FW	References
Agricultural wastes and residues	Wastes from fruits and vegetables, dairy, meat and other miscellaneous (Mirabella *et al.,* 2014); olive production and mill wastes (Zabaniotou *et al.,* 2015; Berbel and Posadillo, 2018); pig slurry and organic residues (Vaneeckhaute *et al.,* 2018); vegetable residues (Stoknes *et al.,* 2016); citrus pulp (Marinelli *et al.*, 2017); slaughterhouse residues (Santagata *et al.,* 2017); pork farm waste (Noya *et al.,* 2017); peels of tomato, potato, orange, and wastes of olive mill (Cristóbal, Caldeira, *et al.*, 2018); Crop straw (Liu *et al.*, 2018); generic agro-wastes (Nizami *et al.,* 2017; Gontard *et al.,* 2018); bread wastes (Adessi *et al.*, 2018); mushroom wastes (Grimm and Wösten, 2018; M. Padolecchia *et al.*, 2018); wastes in anchovy canning industry (Laso *et al.,* 2016;

[13] organic fraction Municipal solid waste (OFMSW)

	Laso and Margallo *et al.,* 2018; Laso and Herrero *et al.,* 2018); wastes along pasta supply chain (Principato *et al.*, 2019); grape pomace powders (Mainente *et al.*, 2019); straw, manure, residues from pruning plantation (Hamelin *et al.,* 2019); animal manure and cereal brans (Antoniou *et al.,* 2019).
Wastes at retail/consumption stage	**Urban organic wastes:** Tanzer *et al.,* (2018); Pérez-Camacho *et al.,* (2018); Peng and Pivato, (2019); Paul *et al.,* (2018); Mu'azu et al., (2019); Masullo (2017); Loizia *et al.,* (2018); Ingrao *et al.,* (2018); Hemelin *et al.,* (2019); Fuldauer *et al.,* (2018); De Corato *et al.,* (2018); Beggio *et al.,* (2019); Al-Addous *et al.,* (2019). **Household FW:** Mondésjar-Jiménez *et al.,* (2016); Oldfield et al., (2016); Capson-Tojo *et al.,* (2016); Nizami *et al., (*2017); Mylan *et al.,* (2016); Zorpas *et al., (*2018); Zeller *et al., (*2019); Tikka *et al., (*2019); Slorach *et al.,* (2019); Sarti *et al.,* (2017); Oldfield et al., (2016); Ng *et al.,* (2019); Miliute and Plepys (2015); Hebrok and Nina (2019); Dahiya *et al.,* (2018); Chakraborty and Venkata (2019); Borrello *et al.,* (2017); Andersson *et al.,* (2018) **Catering/retail FW:** FW from cruise ships (Strazza *et al.*, 2015); FW in cateens (Yeo *et al.,* 2019); spent ground coffee (SGC) (Stylianou *et al.,* 2018; Kourmentza *et al.,* 2018; Zabaniotou and Kamaterou, 2019); supermarket wastes (Chang *et al.,* 2018)
Food-related package waste	Geueke *et al.,* (2018); Kaur *et al.,* (2018); de la Caba *et al.,* (2019).

6.4. Food waste management options

There are a lot of options towards food management. The most widely adopted framework is the waste hierarchy (figure 11), which was firstly introduced in European Waste Directive in 1975. The latest version is found at Article 4 under a revised Waste Framework Directive 2008/98/EC (EC, 2008). The waste hierarchy is in an inverted pyramid with the aim is to set out the priority for waste prevention and management options based on their environmental impacts. Accordingly, prevention and reuse of wastes are the most attractive option, followed by reuse and recovery, whereas disposal or landfill is the least favourable one.

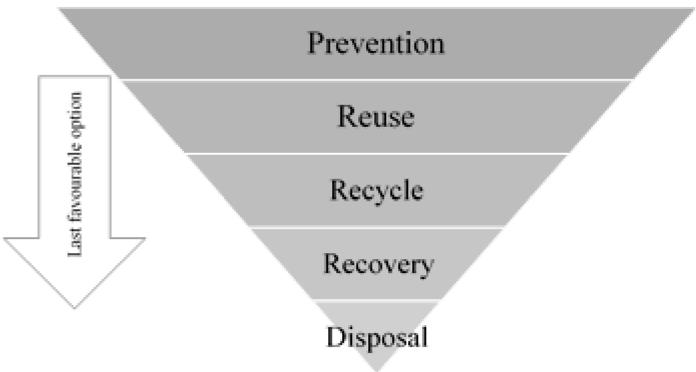


Figure 38: Waste hierarchy adopted from WFD 2008/98

In the context of food wastes and circular economy, waste hierarchy is applied with some modifications. For instance, WRAP produced a guidance on food and drink material hierarchy based on WFD 2008/98/EC (Wrap, 2017). Although prevention and disposal are still the most and worst favourable options, respectively, recycling using AD or composting technologies and energy recovery via incineration are the second and third attractive options in term of environmental performance. Despite energy recovery preferred in the UK, other waste valorisation options are now under consideration (Ng, *et al.,* 2019).

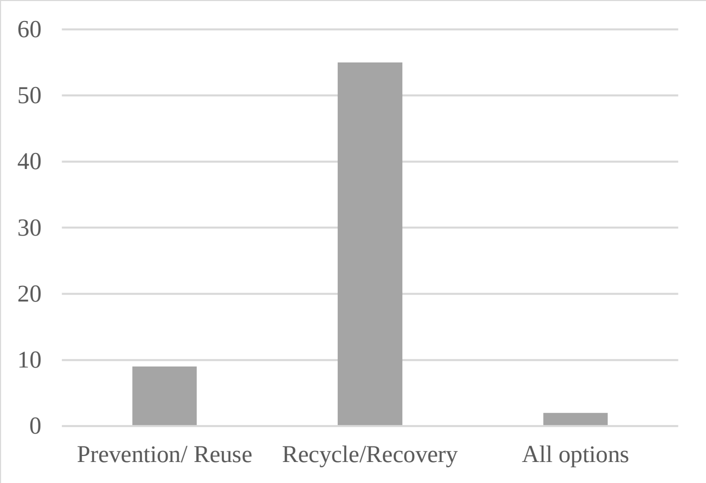


Figure 39: Number of articles on food waste management options

In our review sample, only two studies by Papargyropoulou *et al.*, (2014) and Cristóbal *et al.*, (2018) were found to provide insights on how waste hierarchy can be applied and interpreted. Authors highlighted that waste hierarchy should only be acted as a priority guideline. It can be misleading given it only takes environmental dimension into account. The justification of choices requires an inclusion of other two sustainability pillars (economic and social dimensions). The remaining papers (figure 12) dominantly focused on waste recycle/recovery options. Only nine papers are dedicated on waste prevention options.

Table 14: List of articles on food waste management options

Options		**Literature**
FW preventions (9)		(Miliute-Plepiene and Plepys, 2015; Mondéjar-Jiménez *et al.*, 2016; Oldfield, White and Holden, 2016; Borrello *et al.*, 2017; Sarti *et al.*, 2017; Cristóbal, Castellani, *et al.*, 2018; Zorpas *et al.*, 2018; Hebrok and Heidenstrøm, 2019; Tikka, 2019)
FW recycle/ recovery	**AD (22)**	AD in general: (Oldfield, White and Holden, 2016; Capson-Tojo *et al.*, 2016; Edwards *et al.*, 2017; L. Chen *et al.*, 2017; Masullo, 2017; Paul *et al.*, 2018; Pérez-Camacho, Curry and Cromie, 2018; Stoknes *et al.*, 2018; Vaneeckhaute *et al.*, 2018; Ingrao *et al.*, 2018; Liu *et al.*, 2018; Loizia, Neofytou and Zorpas, 2018; Al-Addous *et al.*, 2019; Antoniou *et al.*, 2019; Slorach *et al.*, 2019; Yeo *et al.*, 2019; Ng, Yang and Yakovleva, 2019) Digestate[14] from AD plant: (Dahlin et al., 2016; Bolzonella et al., 2018; Fuldauer et al., 2018; Beggio et al., 2019; Peng and Pivato, 2019)
	Composting (04)	Generic composting: (Oldfield, White and Holden, 2016; Tanzer *et al.*, 2018) Composting via mushroom production: (Zhao *et al.*, 2009; Ryabchenko *et al.*, 2017)
	Thermal (4)	Pyrolysis: (Elkhalifa *et al.*, 2019) Gasification [15]: (Antoniou *et al.*, 2019; Ng, Yang and Yakovleva, 2019) Combustion: (Melania Padolecchia *et al.*, 2018)

[14] Digestate and biogas (methane) are two by-products of an AD plant.
[15] Gasification is generally combined with AD to enhance energy recovery and material recovery.

	Cascading/ integrated biorefinery (13)	(Mirabella, Castellani and Sala, 2014; Zabaniotou *et al.*, 2015; Nizami *et al.*, 2017; Berbel and Posadillo, 2018; Sadhukhan *et al.*, 2018; Santos and Magrini, 2018; Stylianou *et al.*, 2018; Cristóbal, Caldeira, *et al.*, 2018; Dahiya *et al.*, 2018; Gontard *et al.*, 2018; Grimm and Wösten, 2018; Kaur *et al.*, 2018; Kourmentza *et al.*, 2018; Chakraborty and Venkata Mohan, 2019)
	Comparison of treatment options (6)	(Laso *et al.*, 2016; Edwards *et al.*, 2017; Imbert, 2017; Cristóbal, Castellani, *et al.*, 2018; Jara Laso, García-Herrero, *et al.*, 2018; Jara Laso, Margallo, *et al.*, 2018)

6.4.1. FW prevention

FW prevention is limitedly investigated in the literature, and all of them focused on consumption stage. For instance, some papers investigated customers' viewpoint on FW prevention under CE (Borrello *et al.,* 2017) or contexts to prevent food wastes at household level (Hebrok and Heidenstrøm, 2009) or the role of sorting household wastes (Miliute-Plepiene and Plepys, 2015). Other papers emphasised the role of government in changing households' behaviour (Zorpas *et al.*,2018), or the role of supermarkets with marketing and sale strategy on FW prevention (Mondéjar-Jiménez *et al.*, 2016). Cristobal *et al.,* (2018) is the only one paper in the record comparing twelve waste prevention practices.

Re-use/re-distribution of food via food sharing and food charity are studied in the papers of Sarti *et al.*, (2017) and Tikka (2019). New business models in food sharing include social eating platform (SE business model) and food alerting platform (FAP business model). New social platforms were discussed including social sharing platform and corporate social sharing platform. Problems with sharing model are associated with dominant player and high fragmentation of users (Tikka, 2019).

6.4.2. Food waste recycling/ recovery

Although prevention and reuse are generally preferred over other options under CE packages (Loizia, Neofytou and Zorpas, 2018), not all food wastes are preventable. For unavoidable fractions of foods like banana peel or citrus pulp, recycling or recovery options have been studied (Corrado and Sala, 2018). In general, there are four main pathways of FW recycling and recovery options: mechanical, thermochemical, physicochemical and biochemical process (Cherubini, 2010). Mechanical process aims to reduce the size or separate the component of food wastes. Therefore, it is generally applied first before the implementation of other options. Figure 13 provided the most common waste treatment methods under three remaining pathways. A generic review of these options is available in the study of Nizami *et al.,* (2017).

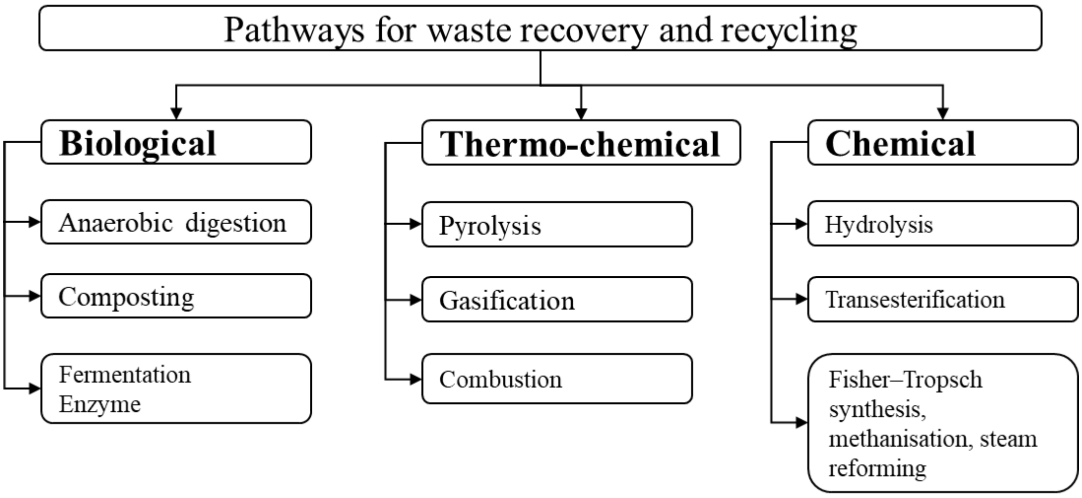


Figure 40: Common waste treatment pathways

Among these options, biochemical process using anaerobic digestion (AD) attracted the largest attention in literature (22 papers) (table 5). Traditional composting and thermal conversion process are limitedly addressed in the literature. Chemical conversion is hardly mentioned separately, but normally combined with other options under cascading or integrated bio-refinery.

AD is believed to be one of the best and most mature FW treatment due to FW characterised by highly biodegradable and nutrient rich (Gontard *et al.*, 2018; Xu *et al.*, 2018). Two end-products are generally released from biogas plants: methane/biogas and digestate (Paul *et al.*, 2018). While the former is used to replace fossil fuels, the latter is utilised as bio-fertiliser to return the nutrients to soils. A large portion of AD-related paper focused on technology enhancement or biogas/ electricity production from AD plants (also known as biogas plants) e.g. (Liu *et al.*, 2018; Slorach *et al.*, 2019), five papers are dedicated to digestate management (table 5). Traditionally, AD plant operators only care about revenue streams from electricity or biogas yields, while classifying digestate as waste (Dahlin et al., 2015). From CE perspective, nutrient-rich digestate should be recognised as a value resource to be recovered and contribute to close the nutrient loop of the FSC (Beggio *et al.*, 2019). However, the commercialisation of digestate as bio-fertilisers has not been supported by current legislation framework (Fuldauer *et al.*, 2018). In fact, legal status of digestate varies from country to country. In some countries, e.g. the case of Italy, digestate from AGRO feedstock is classified in a positive list whereas the one from OFMSW is not. However, statistical analysis for the quality of two digestate from AGRO and OFMSW show no statistically significant difference as presented in the research of Beggio *et al.,* (2019). As a result, there is a call for regulation to support the commercialisation of AD-effluent (Fuldauer *et al.*, 2018).

Integrated bio-refinery or cascading biorefinery is an emerging research direction with increasing number of publications. Compared to mono-process, cascading biorefinery contributes to maximise material recycling and energy recovery in a close loop approach. Implementation of different bioprocesses from fermentation, methanogenesis, photosynthesis, acidogenesis can generate a spectrum of bio-based products, from biofuels to biochemicals (sugars, acids, bioethanol), bio-fertilisers, animal feeds, bioelectricity, biomaterials (Dahiya *et al.,* 2018). Current studies set the foundation for the future development of integrated biorefinery technologies. Some case studies are illustrated, including anchovy fish supply chain (Laso, *et al.,* 2016; Laso *et al.,* 2018), spent coffee grounds (SCGs) in cascading biorefinery (Zabaniotou *et al.,* 2019) , spent mushroom substrate to produce packaging, construction materials, biofuels or enzymes

(Grimm *et al.,* 2018); olive by-products (Berbel and Posadillo, 2018). Some experimental papers for integrated biorefinery include three-stage integrated bioprocess (Chakraborty *et al.,* 2019) or bio-degradable plastics from food wastes (e.g. Kaur *et al.,* 2018)

6.5. Sustainability

The articles were analysed and categorised in table 6 considering the triple bottom-line of sustainability in accordance with the definition of CE by Kirchherr *et al.,* (2017). As emphasised above, FW treatment option is considered as a decision-making process where multi-criteria should be taken into account from environmental, economic, and social dimensions. Figure 14 illustrated a primary interest given to the first two dimensions and a limited interest in the last one. Also, only four papers in our sample evaluated all three pillars using different indicators.

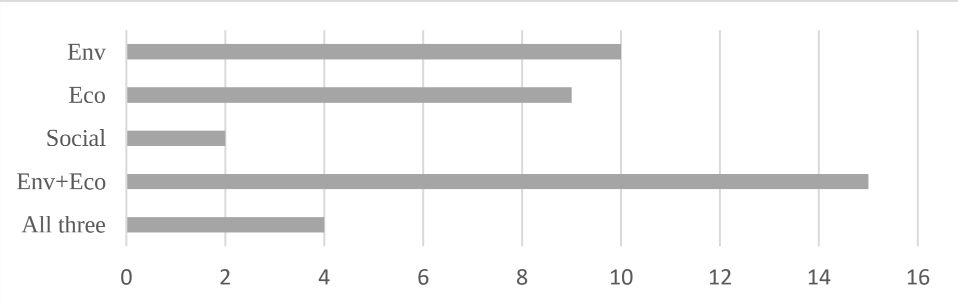


Figure 41: Number of articles on sustainability dimension

Indicators to measure each sustainable pillar are different in different articles. For instance, with environmental indicators, some authors measure all four sets of indicators, water-energy-food-climate (e.g. Laso *et al.,* 2018) while some only addressed three sets (e.g. Strazza *et al.,* 2017) or only one indicator like CO2-eq. (e.g. Slorach *et al.,* 2018). For economic dimension, popular indicators include total investment costs as budget constraint (Laso *et al.,* 2018), return on investment (ROI), profit and payback period (e.g. in Cristobal *et al.,* 2018; Fuldauer *et al.,* 2018) or methane yield (Zabaniotou *et al.*, 2015). Social indicators include job creation (Chen *et al., 2017*; Santos *et al.,* 2018) or stakeholders' perception survey on the use of bio-fertilisers in Vaneeckhaute *et al.*, (2008), or health and safety aspects in de la Caba *et al.,* (2019) and Dahlin *et al.,* (2016). The reason of lacking of social dimension is explained due to a lack of indicators and reliable data (Cristóbal, Castellani, *et al.*, 2018).

This clearly revealed a lack of attention on social issues, as well as a consistent approach to measure environmental and economic dimensions. Future research should focus on these topics.

Table 15: List of articles on sustainable dimensions

Three pillars	**References**
Environment assessment	(Strazza *et al.*, 2015; Laso *et al.*, 2016; Edwards *et al.*, 2017; Noya *et al.*, 2017; Santagata, Ripa and Ulgiati, 2017; Jara Laso, Margallo, *et al.*, 2018; Pérez-Camacho, Curry and Cromie, 2018; Pauer *et al.*, 2019; Slorach *et al.*, 2019)
Economic assessment	(Zabaniotou *et al.*, 2015; Marinelli *et al.*, 2017; Bolzonella *et al.*, 2018; Cristóbal, Caldeira, *et al.*, 2018; Fuldauer *et al.*, 2018; Kourmentza *et al.*, 2018; Al-Addous *et al.*, 2019; Antoniou *et al.*, 2019; Chakraborty and Venkata Mohan, 2019)
Social assessment	(Dahlin *et al.*, 2016; Geueke, Groh and Muncke, 2018)

Environmental and economic assessments	(Zhao *et al.*, 2009; Capson-Tojo *et al.*, 2016; Oldfield, White and Holden, 2016; Sadhukhan and Martinez-Hernandez, 2017; Ryabchenko *et al.*, 2017; Cristóbal, Castellani, *et al.*, 2018; Ingrao *et al.*, 2018; J Laso *et al.*, 2018; Jara Laso, García-Herrero, *et al.*, 2018; Liu *et al.*, 2018; Paul *et al.*, 2018; Ng, Yang and Yakovleva, 2019)
All three pillars	(W. Chen *et al.*, 2017; Santos and Magrini, 2018; Vaneeckhaute *et al.*, 2018; de la Caba *et al.*, 2019)

6.6. System thinking

The transition towards CE requires the involvement of three levels of society, macro, meso, and micro (Ghisellini *et al.,* 2016). The Macro level consists of the activities of society at national, regional and city levels. The meso level or inter-firm level refers to the network of firms with proximity, such as a supply chain network or an industrial symbiosis, or an eco-industrial park. The activities at consumers and single firm are considered as the Micro-level.

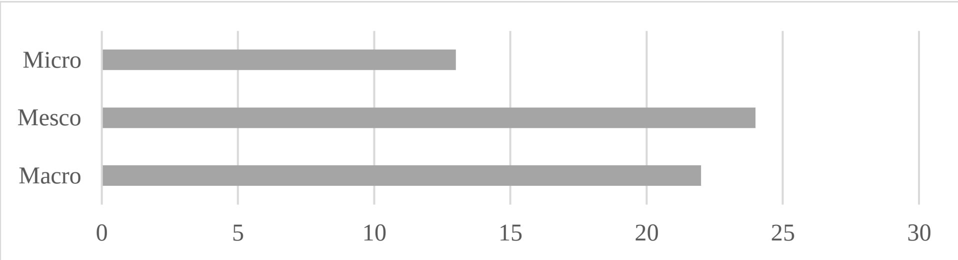


Figure 42: Number of articles at three levels of system thinking

Figure 15 represented that majority of the articles researching CE implementation in FSC focus on a macro level and meso level. ***Regarding macro level***, some articles studied FW at regional level, e.g. developing countries (Nizami *et al.,* 2017) or Europe (Corrado and Sala, 2018). Others focused on national level (Zorpas *et al.*, 2018, Andersson and Stage, 2018; Beggio *et al.,* 2019; Mu'azu *et al.*, 2018 ; Ryabchenko *et al.,* 2017), city level (London in Edwards *et al.,* 2017 or Brussels in Zeller *et al.,* 2018) or an area (like refugee camp in Al-Addous *et al.,* 2019). ***At meso level,*** several food supply chain has been investigated, e.g. supply chain of pasta (Principato *et al.*, 2019), of pork (Noya *et al.*, 2017), of olive (Zabaniotou *et al.,* 2015), of anchovy (Laso *et al.,* 2018). The concept of industrial symbiosis is also popular at meso level where waste of one company becomes resource of another company. For instance, Santos and Magrini (2017) investigated an an agro-industrial symbiosis network (ISN) in Brazil; or Liu *et al.,* (2018) evaluated a model of using corn straw as a feedstock for bio-natural gas plants. Similarly, Marinelli *et al.,* (2017) explored industrial symbiosis involving citrus, zoo-technical and processing industries to produce animal feed from citrus pulp in an innovative processing plants. ***At micro level,*** while several papers focused on studying a single firm, such as the case of Verzì Liberto located in Contrada Scalilli (Padolecchia *et al.,* 2018) or a canteen in Hongkong (Yeo *et al.,* 2019); a few papers explored the behaviours of consumers towards circularity of the supply chain, such as consumers' perspective towards CE implementation by returning organic wastes to supermarkets (Borrello *et al.,* 2017).

There is only one paper in our sample integrating three levels of analysis using a novel framework called as a System Thinking approach to Resource Recovery (STARR) (Ng *et al.,* 2019). Authors applied the framework at all three levels, from national level to community level (household wastes) and organisational level (supermarket waste) in a single study.

Table 16: List of articles on three levels of system thinking

Levels of system thinking	References
Macro level (city/province, national, regional)	**Regional level:** European (Corrado and Sala, 2018; Cristóbal, Caldeira, *et al.*, 2018; Cristóbal, Castellani, *et al.*, 2018; Hamelin *et al.*, 2019); developing countries (Nizami *et al.*, 2017) **National level:** the UK (Ng *et al.,* 2019; Slorach *et al.,* 2019), Norway (Strazza *et al.,* 2015); 87 counties in the US (Springer and Schmitt, 2018); Finland (Tikka, 2019) or Austria (Tanzer *at al., 2019);* Ireland (Oldfield, White and Holden, 2016); Sweden (Miliute-Plepiene and Plepys, 2015; Andersson and Stage, 2018), Australia ((Edwards *et al.*, 2017); Brazil (Santos and Magrini, 2018); Ukrainian (Ryabchenko *et al.*, 2017); Italian (Beggio *et al.*, 2019); Cyprus (Zorpas *et al.*, 2018). **City level:** London (Fuldauer *et al.*, 2018); South East Spain (Egea and Torrente, 2018); KSA in Saudi Arabia (Mu'azu *et al.,* 2019); Brussels (Zeller *et al.*, 2019); Ontario, Canada (Paul *et al.*, 2018); Beijing (L. Chen *et al.*, 2017)
Meso level (Inter-firm with geographic proximity e.g. Industrial symbiosis and eco-industrial parks)	**Supply chains:** Stoknes *et al.,* (2016); Laso *et al.*, (2016); Laso *et al.*, (2018); Laso, Margallo *et al.*, (2018); Principato *et al.*, 2019; Berbel *et al.,* (2018); Noya *et al.*, 2017; Grimm and Wösten (2018); Kourmentza *et al.,* (2018); Zabaniotou and Kamaterou (2019). **Industrial symbiosis:** Zhao *et al.,* (2009); Strazza *et al.,* (2015); de la Caba *et al.,* (2019); Gontard *et al.,* (2018); Liu *et al.,* (2018); Loizia *et al.,* (2018); Marinelli *et al.,* (2017); Mirabella *et al.,* (2014); Santos *et al.,* (2018); Ingrao *et al.,* (2018); Al-Addous *et al.,* (2019).
Micro level	**Firm level:** (M. Padolecchia *et al.*, 2018; Stylianou *et al.*, 2018; Vaneeckhaute *et al.*, 2018; Antoniou *et al.*, 2019; Chakraborty and Venkata Mohan, 2019; Slorach *et al.*, 2019; Yeo *et al.*, 2019) **Consumer level:** (Mondéjar-Jiménez *et al.*, 2016; Mylan, Holmes and Paddock, 2016; Borrello *et al.*, 2017; Sarti *et al.*, 2017; Zorpas *et al.*, 2018; Hebrok and Heidenstrøm, 2019)
All levels	Ng *et al.,* (2019)

7. Conclusions

There is an ample room for future research in the topic of FLW management under Circular Economy landscape. Largest number of articles focused on waste treatment options for food waste at consumption stage (particularly OFMSW), followed by residues in agricultural or food processing industry. Despite the benefits of optimising OFMSW, logistical concerns such as transportation, storage space, proximity to the buyers or collection points, decentralised versus centralised locations of plants are emphasised as the underlying issue, which requires further attention. The disciplines of supply chain network design, reverse logistics, cross-sectional collaboration and resource exchange can be applied to handle these challenges in the future research.

Among waste treatment options, anaerobic digestion for nutrient recycling and energy recovery attracted the largest attention. While CE thinking fosters (i) waste prevention, (ii) close and (iii) optimise material loops, the attention has now primarily paid to close material loops via AD. Future research should address FW preventions, and optimisation via cascading biorefinery using multi-process and multi-product approach to generate high value by-products from FW. While waste hierarchy acts as a guideline, decisions of selecting waste treatment options should be made by analysing three sustainability dimensions using well-established tools, like LCA. However, mainstream of studies overwhelmingly focused on environmental aspect followed by economic indicators, social dimension is limitedly addressed in the review sample. Also, there is lack of a set of indicators to evaluate and monitor CE implementation. For instance, some models used CO2 equivalent as an environmental indicator and Return on Investment as an economic indicator, while others employed payback period, profitability or cost as economic indicators etc.

Survey method is limitedly carried out in the literature. Also, only few papers discussed behaviours of consumers and perception of firms in circularity of FSC. There is a call for the survey study on stakeholders' perception towards CE implementation in FSC with a particular emphasis on the market acceptance for by-products.

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COLD CHAIN OPERATIONAL STANDARDS AND A CERTIFICATION CASE STUDY IN TAIWAN

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ABSTRACT
Purpose – Cold chain logistics is fast growing, but service failures frequently occur. This paper shows an experimental project on cold chain operations evaluation and certification of the parcel delivery service in Taiwan. Three major cold chain service providers participated in the project.

Design/methodology/approach – We develop a field auditing process and a scoring scheme comprising nine categories: facility, refrigerated storage and/or vehicles, refrigerating systems, temperature control, IT applications, process control, emergency plans, customer service, and human resource development. Each category is further classified into several features with individual weights. A rubrics guideline for scoring is also provided. We invited leading companies in Taiwan to participate in the test run.

Findings – This study obtains many suggestions by panel members and the responses from parcel service providers. We discuss key findings in each category as well as the challenges faced by the industry. At the end, we further describe the development of the first international cold chain standard bsi (British Standards Institution) PAS 1018:2017 and its linkage to ISO 23412.

Originality/value – Despite the importance both in academia and industry, not many studies address cold chain standards or quality systems that are considered as factors and systems affecting the service quality of cold chain service providers. This study presents recent development of cold chain operational standards in Taiwan and an experimental project on evaluation and certification. The findings further provide the pros and cons of results as well as the development of ISO 23412 from PAS 1018:2017.

Keywords: Cold chain standards, evaluation, certification, PAS, ISO

Category of the paper
Research paper

INTRODUCTION
A cold chain is a temperature-controlled supply chain to ensure safety and quality of perishable and temperature-sensitive products along the process flow of production, storage, distribution, and consumption. Modern cold chain logistics has been growing fast in Taiwan. Not only is B2B service widely available, but also there are several logistics providers competing for B2C and C2C parcel delivery services, due to growing on-line shopping of fresh grocery and food products. The parcel delivery system to consumers

(either to home or to stores for pick-up) is usually constructed as a hub and spoke network for efficient aggregation and allocation of parcels. The process starts with dispatching refrigerated trucks to business cold warehouses for B2C parcels or convenience stores to collect refrigerated parcels sent by small businesses or customers. Trucks then return to the operational sites to transfer parcels to larger trucks heading to transshipment centers. Parcels are sorted based on the destination and shipped to the designated transshipment centers during the midnight. Parcels to be delivered by the same operational sites are consolidated and transported via trucks. Finally, small refrigerated trucks from the sites deliver parcels to receipts along the route. Nevertheless, the service quality has been inconsistent due to lack of government regulations and outdated guidelines. In 2011, the Cross-Strait Cold Chain Alliance (CCCA) was founded in Taiwan with 2/3 of members from Taiwan and 1/3 from China. Members of the alliance consist of food manufacturers, logistics service providers, equipment providers, and research institutions and had a total of more than 300. One of its key missions, besides building relationship and seeking the business opportunities in China, was to improve cold chain logistics performance.

This study is based on a series of projects collaborating with Service Systems Technology Center of Industrial Technology Research Institute (ITRI) and members of CCCA. Partially funded by the government, two of the projects intended to establish a certification program that provides proper guidelines to cold chain operations and to distinguish companies that have achieved excellent performance. The program covered certification for warehousing services and transportation services. Another project supported by the alliance is the development of a cold chain training course for employees of member companies. In the summer of 2016, we invited three service providers to participate in a test run to evaluate the effectiveness of the certification program. Two of the participants provide refrigerated parcel delivery service. This study summarizes key findings of the transportation service program and discusses its impact on cold chain logistics in Taiwan.

RECENT DEVELOPMENT AND LITERATURE REVIEW

There is a rich stream of literature on cold chain logistics, especially on assuring safety and quality of perishable and temperature-sensitive products. Kuo and Chen (2010) suggest that temperature and time are two main factors that significantly affect the safety and quality of products. Sharma and Pai (2015) list ten relevant factors that can influence the effectiveness of a cold chain: food safety, temperature control, traceability, infrastructure, information technology, standardization, ability of the handlers, quality of communications, transaction costs and government policies. Ndraha et al. (2018) provide a review of temperature abuse in food cold chains that operate in developed countries. Most events that occur are related to air or sea transport and retail storage and display. There is a need to study the home delivery of chilled parcels or perishable products.

Lisa (2015) suggested that cold chain operators must continually upgrade technology to cope with additional requirement of refrigeration and compliance to ensure efficiency, integrity, and safety. However, refrigerated parcel delivery is usually the media focus when there is a cold chain failure in Taiwan. In 2014, Taiwanese government officials raided and inspected 48 refrigerated or freezer trucks at various locations and found the majority of the vehicles failed to maintain the temperature in the compartments at a level required by the law (Hsu, 2014; CPC, 2015). There were 35 violations of the regulation requiring that the compartment must maintain at the desired temperature before goods are loaded. In

2016, a Taiwanese news media placed thermometers inside frozen parcels to test four major service providers and found similar temperature problems.

Major service providers complained to the government that maintaining compartment temperature at -18^{0}C for B2C and C2C delivery services is much more challenging than that of B2B. They demanded that regulations should be revised. Muramatsu (2016) reported that Japanese logistics provider - Yamato Holdings, with its network expanded to Hong Kong, Shanghai, Taiwan, Singapore and Malaysia, has sponsored the development of PAS 1018, an international standard for door-to-door refrigerated parcel delivery services. PAS 1018 states that, as a result of the global trend towards more online trading, there is a greater demand from the agricultural and fishing industries for individual and small business online sales and purchases. Several Asian countries have started to provide temperature controlled refrigerated delivery services of this nature. At a conference held in Taiwan, Okabe (2016) suggested acceptable exposure times for refrigerated parcels for various environmental conditions. Although it is not included in PAS 1018, these time standards are applied to both chilled and frozen parcels as they are exposed to non-temperature-controlled environment during the delivery process. The time standards proposed by Yamato Holdings are supported by the findings of Tsai and Lin (2018). They study how the quality and safety of refrigerated food are affected when the food is exposed to ambient temperatures. The test results of foods stored at 25 °C show no significant change in microorganism growth for the first 3 hours. It is reasonable to set the ambient temperature below 15°C for loading/unloading processes and the time in these processes should be less than 30 minutes for interface operations in the food cold chain logistics.

THE CERTIFICATION PROGRAM

The content of the certification program originated from guidelines prepared by ITRI for members of CCCA. We visited cold chain facilities and held meetings with industry professionals to finalize two sets of evaluation criteria, one for warehousing service and the other for transportation service. Each set contains nine categories: facilities, refrigerated storage and/or vehicles, refrigerating systems, temperature control, IT applications, process control, emergency plans, customer service, and human resource development. Each category consists of several subcategories with individual weights. Since the program was intended to improve the cold chain logistics performance, most of the discussion focused on technical specifications such as temperature stability, data transmission frequency, and time limit out of a temperature-controlled environment.

In 2016, we invited two C2C delivery service providers and one warehousing service provider to participate in a pilot study to test the evaluation criteria defined in the certification programs. In this paper, we only describe the certification system and auditing process for transportation service with comparison of the two delivery service providers.

Criteria for the Certification

Table 1 summarizes the content and criteria of the certification. We briefly explain each category as follow. Firstly, the main facility for refrigerated parcel delivery is the transshipment center which receives parcels from operation sites, retailers, and convenience stores. Secondly, depending on the number of vehicles currently available, we select vehicles of all ages for functional inspection. For the third category, thermal sensors must be installed at proper locations. Drivers should be able to monitor and control the compartment temperature while driving. Regarding temperature records, all refrigerated vehicles should have equipment to record temperature and transmit data in near real time. Temperature records of vehicles must be well kept. For IT applications, the service provider should use TMS to assist daily operations and maintain complete records. The system should be capable of tracking every vehicle and every delivery and integrating with temperature monitoring.

For the sixth category, we examine documents related to operational procedures, quality control, and performance records with focus on control of time and temperature. Regarding prevention and emergency response, the service provider should have installed automatic detection and control devices, well-established procedures for employee safety and potential risks, adequate backup systems such as power generators, additional vehicles, and backup data storage. For customer service quality, the service provider should provide key information such as temperature and expected delivery date to service users/consumers before accepting parcels. There should be forms and procedures publicly available for filing complaints. The last category is about cold chain training courses and employee health checks. We provide rubrics guidelines to panel members for scoring. The overall score is the sum of scores for all subcategories and bonus points.

Table 1: Content and Criteria for certification

Domain	Category	Feature (feature weight in parentheses)	Weight
Hardware	1. Facility	Internal Layout (6), Dock Design (6)	12
	2. Vehicle	Years of Use (6), Body and Seal (4), Maintenance Records (2)	12
		Bonus: Thermal Insulation Equipment at Delivery (2)	
	3. Cooling and Monitoring Equipment	Refrigerating Systems (6), Insulation Materials (3), Temperature Monitoring (3), Measurement Calibration (3)	15
Software	4. Temperature Records and Management	Stability (5), Temperature Recording and Transmission (3), Record Keeping (2)	10
		Bonus: Full thermal information and/or real-time temperature measuring upon request (2)	
	5. ICT Applications	TMS applications (6), ICT and Decision Support for Performance Improvement (4)	10
Management	6. Process Control	Critical Point Control (6), Pre-cooling (3), Loading (3), Unloading and Delivery (3)	15
	7. Prevention and Emergency Response	Emergency Plans (6), Prevention and Maintenance Records (4)	10
		Bonus: Energy Savings and Green Solutions (2)	
	8. Customer Service	Customer Satisfaction and Handling of Complaints	6
Human Resources	9. Training and Development	External Cold Chain Training or Certificates (5), Internal Training Programs and Health Certificates for Employees (5)	10

The Auditing Process

The panel consisted of six to seven members, including both authors. For parcel delivery service, other members were retired professionals, cold warehouse managers, and equipment providers. No official or competitor was involved. Before the auditing, one of the authors visited the facilities to ensure mutual understanding of the process. Since both service providers performed the transshipment in the night, the auditing process began in the afternoon and ended at about 10 pm. We held a meeting one month after the auditing so that panel members could examine documents and records, exchange findings and opinions, and revise the scores, if necessary. The final score was averaged after removing the highest and the lowest scores among panel members.

The main challenge we faced was the selection of operation sites and vehicles for auditing. The auditing required functional inspection of facilities, vehicles, and IT application, in addition to reviewing documents. We did not have enough professionals and time to visit more than one operation sites, as usually required by ISO systems. Another challenge was some information withheld by service providers due to confidentiality claims. Without direct government involvement, we were unable to verify their capabilities in some cases.

RESULTS AND FINDINGS

Table 2 summarizes key findings of the auditing process. These two service providers were among leaders in the industry. What performed well was not necessarily a representation of the industry. On the contrary, what could be improved by both companies merits more attention from the industry. We also received valuable input from field managers.

Table 2: Summary of Auditing Results

Category	Key Findings
1. Facility	Both transshipment centers maintained a temperature-controlled environment and installed conveyor systems for parcel sortation. Cold storage rooms were used for temporary parcel storage, but without temperature records.
2. Vehicle	Company A had kept a few older vehicles as backups which performed poorly. It needed to replace older vehicles at a faster pace. Company B owned a younger fleet of trucks, but the temperature monitoring device could not alarm the driver if the compartment temperature is out of range. Refrigerated or insulated roller cages were used for inter-city transportation and deliveries to remote islands.
3. Cooling and Monitoring Equipment	Calibration of the temperature monitoring devices was not performed regularly for vehicles and roller cages. No calibration record was available. Some roller cages could not display proper temperature due to frequent collision.
4. Temperature Records and Management	All refrigerated vehicles for collecting or delivering parcels were equipped with GPS, temperature monitoring devices, and real-time data transmission. However, this is not a common practice in the industry.
5. ICT Applications	Both had a very good information system for real time vehicle and parcel tracing and tracking using computers or mobile phones. Company B further installed a big screen TV at its operation site, showing the status of all vehicles.
6. Process Control	Both companies turned on the truck engine for precooling, which was not environmentally friendly for employees. Neither considered switching to vehicles that can be precooled using electricity at the loading dock. A big concern is outsourcing. Company A outsourced the inter-city transshipment to an affiliated truck company and could not track those trucks due to delays of information systems integration. Company B hired third-party vehicles when demand was high. We were unable to obtain further information.

7. Prevention and Emergency Response	Backup power systems were adequate to support operations in case of a power outage. There were also well-designed emergency procedures in case of vehicle breakdown or traffic accidents.
8. Customer Service	Both kept customer service records and had good service performance. Both did not require employees wearing name tags for identification.
9. Training and Development	Both had developed adequate training programs and provided mandatory health check for employees.

What are the Challenges Faced by Refrigerated Parcel Delivery?

The biggest challenge is to educate users that parcels must be pre-cooled or frozen before being collected by the service provider or sent to a pickup site. Many consumers do not realize that the refrigerated delivery service operates to maintain the temperature of the parcel, instead of refrigerating or freezing parcels to the desired temperature. Service providers do not want to enforce any temperature requirement when receiving parcels. The current solution is to ask customers to sign without knowing that they have agreed to terms listed in small prints. Another issue is keeping parcels in the desired temperature-controlled environment throughout the delivery process. Frequent stops for delivery make it very difficult to maintain the compartment temperature under -15°C. Company A is now using thermal blankets to deliver a parcel from the truck to the customer’s door. We also recommend solutions such as delayed engine shutdown systems and insulated containers.

CONCLUSION AND DISCUSSION

There were several issues that prevented the certification program evolving into official standards, especially scandals of CAS, a widely used standard for certificating agricultural products, raised the public concern about the authenticity of such auditing process. Nevertheless, these projects still achieved some impact on the cold chain logistics industry. Company A began to use thermal blankets for home delivery. Company B changed its vehicle supplier based on auditing results. In subsequent meetings, government officials agreed to new regulations that focus on the temperature-controlled environment instead of the temperature on or inside the parcel. Regulated temperature checking when stopped by officials on the road will be changed from -18°C to -12°C for C2C frozen parcel delivery considering frequent compartment opening. From 2016 to 2018, one of the authors was invited to participate in drafting PAS 1018: 2017, a bsi (British Standards Institution) standard used for indirect, temperature-controlled refrigerated delivery service. Not only had he contributed his expertise to the standard, he also helped edit both traditional and simplified Chinese versions. PAS 1018:2017 is evolving into ISO 23412 in 2020. We believe that an international standard for refrigerated parcel delivery service would help the industry improve service quality to customers.

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COLD CHAIN CAPABILITY FOR FOOD COLD CHAIN MANAGEMENT: CONCEPT AND APPLICATION

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Abstract

Purpose of the paper

This paper aims to investigate the resources and capability required for managing food safety and quality in the cold chain.

Design/methodology/approach

A total of 1834 questionnaires were mailed to frozen and chilled food manufactures in Taiwan. In total, 165 usable responses were received, a response rate of 9.1%.

Findings

Testing using resource-based theory of food cold chain suggested three important findings. First, intangible resources (cold chain knowledge and skills) are more important than tangible resources (cold chain infrastructures). Second, there are four dimensions of cold chain capability: correct temperature maintenance, increased goods moving speed, adherence to hygiene principles and employment of emergency response. Third, there is a positive relationship between cold chain capability and food safety and quality performance.

Value/Originality

Overall, this implied that food companies could develop cold chain capabilities as routine activities to stratify the needs of their customers in pursuit of better food cold chain performance.

Practical implications

In practice, these findings can be used by cold chain food companies when integrated into their cold chain guidelines.

Keywords: chilled food, frozen food, logistics, cold chain

1. Introduction

Cold chain management issues have drawn attentions in recent years (Mercier et al., 2017, Ndraha et al., 2018). A food cold chain is an uninterrupted, temperature-controlled transport and storage system for moving refrigerated goods between upstream suppliers and consumers in order to maintain the quality and safety of food product (Hoang et al., 2016; Montanari, 2008; Piramuthu, 2016). However, the literature has noted the existence of temperature control problems in food cold chains in both transport (Derens-Bertheau et al., 2015, Moureh et al., 2002, Estrada-Flores and Eddy, 2006) and storage (Morelli et al., 2012, Baldera Zubeldia et al., 2016, Laguerre et al., 2002). Unexpected loss of temperature control can lead to food product loss, food waste, and food safety problems (Röhr et al., 2005, Nychas et al., 2008, Knowles, 2002, Derens-Bertheau et al., 2015, Chen et al., 2014). Compromised food safety or food quality could have an impact on human health in addition to causing economic losses for cold chain operators, such as missing revenue growth targets, poor operating margins and inventory performance (Marucheck et al., 2011, Chaudhuri et al., 2015).

A growing number of research studies shed light on the technical solutions to cold chain problems, such as building a time-temperature database (Gogou et al., 2015), food quality prediction modelling (Giannakourou et al., 2001, Olafsdóttir et al., 1997), time-temperature integrator (Arias-Mendez et al., 2014, Giannakourou and Taoukis, 2003, Hsiao and Chang, 2017), temperature monitoring and transparency (Chaudhuri et al., 2018, Göransson et al., 2018a, Göransson et al., 2018b, Óskarsdóttir and Oddsson, 2018, Hsiao and Huang, 2016). From a management perspectives, the literature also indicates that the major bottlenecks for developing countries are weak logistics infrastructure (Kuo and Chen, 2010, Gligor et al., 2018b, Brown et al., 2016). However, reviews of cold chain management in developed countries, where one would expect to find advanced infrastructure, temperature abuse seems also to be a serious problem. For example, Lauzen et al. and Margeirsson (2009) studied Icelandic cold chains involved in fish transportation and found all fish were out of temperature control. In France, Morelli et al. (2012) monitored refrigerated baked produce, pork, ham and dairy products in retail outlets and observed that about 63% of food examined was cold stored at temperatures exceeding 7°C, Zubeldia et al. (2016) in Spain, and Nunes et al. (2014) in USA monitored meat displays in retail shops, berries in cold chains, and fish in transit, and observed that all food exceeded required temperatures. Despite the wealth of studies considering cold chain problems, however, very little empirical research has gone on to examine the basic needs of best practice. To address this gap this research uses the resource based view (RBV) theory to investigate key factors for cold chain management. We do this by following Wernerfelt (1984) "A resource-based view of the firm", which analyzed firms from the resource side rather than from the product side, and Barney's (1991) framework for the study of a firm's internal strengths and weaknesses, which asserts that firms gain and sustain competitive advantages by developing valuable resources and capability (Barney, 1991). The literature has reported the potential benefits from time-temperature control to generate opportunities for competitive advantage in firms, since it could satisfy customer demands and create a completive point of difference (Aung and Chang, 2014, Ruiz-Garcia and Lunadei, 2011). Thus, this paper attempts to explore cold chain resources and capability. In the following section, the existing literature is reviewed to build a theoretical base for proposing comprehensive hypotheses. Section 3 describes the questionnaire design and responses. The results of the statistical analysis are detailed in Section 4. Finally, the concept of cold chain capability was applied in the development of cold chain guidelines (Section 5).

2. Theoretical background and hypotheses

In this section, we extend RBV arguments to cold chains to build a theoretical framework. Figure 1 shows the relationships between cold chain resources, cold chain capabilities and cold chain performance.

2.1 Definition of cold chain resource and cold chain capability

Resources (either tangible or intangible) are the inputs into the organization's value chain and are viewed as the source of a firm's capability (Collis, 1991, Chatterjee and Wernerfelt, 1991, Grant, 1991). In the context of cold chain, tangible resources are such things as insulated pallet, equipment, hardware, trucks and temperature-controlled warehouses (Zwierzycki et al., 2011, Lundén et al., 2014), while intangible resourses are represented by know-how, knowledge and skills (Daugherty et al., 1996). Conventional FCC infrastructure includes pre-cooling facilities, cold warehouses, refrigerated carriers, containers and packaging and traceability measurement tools (Montanari, 2008, Joshi et al., 2012). Resources are assets that are either owned or controlled by a firm, whereas capabilities refer to a firm's ability to deploy resources to achieve a desired outcome (Amit and Schoemaker, 1993). Capabilities are complex bundles of individual skills, assets and accumulated knowledge exercised through organizational processes, which enable firms to co-ordinate activities and make use of their resources (Sergio and E., 1997). In the context of cold chain, the capability refers to maintenance of food quality and safety throughout the cold chain logistical flow.

2.2 Research hypotheses

Cold chain infrastructures and knowledge are important for good cold chain practices. Logistics infrastructure should be capable of supporting distribution in the minimum possible lead time (Bogataj, 2005, Gligor et al., 2018a, Joshi et al., 2012). The availability of chilled or frozen warehouses and distribution centers should enable firms to store production in larger volumes and for a longer period to better deliver downstream partners' demands (Minten et al., 2016). Morelli et al. (2012) studied the temperatures of foodstuffs on sale in refrigerated display cabinets in bakeries, pork butcher's/delicatessens and cheese/dairy shops. They found that 70% of time temperature profiles were unsatisfactory, and suggested that the equipment must be properly designed, used and maintained in order to keep foodstuff temperatures within a range geared to food safety needs. Lundén et al. (2014) investigated the temperatures of products in 32 food stores and exposed the relationship between the product temperature, the temperature of the refrigeration unit (open front) and the temperature settings of the latter. They found that there was a lack of awareness of temperature settings in all chain-store groups. Only three stores (9.4%) were aware of all the settings of the inspected equipment. Thus, it appears that knowledge of temperature settings of equipment is limited among food cold chain operators. Barney & Clark (2007) suggested that the resources controlled by a firm(equipment, knowledge, skill) enable it to conceive and implement strategies designed to improve its efficiency and effectiveness. Accordingly, the following hypotheses are introduced:

H1. *There is a positive relationship between cold chain resources and cold chain capability.*

It has been argued in the logistics and transportation literature that capabilities in services and operational dimensions, such as reliability, customer response are the drivers of firm performance (Yang et al., 2009). Capabilities develop over time and are embedded in the firm as routine activities. As a result of casual ambiguity, they become difficult to copy, leading to a sustainable competitive advantage (Lai, 2004, Shang and Marlow, 2005). Thus, based on the resource-based view, a food firm with the ability to create and deploy resources to satisfy customer's logistics service needs will achieve superior performance. Regarding the relationship between resources and performance, this study argues that firms with appropriate infrastructure and food handling knowledge will prevent food from deteriorating and reduce safety concerns because the logistical personnel will be supported in maintaining food quality by equipment and procedures that enhance their functionality. Such a firm can further improve performance of its assets by increasing the number of functions and features being utilized. By so doing, it can strengthen the proficiency with which cold chain management tasks are accomplished. Hence, the following two hypotheses are formulated:

H2. *There is a positive relationship between cold chain resources and cold chain performance.*

H3. *There is a positive relationship between cold chain capability and cold chain performance.*

Capabilities are complex bundles of skills, competencies, and collective learning, exercised through the organizational routines that ensure superior coordination of functional activities (Day, 1994, Lin et al., 2015). The dynamic capability is the firm's ability to integrate, build, and reconfigure internal and external competencies to cope with changing environments (Teece et al.). Therefore, organizational capabilities are the source of competitive advantage.

3. Research method

In order to answer our formulated research questions, we mailed a total of 1,834 questionnaires to members of the Taiwanese Industry & Technology Intelligence Service (www.itis.org.tw). The selection criteria were food manufacturers who produce chilled and frozen food. Food manufacturers were chosen over the logistics companies was that the latter is still in its infancy and it was considered they would yield limited information. Questionnaires were mailed to logistics managers. The survey entailed two waves of mailings, with all non-respondents to the first wave receiving a second-wave, replacement questionnaire. Based on Armstrong and Overton (1977), non-response bias was examined by comparing early and late respondents. No significant differences in firm size, sales growth rate and food sectors between early and late respondents were detected, indicating that non-response bias is not an issue in this study.

3.1 Survey research instrument

Our procedures for survey design included a literature review and interviews with food quality and safety professionals. The 7-point Likert Scale questionnaire was examined and improved before general distribution by three academic experts and two business managers with experience in food logistics, food hygiene and food safety. A pilot postal survey was dispatched to three food enterprises. The survey questionnaire consisted of six parts: (1) general information about the company's profile, (2) food product characteristics, (3) cold chain resources (Germanischer Lloyd Certification & Cool Chain Association, 2008, Australian Food & Grocery Council, 2017, Wong and Noorliza, 2010, Aung et al., 2012, Oliva and Revetria, 2008, Zhao and Stank, 2003, Kuo and Chen, 2010), (4) cold chain capability (Germanischer Lloyd Certification & Cool Chain Association, 2008, Australian Food & Grocery Council, 2017, Bogataj et al., 2005, Fuller, 1998), (5) cold chain performance (Stank and Lackey, 1997, Beamon and Ware, 1998, Fawcett et al., 1997) (see Appendix)

3.2 Method of data analysis

Structural equation modeling (SEM) with LISREL 8.52 (Joreskog and Sorbom, 1993) was used to test and analyze the hypothesized relationships of the research model. SEM involves the analysis of two models: a measurement (or factor analysis) model and a structural model (Anderson and Gerging, 1988). The measurement model specifies the relationships between the observed measures and their underlying constructs, with the constructs allowed to inter-correlate. The structural model specifies the posited causal relationships among the constructs. Factor analysis with varimax orthogonal rotation aims to gain the interdependencies between observed variables and can be used to reduce the set of variables in a dataset. Multicollinearity, unidimensionality, scale reliability and construct validity were also undertaken (Hair, 2006). Multicollinearity type problems did not appear in the study. The reliability of all the extracted factors is confirmed through Cronbach's alpha coefficients (de Leeuw et al., 2008, Hair, 2006). The model and the hypotheses are tested using SEM via path analysis, as it is a multivariate analytic methodology that gives insights into the causal ordering of variables in a system of relationship.

4. Results and discussions

A total of 1,834 questionnaires were mailed. Thirteen surveys were returned as undeliverable, or from recipients disqualifying themselves as respondents. In total, 190 responses were received, of which five had missing data and were judged unusable, while twenty turned out not to be companies engaged in chilled and frozen food production, yielding an effective sample size of 165; a response rate of (190-5-20=165)/(1834-13=1,821) = 9.1%. The survey included several questions about the respondents and their organizations (Table 1). The 'total' column shows information about the profiles of all respondents. The majority of organizations employ fewer than 50 and more than 5 employees (57%). The majority of responses were from chilled and frozen seafood firms (21.8%). Respondents were also asked to name their firm's main food item based on storage temperatures. 59.4% of respondents reported frozen foods in this category, followed by chilled food (28.5%), ambient food (3.6%) and frozen food (3%).

Table 2 presents the factor analysis results for scales of cold chain resources, cold chain capability, and cold chain performance, and Cronbach's α. In this study, the score of 0.60 is used as the mark for the identification of high factor loadings. Figure 2 describes the structural equation model results. Various goodness of fit values show that consistence of the model to the data is acceptable. The fit indexes were acceptable (CFI=0.969, TLI = 0.962 > 0.80, RMSEA = 0.049 < 0.08). Thus, the hypothesized model for resources, capability, and performance has a good fit. The hypotheses and results obtained are given in Table 3. The first hypothesis (H1) is supported. There is a significant impact of cold chain resources on cold chain capability (λ=0.810; p<0.01). The third hypothesis (H3) is also supported , indicating that cold chain capability has a positive impact on cold chain performance (λ=0.836, p<0.01). The second hypothesis (H2) is not supported, showing cold chain resources was found not to impact directly on cold chain performance.

According to factor analysis results, tangible resources (cold chain infrastructures) are not correlated with cold chain capability. Our research indicates there is a significant impact of intangible cold chain resources on cold chain capability. This result is congruent with other studies (L. et al., 2002, Yang et al., 2009). The literature often mentioned the importance of logistics infrastructure to food cold chain efficiency (Kuo and Chen, 2010, Gligor et al., 2018b, Brown et al., 2016). Furthermore, the major difference between food cold chain management in developed and developing countries is also related to the lack of infrastructure supports (Parfitt et al., 2010). Cerchione (2018) reviewed cold chain management problems and contends that in the context of emerging economies, the major bottlenecks for the efficient and effective management of the food cold chain are weaker logistics infrastructure, lack of cold storages, shortage of refrigerated carriers, high costs, improper traceability, the absence of integration, irregular information flow and the lack of expertise. This study showed that intangible cold chain resources (ex. professional knowledge or relationships) are correlated with cold chain capability. Fuller (1998) stated that loading and uploading is an important step for chilled food products. Having operators with the necessary skills can avoid food quality loss. Moreover, supply chain operators should be aware of process, product characteristics and temperature requirements (Oliva and Revetria, 2008). Gligor (2018a) studied cold chain obstacles in Vietnam and found the following key obstacles: deficient professional skills, lack of quality and safety-control measures, a high concentration of intermediaries, poor infrastructure, lack of information systems, high cost of installation and operation, inadequate education and training at farmer level, deficient standardization, lack of government support for local businesses and social norms. Hence, cold chain capability had to rely on firms' intangible resources, such as people, equipment, knowledge etc.

In addition, this research also indicates cold chain capability is correlated with cold chain performance. This implies that cold chain capability is more important to cold chain performance than cold chain resources. These results are in line with other studies (Yang et al., 2009, Shang and Marlow, 2005). According to Joshi et al. (2009), food cold chain management is not an easy task even in the developed countries, despite their having the benefit of better supply chain infrastructure. For example, in France, Morelli et al. (2012) found that the temperature of 70 % of the chilled products in retail shops exceeded 7 °C. In the United States, Nunes et al. (2009) observed serious temperature fluctuations of chilled products on retail shelves. Cold chain capability can be the source of competitiveness. Mellat-Parast and Spillan -Parast (2014) mentioned that logistics and supply chain management could play an important role in the ability of firms to remain competitive in the marketplace. Managers involved in the logistics or supply chain process use strategies consistent with delivering high-quality products at competitive prices and service levels. These strategies can translate into functional policies that will bring the goods and services to the customer (Stock and Lambert, 2001; Wisner et al., 2005; Goffnett et al., 2012). The literature has reported the potential of time-temperature control to generate opportunities for competitive advantage in firms, since it could satisfy customer demands and create a completive point of difference (Aung & Chang, 2014; Ruiz-Garcia, 2010). Aung & Chang (2014) stated that the proper control and management of temperature is crucial in delivering perishables to consumers and ensuring that those perishables are in good condition and safe to eat. Jie et al. (2013) studied Australian beef processors and stated that food quality has a significant influence on processors' competitive advantage. Furthermore, enhancing perishable products shelf-life could improve firm performance, enhancing a firm's market share, goodwill and profitability (Cerchione et al., 2018).

This study further identifies four dimensions for cold chain capability, namely, managing temperature setting, speed, hygiene and emergency response, which a food company could create and deploy resources to stratify the needs of their customers in pursuit of better performance (such as lowering break-down of cool or frozen vehicles, shortening operation time, better temperature fulfilment, and faster delivery). The ability to manage temperatures, speed, hygiene and emergency response cannot be rapidly imitated by competitors merely by understanding theory, and so once gained cold chain capability can give a firm a key competitive advantage (Grant, 1991). These four dimensions of cold chain capability are further explained below.

(1) Managing correct temperature: setting the correct temperature is important for chilled and frozen foods. Food deterioration induced by microbial and chemical activity takes place rapidly when perishable products are exposed to temperatures between 5°C and 60°C (Adamberg et al., 2003, Zhou et al., 2008). For example, the number of *Bacillus cereus* in cooked chicken rice products stored at 10°C reached 10^7 CFU/g after 3 days of storage (Ayari et al., 2012),. Additionally, for frozen foods, ice crystals form and grow when products are exposed to temperatures between -5°C and 0°C (Kaale et al., 2011), adversely affecting the quality of frozen food.
(2) Managing speed: fast movement is recommended when temperature-controlled foodstuffs are stored at sub-optimal temperature conditions because of quality and food safety consideration (Likar and Jevšnik, 2006, Derens et al., 2006). For example, better route planning to shorten transportation time and distance, or enough storage room for fast cooling product temperatures (Fuller, 1998).
(3) Managing hygiene: maintaining hygiene during transportation and in storage facilities requires separation of frozen and chilled storage, and a first-in-first-out principle based on shelf-life is essential to good hygiene practices (FAO, 2003).
(4) Managing emergency response: this requires that a plan is in place that specifies procedures for handling sudden or unexpected temperature loss or shut down of the cooling system.

5. Application: cold chain guideline example

(1) Guidelines generally refer to applied recommended practices for food safety. Recentliterature has proposed a need for operational guidelines for cold chain problems (Ndraha et al., 2018, Baldera Zubeldia et al., 2016). Production of safe and high-quality food products by a food-processing and handling facility requires

developing and implementing effective Standard Operating Procedures (SOPs) for key day-to-day functions and activities (Schmidt and Pierce, 2016). These standard operational procedures could provide the foundation for effective food safety and quality programs (Sutton, 2010, Schmidt and Pierce, 2016). Our results lend support to our conceptual model grounded in the RBV of the firm. Based on these results, we have thus proposed cold chain guidelines for frozen and chilled food companies. Table 4 offers an example of such guidelines. In a sequence of logistical procedures: receiving, storage, value-added activities, loading, transportation, we suggest that food companies consider the four dimensions-related activities of temperature (T), speed(S), hygiene (H) and emergency responses (R). For example, at the receiving step, the following activities are necessary to ensure good performance: Product temperature should be measured and recorded (T).

(2) Product temperature should meet requirements, 0-7℃ for chilled food, -18℃ for frozen food (T).

(3) Environment should be maintained below 15℃ (T), or operations time should be controlled within 30 minutes below 15℃ to prevent dynamic temperature fluctuation. (S).

6. Conclusion

This paper was designed to investigate cold chain resources and cold chain capability and examine their relationship to firm performance. The results indicate that cold chain capability is positively related to cold chain performance. Intangible resources are more important than tangible resources. Capabilities in cold chain, including abilities of managing temperature, speed, hygiene and emergency response are drivers of cold chain performance. Overall, this implies that food companies can create and deploy these intangible resources and develop capabilities over a period of time as routine activities to stratify the needs of their customers in pursuit of better cold chain performance. On a practical level the paper also suggests operational guidelines, derived from cold chain capability, for companies involved in cold chain logistics to follow over the four process dimensions in order to improve operational performance and food quality. Overall, cold chain guidelines can benefit cold chain operators in monitoring and controlling the cold chain process to achieve a safer cold chain operation.

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Appendix. Questionnaire

Cold chain resource

r1. We have more temperature-controlled vehicles than our competitors
r2. We have more cold room capacity than our competitors
r3. Our employees perform better compared to those of our competitors.
r4. We have more capital than our competitors.
r5. We have better professional knowledge on cold chain logistics than competitors.
r6. We have better frozen and chilled infrastructures than competitors.
r7. We have better relationships with suppliers when compared to competitors

Cold chain capability

o1. We have a standard operation procedure for cold chain logistics.
o2. We have professional educational training program for our employees.
o3. When electrical power is lost, we are able to react to lost power conditions.
o4. We perform temperature instrument calibration regularly.
o5. We have back-up power for cooling facilities.
o6. We perform cold room and vehicle maintenance regularly.
o7. We have installed temperature alarm systems in cold room areas.
o8. We regularly maintain hygiene control for cool and frozen warehouses, loading areas, and vehicles.
o9. We isolate different types of food products to prevent cross-contamination.
o10. We store food products according their shelf-life and on a first-expired-first-out principle.
o11. We have established whole, continuous temperature records and are able to track temperatures throughout the supply chain.
o12. We have the ability to achieve delivery requirements for our customers.
o13. Our drivers always pre-cool to the required temperatures before loading products in their trucks.
o14. We have measures to maintain temperatures before uploading to trucks.
o15. We have high time efficiency on cargo handling.
o16. We often optimize delivery routes in order to reduce transport times and distances.
o17. We have enough space to store food products in order to speed up cooling effects.
o18. Our employees are able to load and upload efficiently to prevent temperature loss.

Cold chain performance

p1. We have significantly reduced the risk of product temperature loss.
p2. We have significantly reduced the frequency of product returns due to temperature loss.
p3. We have significantly reduced cold room break-downs.
p4. We have significantly reduced the break-down frequencies of cool or frozen vehicles.
p5. We have significantly reduced the operation time of tally, loading and uploading.
p7. We have significantly improved the temperature fulfillment that customers demand.
p8. We have significantly improved the delivery time fulfillment that customers demand.

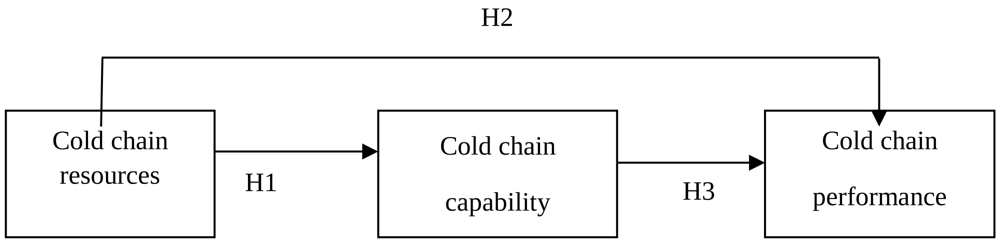
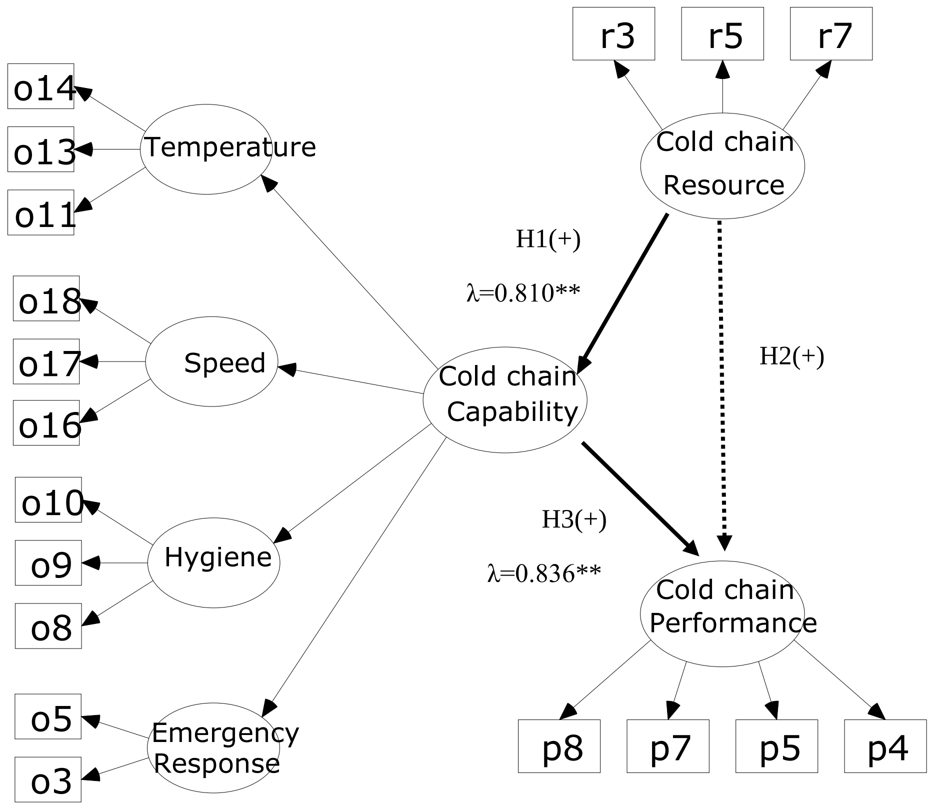


Fig 1. Conceptual framework



Note: **represents p < 0.01; broken lines indicate no significant relationship

Figure 2. The model of cold chain resources, cold chain capability, and cold chain performance.

Table 1 Respondent & firm profile

Demographics	Number of respondents	Percentage
Number of employees		
Less than 5 people	9	5.4
5~50 people	94	57
51~100 people	25	15.1
101~200 people	12	17.3
201~500 people	13	7.9
More than 500 people	12	7.3
Food sector		
Slaughter	8	4.8
Frozen, chilled meat	28	17
Frozen, chilled seafood	36	21.8
Frozen, chilled vegetable	26	15.8
Dairy	13	7.9
Bakery and steam food	26	15.8
Noodle	9	5.4
Prepared food	14	8.5
Food categories*		
More than 18^{o}C	95	38.2
18^{o}C	7	2.8
0~7^{o}C	91	36.5
Less than -18^{o}C	16	6.4

*9 missing data

Table 2 List of construct measurement items

(Cronbach's Alpha, Composite Reliability, Average Variance Extracted)	Coefficient	t-value‡	R^2
Cold chain resource (α = 0.761; CR = 0.773; AVE = 0.539)			
r3. Our employees perform better compared to our competitors.	**0.642**	**-**	**0.385**
r5. We have better professional knowledge on cold chain logistics than competitors.	**0.906**	**6.199**	**0.821**
r7. We have better relationships with suppliers when compared to competitors	**0.620**	**6.674**	**0.413**
Cold chain capability			
Temperature *(α = 0.841; CR = 0.846; AVE = 0.674)*			
o11. We have established whole, continuous temperature records and are able to track temperatures along supply chain.	**0.768**	**-**	**0.569**
o13. Our drivers always pre-cool to the required temperatures before loading products to truck.	**0.884**	**9.797**	**0.782**
o14. We have measures to maintain temperatures before uploading to trucks.	**0.755**	**9.404**	**0.590**
Speed *(α = 0.812; CR = 0.814; AVE = 0.595)*			
o16. We often optimize delivery route in order to reduce transport time and distance.	**0.713**	**-**	**0.656**
o17. We have enough space to store food products in order to speed up cooling effects	**0.787**	**8.249**	**0.619**
o18. Our employees are able to load and upload efficiently to prevent temperature loss	**0.810**	**8.254**	**0.509**
Hygiene *(α = 0.832; CR = 0.84; AVE = 0.56)*			
o8. We regularly maintain hygiene control for cool and frozen warehouses, loading, and vehicles.	**0.763**	**-**	**0.613**
o9. We isolate different types of food products to prevent cross-contamination.	**0.823**	**9.170**	**0.677**
o10. We store food products according their shelf-life and have first-expired-first-out principle.	**0.783**	**9.069**	**0.582**
Emergency response *(α = 0.790)*			
o3. When electrical power is lost, we are able to react to lose power conditions.	**-**	**-**	**-**
o5. We have back-up power for cooling facilities.	**-**	**-**	**-**
Cold chain performance *(α = 0.88; CR = 0.847; AVE = 0.649)*			
p4. We have significantly reduced the break-down frequencies of cool or frozen vehicles.	**0.776**	**-**	**0.646**
p5. We have significantly reduced the operation time of tally, loading and uploading.	**0.803**	**10.448**	**0.698**
p7. We have significantly improved the temperature fulfillment that customers demand.	**0.836**	**10.870**	**0.645**
p8. We have significantly improved the delivery time fulfillment that customers demand.	**0.804**	**10.461**	**0.602**

Note: ‡ All t-values are significant at $p < 0.01$ Level

Table 3. Hypothesis testing of the relationships of cold chain resources, cold chain capability, and cold chain performance

Hypothesis	Paths	β estimate
H1	Cold chain resources → Cold chain capability	0.810**
H2	Cold chain resources → Cold chain performance	-----
H3	Cold chain capability →Cold chain performance	0.836**

**: p<0.05, ***: p<0.001

Table 4 Cold chain guideline example

Steps	Activities
Receiving	• Product temperature should be measured and recorded. (T)* • Product temperature should meet requirements of 0-7℃ for chilled food and -18℃for frozen food. (T) • Environment should be maintained below 15℃ (T) • Or, operations time should be controlled within 30 minutes under 15 ℃ to prevent dynamic temperature fluctuation. (S)
Storing	• Cold room should function properly in order to maintain product central temperature at chilled temperatures at 0-7℃ for chilled food and -18℃ for frozen food. (T) • Frozen and chilled products should be stored in different cold rooms. (H) • Temperature fluctuation should be avoided. (T) • Alert system is needed when cold room temperature is higher than required temperature.(R) • Emergency plan is need in case refrigeration system is out of order.(R) • Personnel hygiene education and environment hygiene control is needed.(H)
Value-added activities	• Environmental temperature should be kept at 7℃. (T) • Places for processing ready-to-eat food should be well isolated to prevent cross-contamination.(H) • Selection of packaging material should guarantee no pollution from environment during transportation and storage.(H) • Personnel hygiene education is needed. (H)
Loading	• Environmental temperature should be kept under 15℃. (T) • Or operation speed should be fast, recommend within 30 minutes under 15℃ for preventing temperature fluctuation and formation of water drops on product surface.(S) • Product temperature should meet requirements of 0-7℃ for chilled food and -18℃ for frozen food.(T)
Transporting	• Loading ducks should be installed with dock shelter.(T) • Pre-cooling is needed and should be below 10℃. (T) • Or before loading, environmental temperature should be able to maintain food product central temperature to fulfill chilled food products' requirement.(T) • Stacking correctly to allow cold air to flow properly.(T) • Door curtains are needed in order to prevent temperature loss.(T) • Emergency plan is needed when cooling system is out of control. (R) • Product temperature should meet requirements of 0-7℃ for chilled food and -18℃ for frozen food.(T) • Temperature fluctuation should be avoided. (T)

*Temperature (T), speed(S), hygiene (H) and emergency responses (R)

STRATEGIC FACTORS GOVERNING BLOCKCHAIN TECHNOLOGY IMPLEMENTATION IN FOOD SUPPLY CHAIN: HYBRID MODEL AND METHODOLOGY INVOLVING SWOT-FAHP

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Purpose
Blockchain technology has been successfully implemented in financial sector, however, in the case of logistics and supply chains there are much hype about ensuring trust, traceability and transparency through blockchain technology but not implemented as equivalent to financial sector. Many large technology companies such as IBM, Oracle are pursuing blockchain implementation strategies for supply chain consortia that use the applications from these vendors. A few notable blockchain applications/projects in the current food system have appeared in last couple of years such as provenance.org, IBM food traceability, ripe.io, blockshipping, SkuChain, Walimai, WaBi and so on, though some of them are still in the pilot stage. The well-known benefits from blockchain implementation in food supply chain are to reduce food fraud and errors, to solve supply chain inefficiency, to enable food traceability, to improve inventory management and safety recalls, to minimize transport costs, to reduce delays from paperwork, to identify issues faster and to increase consumer and partner trust. However, knowing there are substantial benefits out of blockchain implementation still stakeholders in food supply chain are hesitant to implement due to several reasons. Hence, we find there is a huge gap in identifying strategic implementation factors and non-availability of suitable model and methods to make trade-off decisions. The study answers the following research questions: What are strategic factors governs blockchain technology implementation and the suitable model and methodology for wider community to decide on implementation.

Design/methodology/approach
The study identifies several implementation factors through literature review, whitepapers, blockchain projects and discussion with practitioners from food and technology sector. Based on the evidences the study develops a multi criteria decision making (MCDM) model for evaluating blockchain technology implementation factors. The model combines SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis and FAHP (Fuzzy Analytic Hierarchy Process) approach. The study considers implementation strategies related to technology, legal, business and organisational aspects. SWOT analysis helps with strategy formulation to identify strengths and weaknesses (S-W), as well as broader opportunities and threats (O-T) of blockchain implementation, whereas FAHP gives analytical priorities to evaluate blockchain implementation strategies listed under SO, ST, WO, WT to decide on. The developed model is validated with a Turkish food sector case involving multiple stakeholders.

Findings
The developed model is illustratively pursued among participants of a food supply chain consortium to evaluate implementation strategies of blockchain. The decision-makers are out on most of technologies but it is important for every participant to understand that they exist and how they may affect operations in the short and long term. The findings of this study show that the implementation strategies of blockchain depends on the readiness of consortium and the degree to which changes are planned, managed conducted, and utilized. Thirty-two strategic factors according to SWOT are identified and four implementation strategies are determined depends on low, regular, special and high

attentions. In terms of SWOT-FAHP evaluations it is found out under which circumstances a consortium should choose what implementation strategy.

Value

This study adds novel technology application knowledge from the emerging economy perspective in a food sector. This research would be the first research to evaluate the implementation strategies of blockchain technology in the food supply chain ecosystem and also it gives practitioners in food industry a perspective to understand the decision making to adapt blockchain technology to their industry.

Research limitations/implications

The application of this study is limited to the Turkish food sector.

Practical Contribution

This study has several practical implications to the food sector such as implementation strategy of blockchain technology for enabling food transparency and food safety.

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PACKED PRODUCT PARADOXES IN GLOBAL SUPPLY CHAINS: THE CASE OF SOUTH AFRICAN TABLE GRAPES SOLD IN EUROPE

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Purpose of this paper
Current literature on packaging logistics acknowledges trade-offs in supply chains for packed products, but it is less effective in explaining the different characteristics of various trade-offs and the complexity of managing these trade-offs. Grounded in paradox theory, the purpose of this paper is to increase the understanding of the role of packaging (systems) in sustainable global food supply chains. To do so, the paper aims to identify and analyse packaging-related paradoxes in global food supply chains.

Design/methodology/approach
A single case study of four companies in a global food supply chain of table grapes from South Africa to Europe was conducted. The data were collected through interviews, observations and archival data. The analysis was supported by a conceptual framework based on paradox theory with four categories of paradoxes.

Findings
The paper identifies and analyses organisational paradoxes related to the fulfilment of product and packaging requirements throughout the supply chain. The paper describes how the four categories of paradoxes have impacts on logistics efficiency (lead-time and costs), amount of food waste and packaging material efficiency (material recycling, material selection and sufficient amount of packaging material) in the supply chain.

Value
The application of paradox theory to empirical data of packed products deepens the understanding of the eco-efficient performance of global food supply chains.

Research limitations/implications
The four categories of paradoxes and their impacts on packaging for sustainable supply chains extend current knowledge about trade-offs in supply chains for packed products. This provides input to understanding the complexity of managing paradoxes. A limitation is that the case study does not cover the companies in the final stages of the supply chain (i.e. retailers and consumers). Another limitation is that the single case study focuses on one packed product. Future cases should complement with other products.

Practical implications
The findings provide awareness of packaging paradoxes in global food supply chains, which is a first step in managing the paradoxes. The findings also highlight the need for companies to be transparent and use a system perspective on packaging selection and development in order to obtain sustainable global food supply chains.

INTRODUCTION

Packaging follows a food product throughout a supply chain and interact in all logistics operations. The operations may be filling, picking, storing, handling, replenishment, etc. Packaging must fulfil many requirements from various supply chain members to facilitate effectiveness and efficiency in the logistics operations. The longer the supply chains, the more complex are the requirements. To acknowledge these complexities, this paper focuses on food packaging in global supply chains. The global supply chains have the following unique characteristics compared to a domestic supply chain:

- Geographical distance
- Lead time
- Different modes of transport
- Visibility challenges
- More actors – more packaging requirements
- Legislation – different government systems
- Technology issues
- Security concerns
- More handling – different handling equipment
- Producers and exporters have less insights about customers and consumers

Packaging follows food products throughout all stages of the supply chain until consumption. To maximise the value of packaging, it is a delicate and complex matter to incorporate and balance many different stakeholder requirements. Packaging logistics literature addresses such trade-offs, but a literature review emphasises that more research is needed to identify and describe opportunities and obstacles within supply chains (Azzi et al., 2012). Based on paradox theory, the purpose of this paper is to increase the understanding of the role of packaging systems in sustainable global food supply chains. To do so, the paper aims to identify and analyse packaging-related paradoxes in case study of a global food supply chain.

LITERATURE REVIEW

Packaging should be analysed as a system with three components: primary, secondary and tertiary packaging. Analysing packaging as a system emphasises that the performance of a packaging system depends on each packaging component as well as on the interactions between the components.

Packaging has strategic value in logistics and supply chain management. Even if the cost of packaging often is quite low, its strategic value is high (Found and Rich, 2007). Packaging can provide competitive advantage in the marketplace by enabling eco-efficient supply chains and increase sales (Pålsson, 2018). To do so, different packaging features must be addressed. Robertson (1990) presented an early categorisation of basic packaging features: protect, contain, unitise, apportion, communicate, and provide convenience. This categorisation is still useful, but has also been complemented with additional features in current literature to enable logistics and environmental efficiency and ergonomics effectiveness.

METHOD

A single case study of four companies in a global food supply chain of table grapes from South Africa to Europe was conducted. The data were collected through interviews, observations and archival data. The analysis was supported by a conceptual framework based on paradox theory with four categories of paradoxes.

PARADOX THEORY

Recent years' theoretical development within the organisational field of research calls for a renewed understanding of how to manage contradictions and tensions within an organisation (Dameron and Torset, 2014). Whereas some tensions are possible to avoid or solve (Smith and Lewis, 2011), some of them, here labelled paradoxes, are not. Consequently, the core message of a paradox theory is that to manage organisations (or supply chains) effectively, these paradoxes must continuously be coped with (Sandberg, 2017). Creating awareness of these paradoxes and their impact on company performance is considered a major tool for organisational development (Graetz and Smith, 2009). If tackled correctly, the paradoxes could be seen as an important driving force for innovation and development (Sandberg, 2017; Graetz and Smith, 2009; Lewis, 2000).

In their seminal paper on paradox theory, Smith and Lewis (2011) developed a framework of different types of organisational paradoxes. These four types are in this research applied as a framework to structure our understanding of pros and cons with organisational design of packaging development. The four types are (Smith and Lewis, 2011, pp. 383):

1. Performing (goals): Plurality fosters multiple and competing goal as stakeholders seek divergent organisational success.
2. Organising (processes): Structuring and leading foster collaboration and competition, empowerment and direction, and control and flexibility.
3. Belonging (identity/interpersonal relationships): Identity fosters tensions between the individual and the collective and between competing values, roles, and memberships.
4. Learning (knowledge): Efforts to adjust, renew, change, and innovate foster tensions between building upon and destroying the past to create the future.

CASE STUDY OF TABLE GRAPES IN GLOBAL SUPPLY CHAINS

The case study examines packaging-related paradoxes in a global supply chain of table grapes. The primary packaging is a plastic PET tray. A full tray weighs about 500 g. To avoid the risk of pressure damages, the packages must not be filled too high. Another risk in the primary packaging is to get moisture on the grapes. Therefore, the secondary packaging includes a sheet, which slowly emits sulphur to reduce any water on the grapes. The other parts of the secondary packaging is a plastic bag and corrugated board packaging. Ten primary packages are put into the plastic bag, which then is put into corrugated board packaging. The dimensions of the standard secondary packaging are 400 x 600 x 90 mm. The producer also uses secondary packaging measuring 300 x 400 x 120 mm, which better protects the grapes from pressure from above. The secondary packages are put on pallets (1,000 x 1,200 mm) to a height of 2,400 mm. This means that the lowest layer of packaging bears a weight of 90 kg. A full pallet has stabilizing material on the corners and straps to hold them together. The pallets are loaded into a container in a cold storage facility. This packaging system remains unchanged until the grapes reach the port of Rotterdam, where the pallets are loaded onto a truck for transport to the wholesaler. At this point, the secondary packaging is transferred to Euro pallets (1,200 x 800 mm). In the retailer DC, the secondary packaging is repacked onto yet another Euro pallet.

Table grapes are a low-margin product, quite delicate and sensitive to heat. This case focuses on packed table grapes from farmers in the Western Cape in South Africa to the Swedish market, where the main customers are three major retailers. The grapes are harvested from November to April. At the beginning and end of the period, an individual farmer ships 5 containers of grapes per week, and in the peak season the farmer ships 12 containers per week.

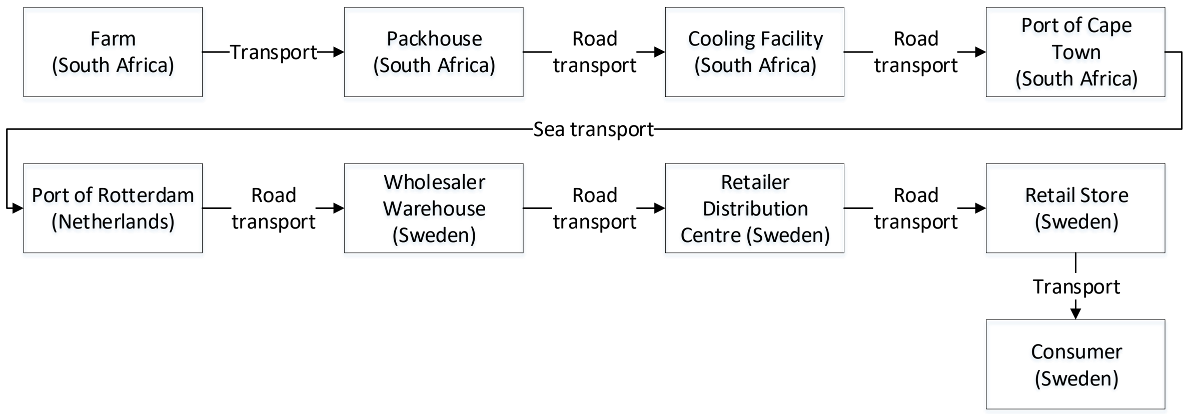

Figure 1. The global supply chain for table grapes from South Africa to Sweden

Figure 1 illustrates the supply chain. After harvesting, the grapes are transported in a plastic crate to a packhouse on the farm where they are precooled to 20–22°C. The quality of the grapes are checked including size, freshness and sugar content. Thereafter, the grapes are packed and stored. From the packhouse, the farmer sends the grapes by truck to a cooling facility where the grapes are cooled. From the cold storage room, the pallets of grapes are moved with forklifts to a non-refrigerated waiting area for loading in a container. When the facility is busy, there is a risk of breaking the cold chain at this point.

From the cooling facility, an exporter manages the transport to Europe. This cargo goes in containers by truck from the cooling facility to the port of Cape Town. The total time in the cooling facility and the port should be a maximum of 7 days, but it sometimes takes longer, as Cape Town frequently suffers from strong winds and operations are stopped. This negatively affects the quality of the packed grapes, as it reduces their shelf life. Sometimes the grapes are delayed 2-3 weeks in the port.

The transport with vessel to the Port of Rotterdam in the Netherlands takes about 3 weeks. On arrival, there is a 72-hour quality control before the grapes are transported by truck to a wholesaler warehouse in Sweden. In the warehouse, the grapes are stored and repacked from one tertiary packaging to another tertiary packaging. Then, a truck transports the grapes to a retailer distribution centre, which stores and repacks them into smaller quantities based on the demand from the retail stores. Thereafter, they are transported to a retail store, where either the secondary or the primary packaging is replenished. In the final step, consumers buy primary packages of grapes and bring them home.

PACKAGING-RELATED PARADOXES IN THE CASE

The paper identifies and analyses organisational paradoxes related to the fulfilment of product and packaging requirements throughout the global supply chain. The paper describes how the four categories of paradoxes have impacts on logistics efficiency (lead-time and costs), amount of food waste and packaging material efficiency (material recycling, material selection and sufficient amount of packaging material) in the supply chain.

These characteristics of global supply chains (see the introduction) affect the paradoxes that occur.

Performing

There are multiple goals on the performance of packaging from the different organisations in the supply chain. The case includes performing paradoxes between a packaging feature and between different packaging features. Performing paradoxes between a packaging feature occur as the different organisations in the supply chain have different requirements on the same feature. For instance, in loading areas, the packaging system should protect against heat, but in containers and in cooling areas, it should provide ventilation. The performing paradox for temperature protection is isolation vs. ventilation. Another example is related to apportionment where manual handling of secondary packaging limits the size on the expense of automatic handling efficiency in other parts of the supply chain. Performing paradoxes between different packaging features are exemplified by the fact that the primary packages are filled as much as possible without being in contact with the lid, as this leads to pressure damage. However, this is a delicate balance in the manual filling process, which occasionally leads to too much grapes in the primary packages. Furthermore, due to ergonomics and pallet utilization reasons primary packaging uses approximately 80% of the volume of secondary packaging, which means that about 20% is unused. A third example is that promotional attributes on the primary package with transparent plastics, the protection features against vibrations and shocks are restricted.

Organising

Competing processes within and between organisations in a supply chain foster organising paradoxes. In this case, we identified two organising paradoxes related to packaging. The best possible overall packaging solution for long-term supply chain effectiveness makes informed trade-offs between the combined packaging requirements from the whole supply chain. However, individual organisations can benefit from sub-optimised packaging solutions in the short term where certain internal packaging requirements are prioritised. Thus, there is an organising paradox between the willingness to collaborate on packaging development and selection vs. maxims internal packaging needs. This can occur in domestics supply chains as well, but are emphasised in this global one due to the visibility challenges and a vast amount of packaging requirements from multiple organisations.

The visibility challenge also leads to another organising paradox. In the port of Cape Town, strong winds leads to vibrations and shocks on containers the loading process. However, potential damage to the grapes cannot be tracked to the port, as the containers are never opened there and there. Increased visibility through technology could identify the root causes of damaged grapes, but such visibility comes at the expense of increased costs.

Belonging

Belonging acknowledges an organisation's identity by highlighting paradoxes between how individuals and groups identify themselves with different values. In this case, we acknowledge belonging paradoxes related to sustainability. Environmental sustainability is about consuming everything that is produced and sold with as little environmental footprint as possible in the supply chain, whereas economic sustainability focuses on selling everything that is produced with as high logistics efficiency as possible in the supply chain. The organisations in the table grapes supply chain traditionally belong to the economic sustainability perspective. An increasing focus on environmental sustainability fosters tensions within and between the organisations. From a packaging perspective, there are belonging paradoxes between sustainable packaging and maximising the economic profit of the packed product. For instance, packaging waste occurs in several stages of the supply chain. It occurs in the packhouse, as excessive material is wasted. After repacking and emptying, there is waste and used tertiary packaging at the wholesaler DC, retailer DC, and the retail store. Some accidents in the forklift operations due to high speed in the cooling facility lead to repacking. The secondary packaging becomes waste at the retail store, and the primary packaging at the consumer end. Product waste is a general problem in table grape supply chains. This case identified a number of supply chain challenges that can lead to damage and waste.

Learning

Learning paradoxes occur when organisations go through changes to meet changed demands. In this case, we identified sustainability is becoming increasingly important, which changes the demands on packed table grapes. Costs and sales are traditionally followed-up, and are still important. However, the changed demands require the inclusion of environmental (packaging waste, avoid product waste) and social (operations: picking, packing etc.) measurements. The increasing demands on environmental and social sustainability on packed table grapes are not always compatible with the current knowledge base. The learning paradox is between building upon current knowledge to increase the profit by improving current measurements vs. changing measurements and build new knowledge around sustainability.

Even without changing measurement focus, there is a learning paradox in the case between the maintenance of the current knowledge base vs. adoption of new, emergent knowledge areas. The farmer selects packaging. The packaging system has been the same for many years with minor changes. Thus, from a learning perspective the focus is on building upon current packaging knowledge rather than capturing new packaging knowledge for radical innovation. This is also strengthened by the fact that other stakeholders in the supply chain than the farmer has limited impact on packaging selection, because there are not structured feedback loops about packaging performance in the supply chain. An exception is error reports.

DISCUSSION AND CONCLUSIONS

This case study of a global food supply chain has explored four categories of packaging-related paradoxes. This case study does not claim to present all packaging-related paradoxes in global food supply chains, but it clearly shows that there are paradoxes in all four categories present. Previous studies focus on trade-offs related to the performing category. Thus, this study helps to increase the understanding of packaging logistics for food supply. By applying paradox theory, this study provides a new way of analysing the complexity of packaging performance in food supply chains.

The global context in the study is particularly interesting, as much food waste occurs in these supply chains. The categorisation and analysis of packaging-related paradoxes in this study offer a more detailed understanding of challenges to design and select packaging. The insights from the analysis should also help improved packaging management, which in turn should have a potential to lead to improved packaging solutions with less food waste. We do not claim that this is the final solution to eliminate food waste, but it is a step in the direction to better understand packaging logistics in global food supply chains, which should lead to reduced food waste.

Food companies in global supply chains can learn from the results of this case study. The study can inspire such companies to look beyond the traditional trade-offs of packaging performance. Food companies can use the analyses in this paper and apply the four categories to their specific contexts.

To extend and deepen the results of this paper, future research should collect empirical data from more cases.

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FIRM SIZE AND PROCESSED SEAFOOD SUPPLY CHAIN MANAGEMENT PRACTICES: INSIGHTS FROM THAI SMEs

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ABSTRACT

The purpose of this study is to empirically examine the current manufacturing practices in processed seafood supply chain management, looking at size difference between specific manufacturing organizations: community enterprises and family businesses. A survey was utilized for data collection from processed seafood producers. It was administered by the leaders or owners of the community enterprises and family businesses. Descriptive statistics, F-test and T-test statistics were used in order to fulfil the objectives of this study. The results indicated community enterprises have a significantly higher potential than family businesses in terms of process delivery. However, community enterprises and family businesses performed equally in terms of process planning, sourcing and making. Specific problems regarding supply chain management practices are provided. The findings should assist both community enterprises and family businesses to implement more efficient processes, leading to higher performance.

INTRODUCTION

Supply Chain (SC) practices have seen a shift towards achieving mutual benefits, sustainable practices and competitiveness (Jalalvand *et al*., 2011). This has led to challenging issues, especially for the food industry, characterized by dynamic and constantly changing customer demand (Ghadge *et al*., 2017). Processed Food Supply Chain Management (PFSCM) can be defined as all food that has gone through some value addition and may or may not have been through the cold chain based on the nature of the product under Supply Chain Management (SCM) (Mahajan *et al*., 2017). In Thailand, the contribution of processed seafood products to the export total was 20.2 percent (Kasikorn, 2017). Canned tuna and shrimp products are the two main processed seafood goods, which provided over 70 percent of total food exports.

The Supply Chain Operations Reference (SCOR) model is a process orientated approach that provides a standardized language to communicate among SC partners in terms of Plan, Source, Make, Deliver, and Return (Lockamy and McCormack, 2004; Mccormack *et al*., 2008), and to gain a better design of the SC network (Hwang, *et al*., 2008). The model is widely accepted because it can provide a standardized language to express performance measures (attributes and metrics) of an SC. Additionally, it assists firms in mapping, developing and referencing SC operations, evaluating and monitoring levels of SC performance (Rotaru *et al*., 2014). The SCOR model can be used to consolidate and categorize the processes within an SC and is widely used by people who are directly involved with SCs such as professionals and academics. Therefore, it has become the method for talking about benchmarking and comparing SCs and SCM practices (Lockamy and McCormack, 2004; Mccormack *et al*., 2008; Rotaru *et al*., 2014).

Manufacturing practices differ across the size of industry as well as country (Caglino *et al*., 2001; Bourlakis *et al.*, 2014). There are not only medium and large sized firms, which have an effect on competitive pressure, but also micro and small-sized firms (Bourlakis *et al.*, 2014). Small and medium scale businesses also play a vital role in terms of providing employment opportunities, strengthening industrial linkages, potential markets both national and international (Islam and Karim 2011). Thailand's government realized the importance of small and medium sized businesses and have tried to improve agricultural products, price fluctuation and to empower people by making them more self-reliant. Therefore, community enterprises were developed. There has been a rapid increase of registered businesses across Thailand. According to the Department of Agricultural Extension, there were 104,206 community enterprises as of 2019 (Department of Agricultural Extension, 2019). This idea is related to the "*Sufficient Economy*" philosophy, perceived and developed by his Majesty King Bhumibol Adulyadej of Thailand, which aims to create balance and stable development at all levels, for the individual, the family and society.

Therefore, with the specific characteristics of community enterprises and the high number of registered businesses, it is valuable to evaluate the SCM practices between the community enterprise and the common family business, as there has been a lack of prior research. Therefore, this research intends to fill this gap in the literature. Our research question can be identified as "What are the differences between the processed seafood SCM practices of community enterprises and family businesses?" This study is based on the four decision areas provided in the SCOR model: plan, source, make and deliver. The following sections provide a review of prior literature, the research and data collection methods, and the data analysis and results. Consequently, a discussion of the results and final conclusion are provided.

LITERATURE REVIEW

SCOR model was developed by the Supply Chain Council with the aim of assisting SCM across firms and benchmarking to increase the effectiveness of their SCs (Lockamy and McCormack, 2004). It is the most popular framework for the measurement of performance based SC processes (McCormack *et al*., 2008; Lima-Junior and Carpinetti, 2016; Gawankar *et al*., 2016). It is used to evaluate and improve enterprise-wide SC performance based on a plan, source, make and deliver framework (Stewart, 1997). Hoole (2005) explained the four process elements; "Plan" refers to all SC activities including demand management, sales and operations planning and overall SC strategy planning, "Source" includes the association of supply sources and the implementation of material and services sourcing on an ongoing basis, "Make" covers all the activities performed internally, and "deliver" refers to taking and fulfilling customer orders, related to the management of distribution infrastructure and outbound transportation. According to Saccomano (1998, p. 27) *"SCOR isn't meant to be a one size fits all solution for doing business. Instead, it is supposed to give organizations a common language to discuss supply-chain issues, develop benchmarking measurements and give direction to the development of supply-chain management software"*.

There is some past research that is related to the SCOR model, for instance Lockamy and McCormack (2004) explored the relationship between SCM planning practices and its performance by using the SCOR model for evaluating the four areas; plan, source, make and deliver, on a scale of 1 (poor) to 5 (excellent). Their results indicated that the measurements from practices in terms of demand planning, supplier transactional collaboration, making planning processes and delivery processes provided the highest impact. Hwang, *et al*. (2008) identified the metrics of the sourcing processes by using the SCOR model in the thin film transistor-liquid crystal display industry in Taiwan. Their results presented a step by step plan for the SCOR model to ensure improvements in the company processes, looking at manufacturing, transaction flow and new product development. Rotaru *et al*. (2014) presented a theoretical analysis of the coverage and integration of the risk management processes into the SCOR model in order to suggest improvements for managing SC risks that contribute to the SCOR model. Regarding the relationship between the SCOR model and firm size, Islam & Karim (2011) investigated the SC performance in SMEs, and large sized firms across various types of manufacturing industries. Their results indicated significant differences in the strategic approach between SMEs and large manufacturers. Bourlakis *et al.* (2014) investigated the performance differences between micro, small and medium-sized firms, looking at the SC members' roles, including producers, manufacturers, wholesalers and retailers in a Greek dairy SC.

It is necessary for different sized firms to have different sustainable measures that are appropriate and context specific (Hassini *et al*., 2012; Bourlakis *et al.*, 2014). Regarding the size of firms, the differences between small and medium-sized enterprises (SMEs) and large firms have been recognized by previous literature (e.g., Hassini *et al*., 2012; Ghadge *et al.*, 2017). For instance, large-sized firms provide significantly higher rates of financial returns compared with SMEs (Ghadge *et al.*, 2017). Pradabwong *et al*. (2015) also asserted that medium-sized firms are usually limited in terms of resources and they are more focused on cost reduction and sales growth, whereas large firms have the ability to provide resources, larger budgets and tend to look at the long term benefits, such as their overall competitive position.

In Thailand, small and medium-sized enterprises (SMEs) are usually the same type of organizations (Naipinit *et al*., 2016). Family run businesses are often managed and financed by the owner or members of the family (Naksung and Piansoongnern, 2018). In addition, community enterprise has been legally recognized in Thailand since 1997 (Naipinit *et al*., 2009). It refers to a group of people in the same community that are officially registered to work together to improve their community's economy, emphasizing self-sufficiency rather than profit. Hence, all community enterprises have to register with the Department of Agricultural Extension, Ministry of Agriculture and Cooperatives. The benefits for community enterprise are the involvement and support from government agencies such as the local administrative organization, the Bank for Agriculture and Argricultural Co-operatives and nongovernmental organizations (Grisanaputi, 2012). However, it needs to abide by government regulations. For example, the Department of Agricultural Extension, 2019 says, (i) it has to involve at least seven families in the community, working together jointly; (ii) the main purpose must be to improve the overall community standard of living and self- reliance; and (iii) the business must be evaluated to satisfy moral standards. Hence, people in the same community work collaboratively and respond to anything within the business operation, for instance finance, design, production, packing and selling. The products are mostly based on the unique and original knowledge that has been transferred from generation to generation (Naipinit *et al*., 2009). It is more concerned with using local material for production, based on local cultural and traditional considerations in the creation of their products.

Many community enterprises depend on government agencies to organize their enterprise, assess their market, help them to join producer networks and deliver a product and service that results in customer trust and help them to expand their market base (Laiprakobsup, 2018). However, many community enterprises in Thailand face a number of problems, for instance a lack of marketing knowledge and skills, financial issues, lack of government agencies' support (e.g., training and knowledge), product and package design and a lack of technological, innovative and development skills (Sakolnakorn and Naipinit, 2013; Naipinit *et al*., 2016). As regards the production processes, there is usually a lack of materials, so they usually have to buy materials from suppliers. However, they are unable to control or influence the price of their raw materials and delivery time (Naipinit *et al*., 2016). Fader *et al*. (2010) studied the problems related to the development of community enterprises in Uganda and India. They found that government agency policies lead to delays in the production process and connection to the market. Therefore, some community enterprise have decided not to rely on government agencies for assessing the market and decided to build their own networks and access the market directly.

There is a number of previous research regarding SC performance measurement (e.g., Lockamy and McCormack, 2004; Hwang, *et al*. 2008; Bourlakis *et al.*, 2014; Gawankar *et.al*., 2016). Hence, prior SCOR model research has been more focused on detailed application for specific industries or specific processes (E.g., Hwang, *et al*., 2008). However, the majority focus on providing a SC performance measurement in general via medium and large sized manufacturing operations (e.g., Hwang, *et al*., 2008; Field and Meile, 2008; Pradabwong *et al*., 2015). Only a little of the past research has considered the more specific context of micro and SMEs (e.g., Islam & Karim, 2011; Bourlakis *et al.*, 2014). Therefore, this study is focused on micro and small businesses, the main contribution of this study is to identify the differences between the processed seafood SCM practices of community enterprises and family businesses.

METHODOLOGY

The data was collected by survey, and a questionnaire was developed based on prior literature (e.g., Lockamy and McCormack, 2004; Hoole, 2005; Islam & Karim, 2011; Lima-Junior and Carpinetti, 2016; Gawankar *et al*., 2016) to cover the main constructs of plan, source, make and delivery. The answers are mainly based on a five-point Likert scale. The survey also included some specific open-ended questions regarding problems and suggestions of SCM practices, so as to gain a deeper understanding concerning some specific issues, resulting in more intense evidence from key practitioners. Therefore, there were questions such as (i) describe a current situation of process of planning, sourcing, making, deliver; and (ii) describe any obstacle in the SCM practices. A pretest and pilot test were utilized for item refinement and content validation. The responses were based on the criteria of family businesses and small community enterprises from Thai processed seafood producers in Rayong and Chonburi provinces, which are the main areas of processed seafood production in Thailand. The target respondents were community leaders or responsible people who have knowledge of all the business operations of the enterprises and family businesses, with 48 community enterprises and 33 family units being the target population for the data collection. The data collection started with a telephone call in advance to make an appointment, then personal interviews were carried out, with the interviewer going to their premises, asking them questions and evaluating the answers. The survey period was from July to September 2018.

ANALYSIS

There were 60 usable responses, providing a response rate of 74.07%. 50% of the participants were from community enterprises and the rest were from household units. The majority of the respondents from the community enterprise were the head of the team (80%) whereas the majority of the respondents from the family units were the business owners. The main items produced were: shrimp paste, fish sauce, dried squid, sweet fish and fish crackers. It was found that only 50% of community enterprises and 37% family units were certified for food standards (e.g., Good Manufacturing Practice; GMP and the Food and Drug Administration). Non-response bias was utilized using the Chi-square test. The results indicated that the data was free from non-response bias.

The measure variables of plan, source, make and delivery were analysed by using T-test statistics to compare the mean difference between the two groups of processed seafood producers by using Minitab 17. Table 1 shows the measurement variables of all the constructs, providing 10 items to measure plan, 7 items to measure source, 8 items to measure make and 5 items to measure delivery.

Table 1 Descriptive statistics for community enterprises and family businesses

Constructs and items	Community enterprise	Family business

	Mean	Std.	Mean	Std.
Plan	4.299	0.485	4.247	0.923
P1: Be able to find the main raw materials	4.27	0.944	4.20	1.038
P2: Provide enough quantity of the raw materials	4.43	0.935	4.28	1.01
P3: Be able to make production planning in advance	4.18	0.907	4.22	0.881
P4: Provide enough facilities to support the production plan (e.g., storage room and production facilities)	4.23	0.858	4.35	0.732
P5: provide flexibility to respond to the needs of customers (e.g., change of customer demands)	4.30	0.952	4.27	0.972
P6: Provide enough alternative sources to support demand variation (e.g., back up sources of main raw materials)	4.41	0.501	4.37	0.525
P7: Be able to produce based on customer demands	4.73	0.583	4.75	0.544
P8: Provide facilities to transfer products to customers (e.g., transportation)	4.71	0.644	4.83	0.501
P9: Provide diversity of product distribution channels (e.g., front shop and selling products online)	3.77	0.679	3.73	0.660
P10: Availability of basic facilities such as utilities, electricity and energy sources	3.96	1.083	3.72	1.341
Source	4.205	0.484	4.212	0.425
S1: Easy access to the sources of the main raw materials	3.40	1.404	3.67	1.422
S2: Provide enough sources of raw materials to serve the production processes	4.53	0.730	4.39	0.891
S3: Appropriate price of raw materials	3.33	1.061	3.43	1.079
S4: Raw materials from suppliers that meet requirements	3.73	0.450	4.70	0.497
S5: Ability to negotiate with the suppliers	4.13	3.44	3.96	0.587
S6: On-time delivery of the main raw materials from suppliers	4.70	0.750	4.78	0.677
S7: Transportation costs of the main raw materials are acceptable	5.00	0.000	4.67	0.522
Make	4.473	0.273	4.383	0.333
M1: The production is related to the production planning	4.48	0.58	4.37	0.747
M2: Be able to produce products based on customer needs	4.80	0.407	4.82	0.39
M3: Provide enough raw materials based on the production planning	4.13	0.86	4.03	0.938
M4: No disruption in between the production processes	4.23	0.504	4.30	0.619
M5: Provide appropriate equipment in the production processes	4.63	0.576	4.65	0.520
M6: the design of packaging is related to product quality (e.g., compatible with light, waterproof, convenience of storage)	4.60	0.563	4.13	1.065
M7: Provide an accuracy of weight of each package	4.53	0.681	4.34	0.940
M8: Provide appropriate areas for storing finished goods before sending to distributors	4.46	0.508	4.46	0.753
Delivery	4.639	0.326	4.424	0.486
D1: Provide systematic customer information management (e.g., data recorded of customer purchases, quantity and time for delivery)	4.20	0.941	3.67	0.929
D2: Provide account management for selling and purchasing products systematically (e.g., on-time payment from customers)	4.59	0.501	4.25	0.851
D3: Appropriateness of transportation costs	4.90	0.316	4.87	0.344
D4: On-time delivery of products to customers	4.79	0.559	4.80	0.581
D5: An appropriateness of transportation options to transfer products to customers (e.g., route of delivery and transportation safety)	4.70	0.571	4.74	0.644

Then F-test was performed to see whether there was an equal variance between the two groups. Then, T-test statistics were used to analyze if there were any significant differences between processed seafood supply chain management practices (plan, source, make and delivery) when grouped by community enterprises and family businesses. Table

2 shows the results of the data analysis. As regards "plan", the statistical results indicated that there were no significant differences (T-test = 0.23, p-value = 0.822) between the community enterprises and family businesses. The results also showed no significant difference of SCM practices in terms of sourcing (T-test = -0.06, p-value = 0.953) among those two groups. The results also found no significant difference between community enterprises and family businesses in terms of process making (T-test = 1.14, p-value = 0.257). Lastly, looking at delivery, the results show that community enterprises performed better than the family businesses with a T-test = 2.01, p-value = 0.05.

Table 2 Data analysis results

Construct	**Mean (Std.)**		**F-test (p-value)**	**T-test (p-value)**
	Community enterprise	**Family business**		
Plan	4.29 (0.485)	4.247 (0.923)	0.28 (0.001)	0.23 (0.822)
Source	4.205 (0.484)	4.212 (0.425)	1.30 (0.488)*	-0.06 (0.953)
Make	4.473 (0.273)	4.383 (0.333)	0.67 (0.290)*	1.14 (0.257)
Delivery	4.639 (0.326)	4.424 (0.486)	0.45 (0.035)	2.01 (0.050)**

*Equal variances**significant at 0.10

The key findings from the open-ended questions during the interviews are that community enterprises and family businesses both faced problems with a fluctuation of raw material prices (e.g., shrimp and fish) due to the weather. This was especially true, during the monsoon season when they found it difficult to find a supply of raw materials. Additionally, there were some changes regarding the fishing laws on the issue of ship issuance and license, causing a reduction in the number of fisherman in the local areas. Hence, there was instability with the production planning process (e.g., unable to schedule production, production capacity management and production dates), causing missing production plans for both the community enterprises and family businesses. In addition, there were limitations regarding sourcing distribution. The relationship between producers and suppliers (local fisherman) has to be seen as a long-term collaboration, since they have worked together for more than 5 years. However, both the community enterprises and family businesses were supplied from the same local raw material sources (same ports), and they lack the ability to find new suppliers. Regarding the diversity of product distribution channels, community enterprises usually provide their own storefront for retailing and wholesale operations with their main customers being local people, therefore it is easy to deliver goods to the customers.

CONCLUSIONS

This study empirically identified the difference between community enterprises and family businesses, highlighting practices and management in the processed seafood SC, focusing on planning, sourcing, production and delivery. The results enhance our understanding of the efficiency of these two entities, and how they contribute to the improvement of their SCM practices. More specifically, the results reveal that there are no significant differences of SCM practices in terms of *process planning, sourcing and making* between community enterprise and family business. This is consistence with the information received from the open-ended questions during the interviews, indicating community enterprises and family businesses are reliant on the same suppliers, whose prices and availability are liable to fluctuate depending on the seasons, and weather and regulation requirements. Hence, this has resulted in a lack of ability in planning, sourcing, and producing processed seafood to the market. The findings are in line with prior research, for instance Fader et al. (2010), Sakolnakorn and Naipinit, (2013), Naipinit et al., (2016) who identified the problems regarding process planning in community enterprises. Moreover, the results reveal that community enterprises performed better than family businesses in terms of process delivery. In addition, the community enterprises provide a more systematic approach to customer satisfaction management in terms of acquiring a data record of customer purchases, the quantity and delivery details. It also provides a more systematic approach to account management, having information for items such as on-time payment from customers. The interview results also provided information, which supported this evidence. Community enterprises have government agencies' support; therefore, they have the ability to provide a diversity of product distribution channels and transportation options to transfer products to their customers. These results are consistent with previous studies (e.g., Grisanaputi, 2012; Laiprakobsup, 2018) who indicated that government agencies' support leads to community enterprises gaining advantages in terms of assessing the market, networking and delivering products to customers.

Past research (e.g. Bourlakis *et al.*, 2014; Ghadge *et al*., 2017; Mahajan *et al*., 2017) has identified the challenge and importance of food SCM, especially in small and medium-sized enterprises and so for small communities. Our study provides empirical based evidence, using an explicit comparison of processed seafood SCM practices between community enterprises and family businesses by using the SCOR model, providing a deeper understanding of SCM practices for processed seafood. Therefore, the findings should assist both community enterprises and family businesses to implement more efficient processes, leading to higher performance. The results can be used as a guideline for improving the SCM practices of both Thai community enterprises and family businesses.

ACKNOWLEDGEMENTS

We would like to acknowledge the contribution by Miss Aunnada Manathanya and Mr. Haris Buranawanich in the questionnaire development and data collection phases.

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3D FOOD PRINTING IN EUROPE: BUSINESS MODEL AND SUPPLY CHAIN ASPECTS

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ABSTRACT

Purpose: 3D food printing is an emotive and interesting business proposition that has caught the attention of the media, as well as the imagination of entrepreneurs. Several 3D food printers are now commercially available but are currently primarily used for niche applications such as printing bakery decorations, to make easy to eat meals for patients with chewing/swallowing conditions and for 'pop up' restaurant meal experiences. Indications are that the next few years are likely to bring newer, more mainstream applications, processes and materials (Brunner, et al., 2018; Dabbene, et al., 2018).

This paper reports on a study that conducts a comparative analysis of consumer and companies' expectations for the future development of additive food manufacturing in Europe. More specifically, with a focus on business model and supply chain implications, the project goals were to identify use cases of 3DFP in European and especially German-based companies; gauge consumer perception of- and interest in 3D printed food and evaluate risks and opportunities.

Design/methodology/approach: The study involved a) analysing the websites of existing and developmental 3DFP firms b) conducting semi-structured interviews with managers (from both 3DFP and food engineering firms) and c) carrying out an online consumer survey to gauge consumer appetite for 3D printed food. This information was then analysed in terms of the implications for business models and supply chain configurations (Braziotis, et al., 2019; Rogers, et al., 2016; Rogers, et al., 2018).

Findings: The consumer survey was answered by 200 respondents from 23 countries. The key findings were that 3D printed food is currently not perceived as something suitable for everyday life (indeed over 50% are unsure how they feel about 3D printed food) but rather better as 'decoration' or as a product for people with special nutritional needs. The main risks and challenges identified by discussions with the 3DFP and food engineering managers were; technical feasibility, customer perception, production time (duration) and total supply chain cost. The biggest challenge is the need to clearly identify the market. Layered food manufacturing is such a novel technology that it is necessary to demonstrate its value and ease of use to convince customers of its potential.

Value: The burgeoning interest in 3DFP (e.g. number of journal articles and online content) indicates the business potential of this technology. By analysing market data on 3DFP investments and current academic literature on applications of the technology and associated business models, we provide a useful overview of potential future developments and expectations in this field. The inclusion of opinions from both industry experts and consumers ensures relevance.

Research limitations/implications: One of the most important challenges of the research is that 3DFP is in the very early stages of commercialisation. This makes market data difficult to verify. However, now is the time for emerging 3DFP companies to determine what their business models and in particular, what their supply chains should look like, making this research timely.

INTRODUCTION

Rising public concern for health is leading to the emergence of new food trends that focus on lifestyle and healthy nutritional concepts. This is driving a market growth for personalised healthy nutrition, aimed to adapt and create nutrition tailored to the individual's needs. Such requirements cannot be fulfilled using traditional food production methods, even those using advanced processing technologies. Three-dimensional food printing, also known as food layered manufacture (FLM) or additive food manufacturing (AFM), has the potential to satisfy these requirements.

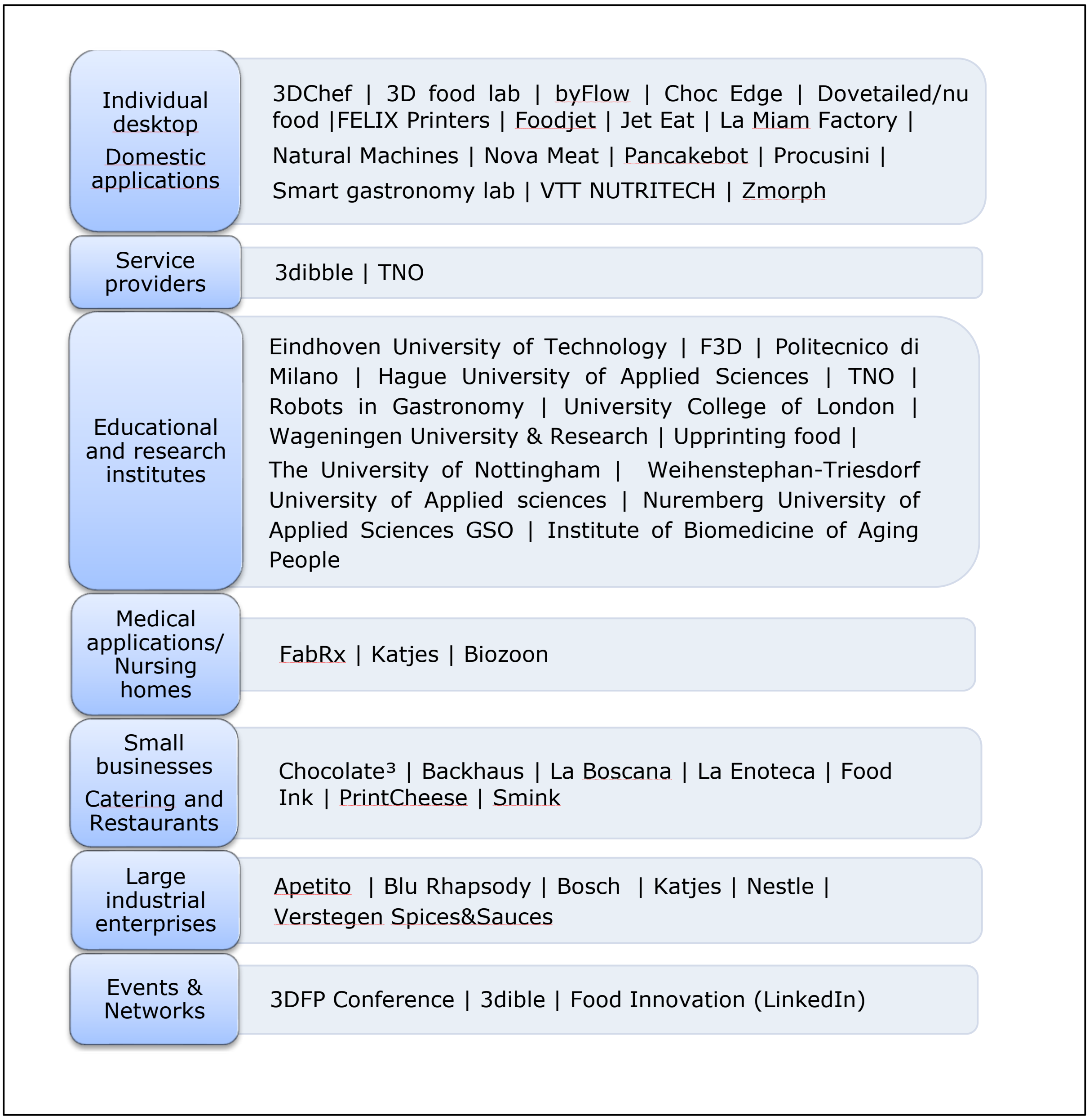
This study analyses 3D food printing as an attractive emerging technology in food engineering, evaluates opportunities and investigates challenges related to supply chain changes and business model development. Based on the market data analysis, as well as interviews conducted with experts from companies working with 3DFP technology and existing literature, this paper provides a review of the potential supply chain changes and emerging business models. It furthermore offers insights into challenges, risks and opportunities faced by 3DFP companies in Europe and particularly in Germany.

LITERATURE REVIEW AND MARKET SEGMENTATION

The increasing number of academic publications on 3D food printing technologies and the related development perspectives reflects the growing interest in this area of research. The 3DFP market spans a network of R&D institutions, production and installation, marketing activities, sales / after-sale support and customer services (Markets Research, 2017). Current benefits include product differentiation, product customization, and direct-to-consumer relationships (Porter, et al., 2015). Market growth is mainly driven by the raising awareness of the need to upgrade food production systems. Growing concerns regarding global food safety and sustainability have led to significantly increased investments from food engineering businesses around the world. The global 3D food printing market is boosted by the growing demand for customized foods with tailored nutritional contents (BIS Research, 2018).

3DFP has the potential to decrease food waste by recycling ‘inferior’ foods such as meat, fish and seafood scraps and distorted fruit and vegetables that would otherwise become landfill. Consumers are, furthermore, increasingly interested in using renewable food sources such as insects, algae, duckweed, grass, lupin seeds and beet leaves to produce foods that satisfy their taste requirements (Prakash, et al., 2018). A limitation of FLM is that most machines were initially developed for non-food purposes; meaning compromises are inherent in the food production process. This affects in particular the creativity of the design and the achievable likeness in terms of ‘look and feel’ of the end product (Pinna, et al., 2016). Another challenge is adjustment of printing parameters to mechanical behaviour variations that exist in in each food ‘raw material’ according to environmental conditions (Rubio & Hurtado, 2018). The 3DP business model industry involves switching from centralized to decentralized manufacturing. Consequently, 3DP could facilitate the shift from traditional mass production to large-scale customisation (Janssen, et al., 2014). To achieve economic sustainability of 3D food printing, a robust and viable business model is needed. Based on existing literature, 3DFP market segments can be classified into several clusters (as shown in Figure 1 European market stakeholders), including service providers, research institutes and end users such as nursing homes (Jayaprakash, et al., 2018).

Figure 1. European 3DFP market segmentation

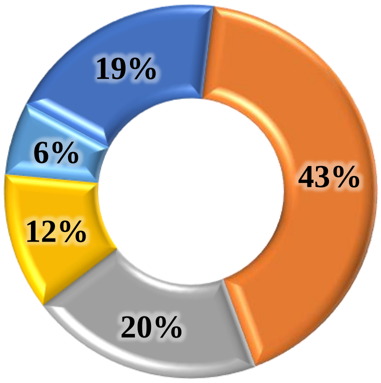


Source: own representation based on conducted research

INTERVIEWS WITH EXPERTS AND CUSTOMER SURVEY

To identify customer attitudes towards 3DFP, an online survey was conducted (200 participants from 23 countries, aged 18-45). The results revealed most potential consumers are not yet ready for 3D food printing technology (see Figure 2). 60% of participants had never heard of 3DFP and many respondents answered that they prefer food in its purest/most natural form. The majority does not perceive 3D printed food as being suitable for everyday life, believing it is art rather than food, better as food decoration or to assist people with special nutritional needs. However, 27% are excited about the technology and its future perspective. Summarising opinions, the data shows 3D food printers could be successful as regular kitchen devices only if the consistency of real food could be reliably reprinted. Over 50% are unsure how they feel about 3D printed food. It is seen as 'innovative' but 'unnatural'. There was a willingness to try it at least once but not to incorporate 3DP food into their everyday life.

Figure 2. Customer attitudes towards 3D printed food



A lack of understanding and the name of the technology (which is perhaps related to equipment originating from the non-food industry) prevents consumers from gaining an appreciation of the main characteristics, appearance and potential benefits of 3DFP. Conversely, these consumers are cautious in their attitudes towards the technology. The word "printer" makes people perceive 3D printed food as artificial, although it is freshly processed. A key challenge facing the 3DFP industry is to change this 'false' perception of printed food (Stachura, 2018). Customer perception and attitude towards 3DFP is a decisive factor for the further commercial success the technology. According to a quantitative study conducted among German-speaking residents from Switzerland, the presentation of various applications of this technology in food preparation and the underlining of 'consumer value' throughout the survey have considerably and positively influenced the attitudes of the surveyed public, whose overall perceptions remained varied and negative (Brunner, et al., 2017).

Semi-structured interviews were conducted (Oct 2018-Feb 2019) to identify opportunities, challenges and risks faced by 3DFP companies. To date, customers purchasing 3D food printers have primarily been businesses such as chocolate manufacturers, confectioners, caterers and restaurants. The main application for this market is customised designs and complex shapes to print for events (Fink, 2018). In the research period contact was made with 21 companies and 12 agreed to be interviewed. Additionally, 2 interviews were conducted with specialists working in the area of innovative food engineering. One of the organisations interviewed is not indicated on the map by request of the company representative. The interviewed experts represent organisations across the supply chain; food manufacturers, hardware & software, services, and market research organisations. As such they have varying visions and goals within this emerging market, as indicated by an extract of the responses in Table 1.

Table 1. Comparison of selected interview aspects

	Biozoon Germany	Katjes Germany	TNO Netherlands
Focus Product	Hydrocolloid developments; Specialised in elderly nutrition, suffering from dysphagia	First food-certified 3D fruit gum printer for on the market (FDA and FSA approval)	Contract research for industrial companies; Prototype printers; Process research; Software engineering; Consultancy

Technology	Fused Deposition Modelling (FDM)	FDM; New, internally developed technology	FDM; Binder jetting; Selective laser sintering; Combination of the three; FDM without heating element
Target customer group	Nursing homes; Gastronomy	Confectionery retailers; Event organisers	Companies working with 3DFP
Future developments	Printers using more than one printing head for production of food series	New 3D printers for printing personalised medicines and nutrition	Open source software that anyone can use
Challenges	Technical feasibility; Quality of printed food; Customer perception; Timing	Customer perception	New food textures; Researching industrial food printing; Scale up

Source: own representation based on conducted research

ByFlow offers a bundle of 3D food printing concepts. Their customers prefer to have planned solutions rather than researching for themselves what could be done. Consumers expect to have answers without having to ask and that is what their company tries to deliver. The experts aim to create new production methods, which are capable of producing personalized and customized food on a large scale and to industrialize 3D food printing. Currently, one machine specializes in producing one product type. Therefore, specialists work on creating a flexible system, which can adapt easily to production changes and create 'multitasking machines', which are able to make different foods. The ByFlow respondent believed it will be possible to create printed food very flexibly even at an industrial level. ByFlow does not, however, consider home use as important development direction in the next 5-10 years, as the business case for home use is hard to prove. Home kitchen appliances should be easy to use, make the food preparation simple and reduce costs. It is more complicated to print food than to prepare it by hand. 3DFP machines from Blu Rhapsody are also not suitable for home use and as such, the company is focused on further industrial applications of 3DFP technology.

3D food printing is a relatively young concept, mainly used by industry professionals and enthusiasts/early adopters. Despite this, some companies working with the technology believe that with the next 10 years people will start to have 3D printers in their kitchens to make food for their everyday meals. For now, 3D printed food is still considered as 'futuristic' and consumers need to get used to the idea. The interview respondents believed that restaurants and catering services are currently the main target customer group. Solutions for other target groups such as people with special nutrition needs and those doing sport / nutrition conscious consumers also have strong future potential.

The growing demand for customized services fosters direct manufacturing of personalized food products and requires redesigning of supply chain strategies. 3DFP companies are working on the development of new solutions that are needed to fully exploit the benefits of FLM and integrate it into future supply chains. Changes in the manufacturing process will also directly impact the packaging requirements.

Transportation is a major challenge within the supply chain, and it will become even more difficult after switching to larger production volumes. Printed food needs to be temperature controlled (e.g. chilled or frozen), unless it is an ambient foodstuff such as chocolate. This can potentially be overcome by changing the food structure (i.e. to make it solid) but there is a need for further market research in this area. In the case of Biozoon, researchers do not face such supply chain-related problems, as the company provides gelling agents and users are printing their own end product freshly at home/in kitchens. Printers from Katjes are mostly located in retail outlets. Here customers place an order, which is printed directly by the retail staff and packed in Magic Candy Factory packaging (box and a bag). In terms of sales to retailers, following on from order placement they get products shipped, to be able to print the product in their stores. Companies that have a B2B business model and do not ship to end consumers are not expected to have major changes in the supply chain. To control the supply chain and ensure that products and services are of the best quality, ingredients as well the software are developed internally.

DISCUSSION

To date, very few of the companies in the 3DFP market are making a profit from these activities. For this to change and for 3DFP to become a commercial success, additional steps need to be taken. The product portfolio offered to consumers needs to be significantly expanded. This means among other things switching from a focus on 'nice shaping' towards real personalization of ingredients to create higher value added for consumers. TNO in particular conducts research in the direction of industrial food printing and this will become a business case for them in the near future.

Already a basic mass market desktop 3D food printer is not too expensive and there are people who are buying them. However the market is very small and there is not a sufficient critical mass to go to the next level of adoption.

In terms of future market and business case development, an important question to address is: who are the direct and indirect competitors in the industry? Some enterprises have developed their patented technologies internally and not yet willing to share the innovation yet. This makes it hard to forecast and evaluate the future market situation. Some believe that 3DFP is still too niche and that all the companies in the branch are competitors of each other. Others believe that the market is too small to analyse the competition and it would be more beneficial if companies would work on common projects for further technology development. The third opinion is that there are no competitors currently because the technology itself is not sufficiently advanced. We suggest that that neither the technology nor the market are yet at the level where the competition is strong.

The research and development is largely focused on small firms/start-ups, indicating that the large organisations are playing a wait and see game prior to committing to the 3DFP market. This could lead to an active round of mergers and acquisitions as the market matures.

CONCLUSIONS AND IMPLICATIONS

The findings of this study identified opportunities, risks and challenges associated with developing business models for companies in the 3D printed food industry. It confirmed that currently, 3DFP is small scale, immature/experimental and fragmented (in terms of industry players). Crucially, customers are not yet ready or do not feel sufficiently informed to accept it as a replacement for conventionally produced food. Companies currently in the market require further R&D investment, a broader product range (particularly in terms of the variety of ingredients that can be used for printing) and increased levels of industrialization. Individual customization is likely to be a key driver for future successful business models, which presents considerable supply chain challenges. Further investigation of supply chain requirements and implications, will form the basis of the next steps of this research.

ACKNOWLEDGMENTS

The research presented in this paper has been kindly funded by the Kettel Stiftung. The authors of the paper wish to acknowledge the funding and express their sincere thanks for the support.

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Session 5: Inventory and Warehousing

CASE STUDY BASED MULTI-PARAMETER OPTIMIZATION AND SIMPLIFICATION OF EOQ MODEL TO REDUCE THE NEED FOR DATA

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Purpose
As most models focus on a specific question (Alard et al., 2014), the effect of multi-parameter optimization is surveyed in the presented paper. To overcome the often cited data availability problem, when implementing Total Landed Costs (TLC) or Total Costs of Ownership (TCO) models, the paper surveys the capability of simplified models, which need much less data.

Design/methodology/approach
Multi-parameter optimization is applied in a real-world case study in industrial goods industry. The model is derived by an eight-step approach, which is proposed by Ellram (1993) and which was already applied by Bremen (2010) for deriving TCO models. The reduction of needed data is done by Linear Regression, whereas the results are validated by a Monte-Carlo-Simulation.

Findings
The paper shows, that multiple parameter optimization exceeds results of classic EOQ models many times over, showing also the effect of different optimization parameters on cost categories. Furthermore, simplified, models enable a deviation of minimum total costs, of below 5%.

Value
This paper (1) shows the effect of multi-parameter optimization by an Economic Order Quantity (EOQ) model, allocating the effects per optimi-zation parameter to cost categories. Furthermore, (2) the by linear regression derived simplified models show relatively good accuracy, reducing the number of independent variables considerably. Therefore, the results support purchasing and supply chain managers in inbound logistics optimization to increase cost reductions by models capable of multi-parameter optimization and helps to overcome one of the most often cited data availability problem.

Research limitations/implications
In order to show models, which enable process parameterization, it is recommended to intensify research on the topic of multi-parameter optimization as well as on the accuracy of models in case of reduced data availability.

Practical Contribution
The paper suggests to derive similar models by an eight-step-approach, which was originally proposed by Ellram (1993) for TCO models. These models have to be capable to answer multiple questions. Optimization parameters have to be chosen based on the cost categories and their share in the as-is-situation. In case of a data availability problem, the paper suggests to derive easier models by Linear Regression

INTRODUCTION

Models shown in the literature are usually tailored to one or a few individual optimization parameters *(Alard et al., 2014)*. As a result, logistics planning in practice is usually still based on the line back principle, in which internal processes are first planned iteratively from the workplace to the warehouse, followed by the subsequent processes to the supplier *(Klug, 2009)*, in most cases experience-based or based on KPIs of the parts *(Maas and Fottner, 2017)*. If companies use models to plan and optimize these processes, data availability and data quality are usually cited as barriers that lead to a low degree of application of these models *(e.g. Pumpe and Vallée, 2015)*. In the presented case study, the data availability was 3.59%, leaving 119 Stock Keeping Units (SKUs) for the numerical study. Therefore, we developed an Economic Order Quantity (EOQ) model with seven cost categories and respect to five optimization parameters, which is implemented in a case study, whereas in previously shown studies a maximum of four optimization parameters have been implemented. But, whereas existing studies doesn´t differentiate the effects and allocate them to each optimization parameter *(Bremen, 2010)*, we survey in the conducted case study the cost reduction potentials per optimization parameter as well as the effect to other process parameters to support strategical and conceptual decisions for supply chain managers. To reduce the problem of data availability and quality, simplified models are derived by linear regression, reducing the number of input parameters drastically to enable the implementation in the industry, beside the data availability problem and achieve a deviation from the cost minimum of below 5%.

This paper contributes to existing literature by (1) surveying the effect of multi-parameter optimization by an EOQ model considering five optimization parameters and allocating the effects per optimization parameter to cost categories in a case study, as well as by (2) deriving simplified models by linear regression with relatively good accuracy measured by the deviation of total costs, reducing the number of independent variables considerably.

LITERATURE REVIEW

Based on the properties of presented model and case study, previous models are analyzed based on the overall degree of similarity as well as similarity in partial aspects of the models. In supply chain literature, different optimization parameters are in most cases treated separately *(Kempkes et al., 2010)*, what´s currently one of the critique points concerning Total Landed Cost (TLC) models in the practical point of view. Therefore, tackling different optimization parameters in one model is needed *(Alard et al., 2014)*. There are numerous models, considering optimization parameters, which are also contained in the in this paper presented model, all of them taking into account at least two of the optimization parameters: transportation mode, EOQ, inventory management, carrier selection, and transport bundling, Just-In-Time (JIT), and the consideration between delivery in disposable containers and repacking or delivery via direct delivery of reusable carriers (see Table 17). Among the analyzed models, a maximum of four parameters are optimized in one model *(Banerjee, 2009; Choudhary and Shanker, 2013; De La Vega et al., 2018; Mendoza and Ventura, 2008)*. There are several models considering transport mode Less Than Truckload (LTL) and one also with respect to milkruns *(Erhun and Tayur, 2003)*. Some of the models calculate LTL transport costs by a freight cost matrix. *Mansendiek (2015)*, who considers repacking costs, takes also return flows of empties into account. Models with multi-parameter optimization, show impressive results: *Degraeve et al. (2005)* implemented a Total Cost of Ownership (TCO) model for defining the purchasing strategy of a European multinational steel company and saved on an average 10% for the considered product groups by changing order quantity, number of suppliers, and market shares. Based on an analysis of different companies where a TCO supplier selection methodology, supported by a management information system, was implemented in case studies, saving potentials of 14.6% and 7% for the product groups resistors, transformers, and PCBs on TCO were identified *(Degraeve et al., 2004)*. *Erhun and Tayur (2003)* developed a TLC model for a retailer to optimize transportation frequency from vendors to stores. This resulted in an increased service level from 98.62% to 99.60%, reduced inventory by 40.3%, and reduced TLC by 20.8%. *Kempkes et al. (2010)* developed a model for optimizing logistics processes from ramp of supplier to production, with 59% of cost reduction. But, each of this models, doesn´t show the effect of each optimization parameter, only the sum. The investigation of the interdependencies of the individual parameters and variables of total cost models is a needed research topic, which visualizes cause-effect networks and identifies elementary cost drivers, giving the basis to simplify cost analyses *(Bremen, 2010)*. Therefore, the potentials of multi-parameter optimization is surveyed and shown in this paper, separately for each optimization parameter.

Table 17: Overview of similar models, concerning parameter optimization

		Decision model																						
		Cost categories							Implementation Transportation							Optimization parameters								
														Trans-port costs										
	Case study	Costs for transport	Costs for stock	Costs for carriers	Ordering costs	Costs for storage space	Repacking costs	Others	Number of considered cost categories	Number of transport modes	Less than Truckload	Milkrun	Flow of empties back to suppliers	Linear	Freight cost matrix	Transportation mode	EOQ - cost optimum order frequency	Inventory management	Direct delivery vs. repackaging	Carrier selection	Transport bundeling	Just-in-time processes	Others	Number of optimized parameters
Chyr et al., 1990	x		x					x	2	0							x					x		2
Degraeve and Roodhooft, 1999	x		x		x			x	5	n.d.	n.d.			x			x						x	2
Erhun and Tayur, 2003	x	x	x		x			x	5	3	x	x		n.d.			x	x			x			3
Degraeve et al., 2004								x	4						x		x						x	2
Degraeve et al., 2005	x	x	x		x			x	7	n.d.	n.d.			x			x						x	2
Feller, 2008	x	x	x	x				x	5	3	x				x	x							x	2
Mendoza and Ventura, 2008		x	x		x			x	5	2	x				x	x	x	x					x	4
Rieksts and Ventura, 2008	x	x	x		x			x	5	2	x			x		x		x						2
Banerjee, 2009	x		x					x	2	2	x			x		x	x	x					x	4
Jearasatit, 2010	x	x	x		x			x	6	3	x			x	(x)	x							x	2
Kempkes et al., 2010	x	x			x				2	3	x				x	x	x	x						3
Choudhary and Shankar, 2013	x	x	x					x	5	2	x			x	(x)		x			x			x	4
Schöneberg et al., 2013		x	x						2	2	x				x	x	x							2
Konur and Schaefer, 2014	x	x	x		x			x	5	2	x			x		x	x							2
Mensendiek, 2015							x	x	2	0			x						x				x	2
Jansson and Nordh, 2016	x	x						x	5	2						x	x						x	3
Saglam and Banerjee, 2018	x	x	x					x	3	2	x			x			x	x						2
De La Vega et al., 2018	x	x	x						2	2	x				x	x	x	x					x	4
Presented model and case study	x	x	x	x	x	x	x		6	2	x	x	x		x	(x)	x	x	x	x	x	x		6

Data availability and quality is one of the most cited barriers, which prevents the intensive use of TLC models in practice *(Bremen, 2010; Carr and Ittner, 1992; Degraeve and Roodhooft, 2005; Ellram, 1993a, 1993b, 1995, 2002; Ellram and Siferd, 1998; Garfamy, 2006; Hurkens et al., 2006; N.N., 2007; Pumpe and Vallée, 2015; Terry et al., 2010; Visani et al., 2016; Wouters et al., 2005; Wynstra and Hurkens, 2005; Young et al., 2009)*. 49% of shippers, which doesn´t use TLC calculations extensively, refer this to a low data availability *(Terry et al., 2010)*. *Pumpe and Vallée (2015)* show in their survey, that "accessibility of cost information" (p. 40) is validated with high relative importance and low perceived performance at companies. Data availability in the case study, presented in this paper, was 3.59%, leaving 119 SKUs for the numerical studies. Therefore, it is of interest to limit the necessary amount of data to a minimum, taking into account the deviation from the minimum costs.

PROCESS AND PROBLEM DESCRIPTION

The process focus is on optimizing the process from supplier´s ramp to storage at the factory. The company has negotiated freight cost rates with transport service providers.

Transport costs are paid, based on a freight cost matrix, with weight on one axis and ZIP codes on the other axis. This transport mode is henceforth called LTL. Additionally, milkrun is validated as an alternative transport mode, which collects deliveries of different suppliers in a certain ZIP code area and delivers it bundled to the factory. Both, reusable and one-way carriers are in use. In addition to the costs of transporting full carriers from the supplier to the factory, return transport of empty carriers to the supplier must be taken into account, for reusable carriers only. If the carrier of the first point of use in the factory is applied for the inbound process, no repacking is required. The one-way carriers can only be used once and therefore have to be procured again for each cycle, while this investment has to be done only once for reusable carriers. In general, it can be assumed that all incoming carriers are first transported to a warehouse. The carriers are stored in racks, within the warehouse. As the company under survey currently builds a new warehouse, which´s dimensions can still be adjusted, a storage constraint is optionally taken into account.

Due to a lack of capacities, tools and know-how, this process area has not been sufficiently optimized to date at the company under survey, and if an optimization is carried out for individual SKUs or suppliers, it is experience-based and comprises only individual parameters. As recommended in literature, the selected parameters make it possible to parameterize the process in order to reduce costs *(Bremen, 2010; Degraeve and Roodhooft, 1999)*. Thus, process changes, which are complex and time-consuming in this process area *(Maas and Fottner, 2017)*, can be reduced, by this multi-parameter optimization.

RESEARCH WORK

As know how is an often named barrier in usage of TLC models *(Ellram, 1993a, 1995, 2002; Wouters et al., 2005; Wynstra and Hurkens, 2005; Young et al., 2009)*, a solution-based search is applied for the presented combinatorial optimization problem, as this approach is easy to understand. The solution based approach optimizes iteratively *(Wu, 2015)* by a greedy algorithm, which chooses for each step the solution, which represents the highest benefit. One of the main disadvantages of iterative optimization is, that instead of the global optimum only local optima are guaranteed. For considering the storage constraint, a drop heuristic is applied, which chooses the variables to do the lowest damage to the objective function, until the constraint can be complied with *(Silver, 2004)*.[17] Due to space constraints, the model is shown in detail in the Supplementary Material. Owed to the complexity of TLC models and the large amount of data normally required, we test a simpler derivation of a model using linear regression. In the present case, various independent variables are tested by different models and compared on the basis of their results and the associated forecast quality of total costs. According to *Boomsma (2000)* the model fit was tested by chi-square, Standardized Root Mean Square Residual (SRMR), Root Mean Square Error of Approximation (RMSEA), Compareative-Fit-Index (CFI) and Tucker-Lewis-Index (TLI). For interpretation, the standardized values are used to be not scale dependent *(Bollen, 1989; Cudeck, 1989)*. For the interpretation of the model the two-tailed significance test for standardized parameters, the Indicator Reliability (IR), the Average Variance Extracted (AVE) and the Composite Reliability (CR) are used. Since no further datasets were available, the linear regression models were validated using data derived from a Monte Carlo simulation, for which 5,000 iterations are done.

RESULTS

The results of the iterative multi-parameter optimization are shown before the simplification of the TLC model with a linear regression model is discussed.

Multi-parameter optimization

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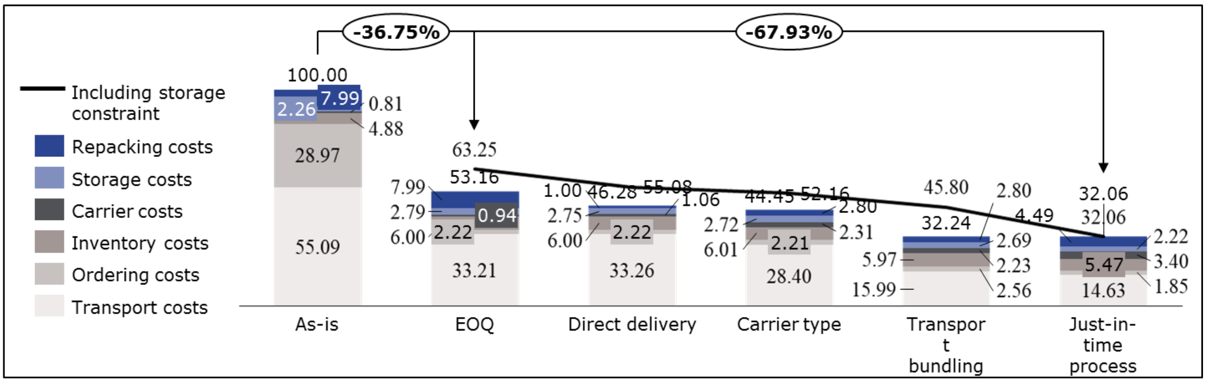
[17] The neighborhood is represented by all combinations for which the order frequency is increased by 1, 2 and 3 days for each SKU. To evaluate the neighborhood, the lowest additional total costs per saved storage places are accepted and this becomes the new solution. This is done as long until the storage constraint is satisfied.

The cost behavior results in an Andler curve, which shows the total costs depending on the Order Frequency (OF). There is a linear increase of cost categories inventory costs C_{st} and storage costs C_{Sp}. On the other hand, there is an inverse proportional decrease of cost categories transport C_{trans}, costs for reusable carriers C_{car}, and order costs C_{ord}. For transport costs, there are smaller deviations due to negotiated freight cost rates. Cost categories repacking C_{rep} as well as costs for one-way carriers are independent of the OF. The basic idea is based on the fact, that even when changing parameters (e.g. changed carrier data), it is essential to define the EOQ again, which was done in each of the optimization iterations, shown in Table 18.

Table 18: Decision variables of multi-parameter optimization

Decision variables	**Solution space**		**Level**
1.) EOQ	1…42 days		SKU
2.) Direct delivery	Repacking	Without repacking	SKU
3.) Carrier type	One-way carriers	Reusable carriers	SKU
4.) Transport bundling	Less Than Truckload	Milkrun	ZIP code
5.) Just-in-time process	Conventional process	Just-In-Time process	Supplier



	As-is	EOQ	Direct delivery	Carrier type	Transport bundling	Just-in-time process
Weighted delivery frequency (by weight)	**7.89**	**18.21**	**18.25**	**18.30**	**17.78**	**13.44**
Repacked SKUs	**77**	**77**	**2**	**25**	**25**	**48**
Relation One-way to reusable carriers	**2 - 117**	**2 - 117**	**0 - 119**	**23 - 96**	**23 - 96**	**73 - 46**
Number of ZIP code areas with bundled transports	**0**	**0**	**0**	**0**	**20**	**20**
Number of storage places	**829**	**1,054**	**1,038**	**1,039**	**1,039**	**653**

Figure 44: Results of multi-parameter optimization

Costs can be reduced by 67.93%, where each iteration optimizes other cost categories. By 1.) determining the optimal OF, ordering costs as well as transport costs can be reduced significantly, whereas by 2.) direct delivery repacking costs can be avoided to a great extent. By adapting the 3.) ratio of one-way to reusable carriers, it is possible to significantly reduce transport costs, since there is no need to return empties for disposable containers. By 4.) bundling the transports via milkruns, transport costs can be reduced to a fraction, while through the 5.) introduction of JIT processes ordering and transport costs can be further reduced. Taking the storage restrictions into account, significant but slightly lower cost reductions are also possible in every iteration except the last one.

Simplification of model

Linear Regression models with 2 to 7 independent variables were created and validated (see Table 19). The model with the lowest number of independent variables, model 2, showed the best performance, with a mean deviation of 4.548% of total costs. It´s surprising, that the model with the lowest number of independent variables performed best, whereas the model with the highest number of independent variables performed second-best.

Table 19: Results of 6 linear regression models

Deviation from the cost minimum solution [%]	Model 1: 2 inde-pendent variables	Model 2: 3 inde-pendent variables	Model 3: 4 inde-pendent variables	Model 4: 4 inde-pendent variables	Model 5: 6 inde-pendent variables	Model 6: 7 inde-pendent variables
Minimum [%]	2.447	3.110	5.220	3.080	3.353	2.863
Mean value [%]	4.548	6.759	8.478	6.448	6.816	4.902
Maximum [%]	7.298	12.166	13.637	12.503	12.058	7.367
Std. deviation	2.960	1.408	1.295	1.556	1.512	0.579

The independent variables of the model with only two independent variables (model 1) are the distance of the supplier and the weight per day's demand. For the model with seven independent variables (model 6) daily demand of carriers, safety stock, carrier costs, material costs as well as daily demand are taken into account as further independent variables. Figure 45 shows the results of the Monte-Carlo simulation.

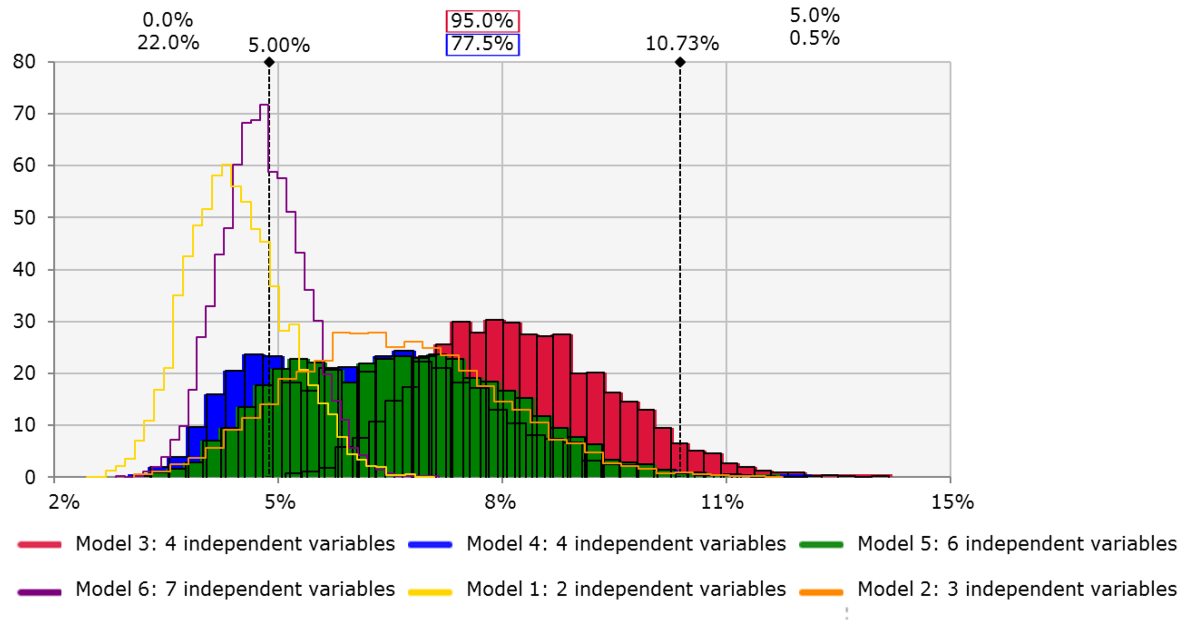


Figure 45: Models´ performances, validated by a Monte-Carlo simulation

For model 1 all except one and for model 6 all except two model fit indices indicate an acceptable model, whereas for model 2 and 4 the SRMR, the AVE as well as the CR show inaccaptable values. The two-tailed significance test for standardized parameters shows that all independent variables for all models are rated between 1.960 and -1.960, showing their significance. The IR is high for the independent variables of model 1 as well as for quite a few independent variables of model 6, whereas IR for the independent variables in model 2 as well as model 4 are relatively low (see Table 20).

Table 20: Model fit values of the four best performing models

	Cut-off	Result Model 1	Result Model 2	Result Model 4	Result Model 6
Chi-square	> 0.05	0.045	0.000	0.000	0.000
SRMR	> 0.08	2.839 (n.a.)	6.905 (n.a.)	6.163 (n.a.)	4.657 (n.a.)
RMSEA	> 0.08	0.000	0.000	0.000	7,066 (n.a.)

CFI	> 0.95	0.000	0.000	0.000	0.000
TLI	> 0.95	-6352.7	-2193.172	-684.663	-1534.2
AVE	< 0.5	0.978	0.061 (n.a.)	0.253 (n.a.)	0.914
CR	< 0.704	0.989	0.120 (n.a.)	0.520 (n.a.)	0.971

n.a. = not acceptable
IR Model 1: 0.981, 0.973
IR Model 2: 0.156, 0.012, 0.012
IR Model 4: 0.421, 0.107, 0.024, 0.398
IR Model 6: 0.866, 0.170, 0.978, 0.021, 0.797, 0.943, 0.152

DISCUSSION AND CONCLUSIONS

The presented case study in the industrial goods sector showed that a significant cost reduction of 36.75% is possible by defining the EOQ, but at the expense of an increased demand for storage places from 829 to 1,054. By optimizing other process parameters, such as direct delivery in the carrier, needed at the first point of use, definition of the appropriate carrier type, transport bundling via milkrun, and the introduction of a JIT process, it was possible to increase the cost reduction further from 36.75% to 67.93%, while simultaneously reducing the number of required storage places from 837 to 653. By each optimization approach, different cost categories can be reduced, enabling supply chain managers to choose the appropriate strategy based on their as-is supply chain costs situation. The area of multi-parameter optimization is an important field in industry, but one which has not been thoroughly examined in literature. Therefore, we recommend an intensification of these studies. We derived a simplified model by linear regression, reducing the number of independent variables drastically and offering relatively good forecasting accuracy. These models are easier for companies to implement, especially in a context of limited data availability – a factor which is often cited as problematic in surveys and in the descriptive literature. A model with two independent variables already represents the best performing model that deviates from the cost optimum by an average of 4.548%. The results enable companies to implement easy to understand cost models with a minimum of required data. Due to the low availability of data in industry, it is advisable to intensify research on different approaches to deal with this issue.

ACKNOWLEDGMENTS

Many thanks to all employees of the company, the case study was conducted at, who contributed to define the model as well as the optimization parameters, who provided data for the case study, and who were deeply interested in discussing the results.

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THE USE OF ASSISTIVE DEVICES FOR MANUAL MATERIALS HANDLING IN WAREHOUSES: A SYSTEMATIC LITERATURE REVIEW

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Purpose
The aim of this paper is to evaluate how technical assistive devices for manual materials handling have been analysed in the literature in a ware-housing context. The focus of the review is to understand the existing scientific evidence on the impact of the assistive devices on both the economic and human factors (i.e., perceptual, cognitive and physical er-gonomics) performance of the logistics system.

Design/methodology/approach
A systematic literature review methodology was used to identify works that describe the use of assistive devices for manual materials handling in warehouses. Scientific databases (SCOPUS, Web of Science, Engineering Village, and Pubmed) that cover the research disciplines of logis-tics/production/operations management as well as human fac-tors/ergonomics were searched. Keywords were used to identify papers that 1) were in a warehouse context, 2) studied an assistive device, and 3) studied the related human factors aspects of the assist. A "snowball" search was conducted by examining the reference lists of relevant pa-pers. Relevant studies were assessed for the type of variables studied (e.g. system centric vs person centric), the tasks supported and the na-ture of the human factors "assist" being provided by the device.

Findings
The preliminary results of the review shows which types of assistive de-vices have been analysed in the literature in the past, and from which perspective these devices have been investigated. Some works adopted a human factors perspective (such works study how these systems can re-duce cumulative or peak load, for example exoskeletons), a management point of view (such works focus on a cost/performance analysis of these systems, for example augmented reality), and a combined management and human factors point of view. Works with an integrated perspective (i.e., that consider both human factors and management perspectives), however, are rare.

Value
This paper supports researchers and practitioners in giving an overview of technical assistive devices that can be used in manual materials handling and their performance measures. It further identifies research gaps in the literature and emphasises the need to understand the interactions be-tween human and system related variables in designing effective manual material handling systems that are sustainable from the workers' and from the company's perspective.

Research limitations/implications
This paper points out a clear research gap regarding an integrated analy-sis of technical assistance systems for manual materials handling in warehouses. To ensure methodical rigor and scientific quality, we limited our sample to works that were published in peer-

reviewed journals and conference proceedings, excluding books and book chapters which might have biased the sample.

Practical Contribution
The results of this paper can be used by warehouse managers to prepare the evaluation of technical assistive devices for manual materials handling from an integrated (economic and human factors) perspective.

1. INTRODUCTION

Despite an ongoing trend to further automate and digitalize industrial processes, manual materials handling continues to play a major role in many industries. In the warehousing sector, for example, automation levels are still quite low, and many processes such as order picking or the packaging of items still rely heavily on manual human work (Napolitano 2012; Behnisch et al. 2017). In the European Union, more than 10.8 million persons are currently employed in the warehouse-transport-storage sector, and the industry reports a value added of EUR 556.0 billion (Eurostat, 2018).

Manual work is an important cost factor in warehousing, with order picking accounting for about 55% of the total warehouse operating cost (Frazelle 2002; Tompkins et al. 2010). To utilize human work in the best possible way, prior research has proposed various methods and tools for optimizing logistics processes and for reducing cost. One stream of research, for instance, develops mathematical optimization models for improving the efficiency of manual order picking operations by improving warehouse layouts, storage assignments or the routing of order pickers through the warehouse (see, e.g., de Koster et al. (2007) and van Gils et al. (2018) for reviews of the related literature). Beyond their influence on cost, manual materials handling activities also impact human workload and safety, particularly from hazards associated with excessive workloads. These human factors (HF) aspects are often overlooked in the industrial engineering literature (e.g., Grosse et al. 2015; 2017).

The physical dimension of manual materials handling in warehouses is obvious. Handling materials may make it necessary to cover long distances in the warehouse (possibly afoot), and in addition, picking items from storage locations and placing them in a cart or into a bin may require stretching and bending of the body while carrying a load. This may manifest in muscle fatigue and lead to a high peak and/or accumulated load on the worker’s spine, which results in a great risk for the worker to develop musculoskeletal disorders (Norman et al. 1998). Prior research has hypothesized that manual materials handling affects mental, perceptual and psychosocial aspects as well, for example by causing visual discomfort or by creating stress or boredom (Grosse et al. 2015).

The lack of attention to HF in the design of systems can have negative consequences for both workers and for system effectiveness (Neumann and Dul 2010). Work-related ill health, caused we argue by flaws in the design of operations systems, carries societal costs on par with all cancers combined (Leigh 2011). The International Labour Organization estimates over 2.78 million work-related deaths annually with costs for work-related ill health at just under 4% of the global GDP (ILO, 2019). Population studies estimate that about 20% of the general population suffers from a work-related musculoskeletal disorder (Vézina et al. 2011). From the company perspective, such injuries carry extensive indirect costs that greatly exceed the basic compensation costs for the injury (Rose et al. 2013). Poor HF in system design has also been broadly associated with quality deficits and errors in manufacturing operations (Zare et al. 2016; Kolus et al. 2018). The underlying theory, building on sociotechnical systems theory (e.g. Cherns 1976), is that the design of operations systems will have an effect on the system operators and that this, in turn, will affect performance (Neumann and Dul 2010; Neumann and Village 2012). If the demands placed on the operators’ perceptual, cognitive, or motor systems exceed their current abilities, then negative outcomes can be expected, particularly under conditions of worker fatigue which compromise human capability (Kolus et al., 2018; Yung et al., In Press). Keeping work demands below employees' maximum capabilities therefore becomes a critical design criterion. To this end, assistive devices that help reduce work demands or enhance human capability become interesting and potentially useful tools to maintain the health and performance of workers. Some assistive devices, such as lift assists, have been developed already several decades ago; fostered by recent advances in information technology, further assistive devices – such as handhelds or augmented reality glasses – have been introduced into the market recently. The various assistive devices that are now available to warehouse managers enable decision makers to better take account of HF in manual materials handling activities, and to better orient the design of the warehouse system and warehouse processes on the requirements of the human operators working in the system.

In light of these recent developments, the objective of this work is to identify and review current research on technical assistive devices for manual materials handling operations in warehouses. A systematic review of the literature was conducted for this purpose, with the intention I) to show which types of assistive devices have been analyzed in the academic literature in the past, and from which perspective these devices have been investigated, and II) to present and synthesize the existing scientific evidence on the impact of the assistive devices on both the economic and the HF performance of the logistics system. Our results show that there are works that adopted either a HF or a management (cost) perspective, but that also publication numbers of works with an integrated perspective that consider both dimensions are increasing. A research agenda proposed in this paper intends to stimulate further integrated research on assistive devices for manual materials handling in warehouses. The remainder of this paper is structured as follows. The next section outlines the methodology employed for identifying relevant literature. Section 3 discusses the results of our review. Section 4 concludes the paper and presents promising ideas for future research.

2. METHODOLOGY

Our literature review differs from earlier surveys in this area. Literature reviews of warehousing and/or order picking in particular, such as those of de Koster et al. 2007 or van Gils et al. (2018), did not evaluate assistive devices or HF aspects. The focus of these works was on mathematical models for storage assignment, order batching, order picker routing, and warehouse design instead. Grosse et al. (2017) stressed the need to consider HF aspects in developing models for planning the order picking process, but did not investigate assistive devices. Three works that are more closely related to our literature survey reviewed assistive devices that can be used in warehousing (De Looze et al., Verbeek et al., 2011; 2016; Haase and Beimborn, 2017). Our review differs from these works as it is more focused on warehouse systems, particularly the order picking function, and not limited to a single type of assistive device. It also discusses the HF aspects supported by a wide range of assistive devices, which has not been done before.

A systematic literature search was conducted for the purpose of this research. In a first step, scholarly databases were searched to identify works relevant for this study. Three sets of keywords were generated for the database search (Scopus, Web of Science, Engineering Village, and Pubmed), one related to the context/sector investigated in this paper (i.e. warehousing), a second one related to tools and assistive devices, and a third one that included ergonomics/HF indicators. Keywords were initially extracted from textbooks on ergonomics as well as from works on materials handling and warehousing (Helander 2005, Tompkins et al. 2010) and refined during discussions within the team of authors. The titles and abstracts of all papers contained in the initial sample were screened by all authors of this paper to evaluate the inclusion of the papers in the final sample. The following selection criteria were applied: selected papers need to study (1) a warehousing environment, (2) the use of assistive devices, and (3) a material handling task. In total, 43 papers could be identified. Once the sample of papers had been finalized, each paper was analyzed for content and tabulated. Each assistive device was examined for its relevance to each of four HF aspects and four material handling-related tasks based on Grosse et al. (2015). The HF aspects reflect human characteristics supported by the device, namely (a) perceptual, (b) mental, (c) physical, and (d) psychosocial working aspects for the operator. Regarding material handling tasks, we split up the warehousing tasks into the following main task steps: (a) set-up, (b) travel, (c) search, and (d) pick. Results from each selected study were also analyzed for effect size and catalogued into three material handling outcomes: (a) performance (time/efficiency), (b) quality (errors), and (c) human workload.

3. RESULTS

Our literature sample consists of 43 papers that discuss assistive devices for manual materials handling in warehouses, out of which 25 were published in academic journals and 18 in conference proceedings. Figure 1 outlines the number of sampled papers published per year. Note that the sample contains only two papers for the year 2019 as the literature search ended January 2019. As can be seen, the number of works published on this topic started to increase around the year 2007, which could be a result of new IT solutions that were introduced into the market around this time, inspiring research afterwards.

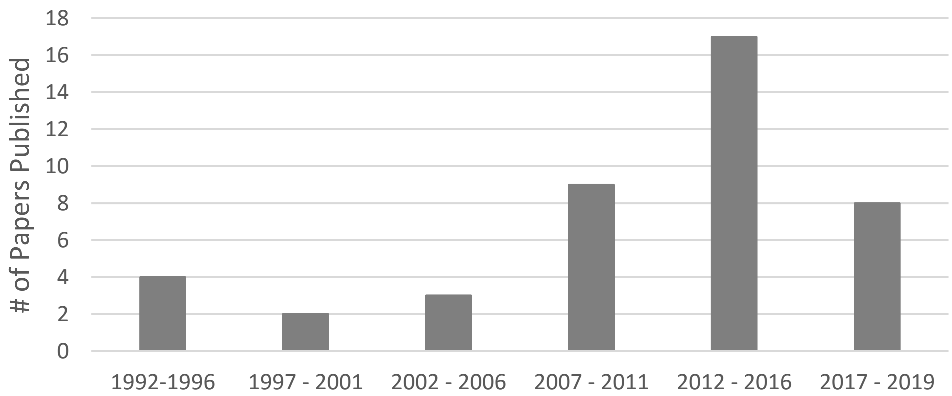

Figure 1: Sampled papers published per 4-year block (last bar is 3 years)

Figure 2 gives an overview of the types of devices investigated in the sampled papers. The classification used in Figure 2 is based on the one proposed by Tompkins et al. (2010) and extended to include newer technologies like virtual reality and exoskeletons. As can be seen, manual devices that can be used for moving, lifting and lowering material, such as carts and hoists, have received some attention in the past; a large share of the sampled works on these devices are journal papers. Technologies that appeared on the market just a few years ago, such as augmented and virtual reality glasses or light and computer aided assists, have also attracted a lot of attention; a large share of works on such devices has appeared in conference proceedings though, which could indicate that these devices have not reached their full maturity or a broad use in industry yet. With regard to the indicators considered for evaluating assistive devices per study objective, our classification of the literature revealed that 58% of the sampled papers studied either a human workload- (30%) or a performance-related (28%) indicator (cost, time or quality), while 42% of the sampled works considered both human workload and performance. Within this group, 14% of the sampled papers studied performance indicators and physical HF aspects, and 28% mental HF aspects together with performance indicators, respectively. Breaking down the different performance indicators, the majority of papers studied how assistive devices impact efficiency and quality aspects (e.g., pick errors) of the warehousing process, whereas only few studied efficiency aspects without quality. There are no papers dealing solely with quality outcomes.

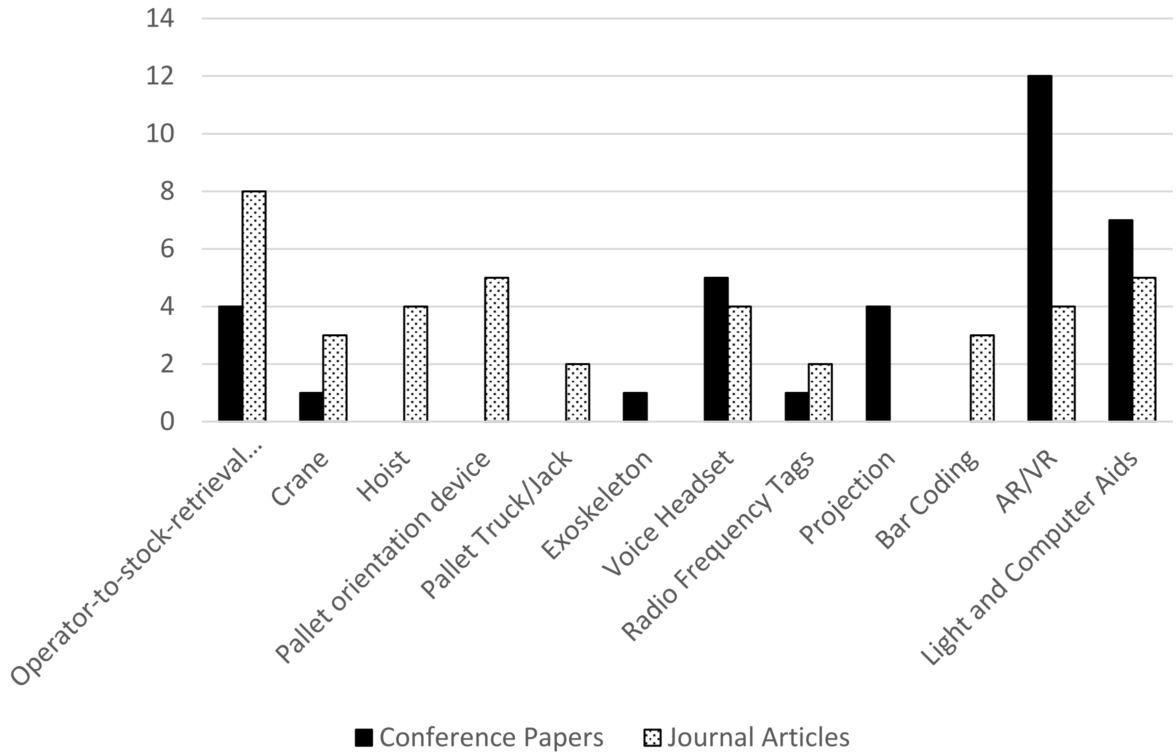

Figure 2: Types of assistive devices by type of publication type

Figure 3 summarizes the devices contained in the literature sample according to the objective of the study. As can be seen, the majority of papers studied the impact of information technology devices (voice headsets, augmented reality, and light/computer aids) on the performance of the warehousing process or on performance together with mental HF aspects. For other devices, such as retrieval equipment, cranes and hoists, the evaluation of human workload was dominant.

Looking at the HF aspects that are supported by the devices by warehouse process step, we note that some papers studied more than a single device or devices that support more than a single process step. We observed that none of the devices was used to explicitly support the setup step. This is surprising given the fact that the setup step may impose both physical, mental and perceptual demands on the warehouse worker. Physical demands arise if the warehouse worker has to set up the workplace before initiating the order picking process, for example by placing empty bins on a hand cart. Given that the bins are usually empty in this warehouse process step (exceptions would be situations where the worker has to refill empty storage positions in addition to picking items), the physical impact on the worker is lower than during the travel and pick steps where the bins are gradually filled. This may be one reason why the setup step has not received any attention in the literature so far. In addition, mental and perceptual tasks that the worker has to perform during setups, such as the understanding and partial memorization of the picklist or the orientation within the warehouse, have often been assigned to the travel or search steps in the sampled works. Assistive devices that support these tasks have hence been assigned to the travel and search steps without referring to the setup step in addition.

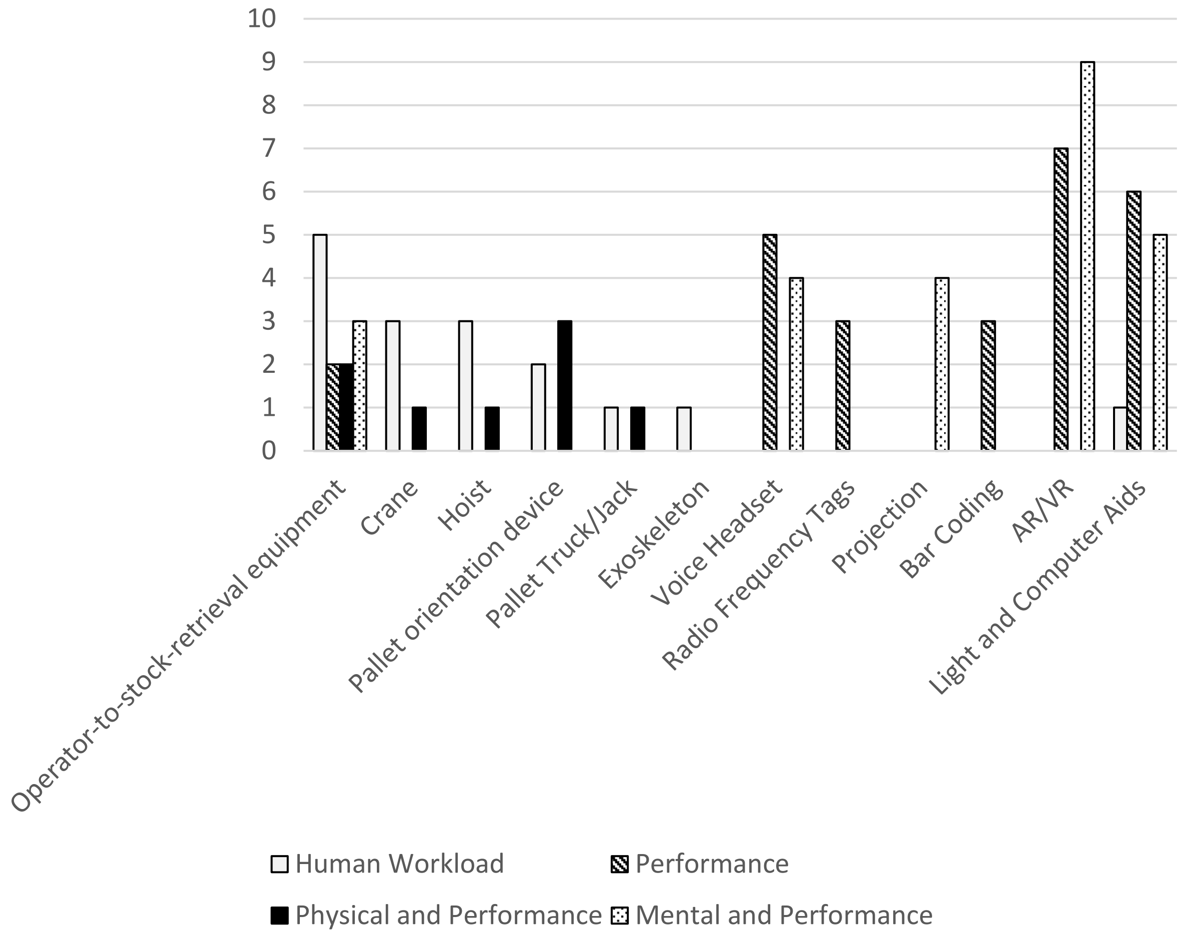

Figure 3: Objectives studied for each device type

With respect to the travel step, the literature has focused especially on different types of carts that support the moving of materials through the warehouse, i.e. a physical task. Regarding the search step, devices that support both mental and physical tasks have been evaluated in the sampled works. Mental tasks, such as processing pick list information or deciding on the next shelf location to visit, were supported by pick-by-voice systems or virtual and augmented reality applications, for example. Only two papers investigated physical tasks during the search step by evaluating the physical strain and head movements resulting from searching. 42% of the sampled papers considered devices that support physical tasks during the pick step. This is not surprising given that heavy and difficult to handle items that have to be picked in many warehouses lead to injury risks that cranes, pallet tilters or hoists can reduce. None of the works contained in the literature sample referred to psychosocial aspects.

4. CONCLUSIONS

This paper presented the results of a systematic literature review on technical devices that support manual human work in warehousing tasks. The literature was analyzed to gain insights about the devices that were studied, and how the use of such devices impacts the outcomes of warehousing processes, i.e. performance (time/efficiency), quality (errors), and human workload. Special emphasis was put on the HF aspects that reflect human characteristics supported by the specific device, namely perceptual, mental, physical, and psychosocial working aspects for the operator. The results indicated that some devices were studied in detail, e.g. augmented reality devices, whereas others were only infrequently studied, such as pallet jacks or exoskeletons. The majority of works focused on a single objective, either performance-related or human workload-related. However, the results also show that the number of works with an integrated focus, e.g. mental HF aspects together with performance indicators, has been increasing recently. The majority of works studied how the device can support the worker in the search or pick task. In contrast, the warehousing setup task and perceptual aspects ware not considered in the literature at all.

This paper supports researchers and practitioners in giving an overview of technical assistive devices that can be used in manual materials handling and their performance measures. It further identifies research gaps in the literature and emphasizes the need to understand the interactions between human- and system-related variables in designing effective manual material handling systems that are sustainable from the workers' perspective. The results of this paper can be used by warehouse managers to prepare the evaluation of technical assistive devices for manual materials handling from an integrated (economic and HF) point of view.

This paper points out a research gap regarding an integrated analysis of technical assistance systems for manual materials handling in warehouses. More works are needed that study the combined effects of technical devices on human (workload) and system outcomes (time or quality). In addition, future work should emphasize a more detailed evaluation of the different human characteristics. With regard to the recent developments of digitalization, the use of assistive devices may increase in warehousing tasks, which makes a thorough analysis of psychosocial aspects of digitally supported manual work (such as work autonomy and work satisfaction) necessary.

This work has limitations. To ensure methodical rigor and scientific quality, we limited our sample to works that were published in peer-reviewed journals and conference proceedings, excluding books, book chapters, and white papers, which might have biased the sample. We also excluded devices that could be helpful for some related tasks, such as telescoping conveyors or articulated arms. We looked only at warehousing, and not at other material handling tasks. We also decided not to include certain devices in the list of relevant papers, as they would then present a whole new set of literature not related to technical devices, e.g. lumbar belts. These and other limiting factors will be addressed in an extension of this working paper.

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EXPLORING THE INFLUENCE OF ONLINE REVIEWS ON SUPPLY CHAIN DYNAMICS

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Purpose: Online reviews (e.g. review rating) play an important role in influencing purchasing decisions. Reflecting on customers' satisfaction with the product, online reviews can change future potential customers' expectation of products and thus influence the product demand. Although such influence is well-documented in marketing and information system literature, supply chain/inventory management models do not always bring this in and fail to investigate its effect on supply chain dynamics. Therefore, the aim of the research is to introduce online review in a supply chain model to explore its influence on supply chain dynamics.

Design/methodology/approach: By integrating automatic pipeline variable inventory order-based production control system (APvIOBPCS) and consumer choice modelling based on customer utility, this paper models an e-retailer supply chain to explore online review's influence on supply chain dynamics, including bullwhip effect and inventory amplification. By conducting simulation experiments, this paper managed to uncover such influence on supply chain dynamics in different scenarios.

Findings: The results show that the mechanism behind the influence of the online review on supply chain performance is complex. On the one hand, if no customer perceives a product above average, or if all customers perceive non-negative utility from the product, dynamics performance will not be influenced by the online review, regardless of whether it is used or not. On the other hand, when some customers perceive negative utility from the product while some others perceive positive utility, retailers' online review using will lead higher bullwhip effect and inventory amplification (than not using it), and the magnitude of such influence is moderated by coefficient of variation of customer numbers, lead time, product quality and mismatch cost.

Value: To the best of our knowledge, this is the first paper which links online review to supply chain dynamics through mathematical models by using consumer choice modelling and APvIOBPCS. Instead of assuming demand pattern as exogenously given, this paper assumes the demand pattern will be influenced by online reviews (e.g. review rating) which is a function of inventory system parameters and customer utility. Our model can enable a better understanding of online review's influence from a supply chain dynamics perspective.

Research limitations/implications: In this paper, only the situation where quality is correctly estimated is explored. Besides, our model assumes customers cannot return the product even they are not satisfied with it. Future research can extend model to the scenario of over-/under-estimation of product quality and the scenario that return is permitted.

Practical Contribution: As online reviews can lead negative influence on supply chain dynamic performance in some scenarios, companies need to consider the corresponding costs generated from such influence and make strategic decision about whether to offer the review systems to maximise their profit.

INTRODUCTION

The development of internet technologies enables customers to share their product evaluation online (Avery et al., 1999). Online reviews, as a kind of e-word-of-mouth communications, deliver customer product evaluations and influence future purchasing decisions (Chen and Xie, 2008). Through online reviews, potential customers can learn more information about product attributes to update their perception and evaluation on products, and make purchase decisions accordingly (Li et al., 2011).

The influence of online reviews on customer demand and product sales is well-documented in marketing and information management research (e.g. Purnawirawan et al., 2015; You et al., 2015). However, there is much less research discussing online reviews' influence on supply chain dynamics (e.g. bullwhip effect, inventory amplification, etc.). As different demand patterns can bring different supply chain dynamics (Gaalman, 2006), and as online review can influence customer demand, it can be reasonably inferred that online review can probably bring new dynamics in supply chain. Given that good management of supply chain dynamics can improve supply chain performance (Sterman, 1989), failing to understand the possible dynamics brought from online review in supply chain decision could cause inefficiency in supply chain. Motivated by this, the paper looks to explore the following question:

Can online review influence bullwhip effect and INVamp value in supply chain?

LITERATURE REVIEW

The influence of online review has been investigated in several facets of supply chain management and one contemporary hot topic is the value of online review on sales forecasting. For example, using neural networks, Chong et al. (2016; 2017) and Hou et al. (2017) demonstrated that the review features, such as review valence and volume can be useful predictors for product sales. Employing online review and transactional data of e-retailers, See-To and Ngai (2018) conducted a sales nowcasting based on an autoregression model with exogenous variables, finding that the combination of two types of data can contribute more accurate forecasts than the forecasts generated from transactional data only. Li et al. (2016) investigated the relationship between sales and Amazon.com online reviews by using hierarchical regression, indicating that online review features can significantly influence product sales, but such influence is moderated by other variables, such as product type and promotion activity. Yuan et al. (2018) proposed a big data methodology to extract the sentiments of online reviews, finding utilisation of sentiment data can improve demand forecasting performance.

Existing research also examined the influence of online review on physical and service operations management. Jin et al. (2016) proposed a big data technique and extracted customer opinion information from product reviews to inform new product design. Abrahams et al. (2012; 2015) and Jiang et al. (2017) proposed methodologies to analyse product reviews in customer discussion forums and identify product defect information to support product quality improvement. Chan et al. (2016; 2017) analysed customer comments and reviews using Facebook and to extract information for new product development based on qualitative content analysis, statistical analysis, and a multi-criteria decision-making approach.

Other supply chain activities influenced by online reviews are also obtaining attention. For example, for physical products delivery, Hou et al. (2018) examined the impact of e-retailers' investment on product delivery under the influence of online review. They found the existence of online reviews can reduce the investment and increase profit in equilibrium point for both competing retailers. Other publications also investigate online review's influence on service delivery, such as Gu and Ye (2014). For product return, Minnema et al. (2016) found that overly positive review valance can lead more product return while Sahoo et al. (2018) found unbiased online product review can contribute better purchase decision and thus lead less product return.

Although online reviews' influence many facets of supply chain management, there is no research linking online reviews to supply chain dynamics. Ignoring this interaction could make supply chains inefficient. Therefore, investigating the influence of online reviews on supply chain dynamics can enhance the understanding of the underlying dynamics and support managers in making more rational decisions in the current e-retailing era.

METHODOLOGY

Model formulation

The customer demand is modelled from a utility perspective. Following previous literatures (Li and Hitt, 2010; Sun 2012; Jiang and Guo, 2015), customers' expected utility before purchase is modelled as $U_{it}^{e} = q^{e} - p - \beta * x_{it}$ in which U_{it}^{e} is customer i's expected utility in day t before purchase, q^{e} the expected quality, and p the product price. x_{it} is used as a preference parameter and is assumed to be uniformly distributed in [0,1]. This essentially reflects the mismatch degree between the real product and the customer i's ideal product. Thus, β is the unit mismatch cost. As p is not the decision variable in this model, it is normalised as 0 without loss of generality and so the expected utility is $U_{it}^{e} = q^{e} - \beta * x_{it}$. q^{e} is interpreted as "net quality utility". If customers are rational, they will purchase the product only when $U_{it}^{e} > 0$. Besides, we assume $\beta > q^{e}$, so that the product cannot cover the whole market.

The utility U_{it}^{r} for customer i in day t after purchase is modelled as $U_{it}^{r} = q - \beta * x_{it}$, where q is the real (net) quality after receiving the products. To simplify our model, we only consider where q^{e} equal to q, in which case the expected quality correctly reflects real quality. It means that customers' information is adequate and their perception about real quality is not influenced by biased information such as excessive advertising. By doing this, we reduced an independent variable for our subsequent experiment.

With online reviews, customers will provide this after receiving the products. We model the rating system with a 1 to 5 scale, as per Amazon. For customers, they will give their rating 1- to 5-star based on their real utility U_{it}^{r} (Jiang and Guo, 2015; Li and Hitt, 2010). To transform U_{it}^{r} to each customer i's rating score in day t which is R_{it}, we adopt Jiang and Guo (2015)'s transform function:

$$R_{it} = k + 1 \quad (1)$$

$$\text{where } k = \arg min_{k=0,1,2,3,4}\{|\frac{k}{5-1} - w_{it}|\} \quad (2)$$

$$\text{and } w_{it} = \frac{e^{U_{it}^{r}}}{(1+e^{U_{it}^{r}})} \quad (3)$$

After modelling the rating score for each customer R_{it}, we can calculate the average rating for the product $\overline{R_t}$ in day t. We notate the number of customers posting rating scores in day t is n_t^r and we assume the rating score will update in the following time period. In day t, the rating score shown is the rounded average value of all rating scores posted from 1st day to day t. If no one posts rating in day $t-1$, the score $\overline{R_t}$ will remain as $\overline{R_{t-1}}$:

$$\overline{R_t} = \begin{cases} \sum_{t=1}^{t-1}\sum_{i=1}^{n_{t-1}^{r}} R_{it} & \text{if } n_{t-1}^{r} > 0 \\ \overline{R_{t-1}} & \text{if } n_{t-1}^{r} = 0 \end{cases} \quad (4)$$

Consistent with Amazon style, just one decimal point is retained. Thus, $\overline{R_t}$ can only be 1, 1.1, 1.2 up to 4.9 and 5.

We notate the customer i's expected utility influenced by online review in day t as U_{it}^{er}. Therefore, if companies provide online review system, for their customers, their expected utility before purchasing U_{it}^{e} is influenced by online review and turns to U_{it}^{er}. Under such circumstance, he/she will buy the product if U_{it}^{er} is greater than zero (even if his/her U_{it}^{e} is not necessarily greater than zero).

To model how customer *i* in day t updates their expected utility, U_{it}^{e}, to review-influenced expected utility, U_{it}^{er}, we first model the utility obtained from product average rating score. We notate the utility generated from seeing a rating score as U_{it}^{score}. To quantify U_{it}^{score}, we modified and use the inverse form of equations (1) to (3).

Finally, adapting previous literatures (e.g. Bhole and Hanna, 2017; Jiang and Guo, 2015), we quantify the online-review-influenced expected utility U_{it}^{er} as a weighted average of expected utility (without online review) U_{it}^{e} and utility generated from online review rating score, U_{it}^{score}. Such update process is also consistent with previous research on combining forecasts (Clemen 1989; Lawrence et al. 2006). Specifically,

$$U_{it}^{er} = \theta_{it} * U_{it}^{score} + (1-\theta_{it}) * U_{it}^{e} \qquad (5)$$

Moreover, to model the heterogeneity that different customers can put different relative weights on rating score as some of them may rely on their own previous expectation on product more while others may not, we let θ_{it} follow a uniform distribution bounded in [0,1] as $\theta_{it} \sim U(0,1)$.

We build our supply chain model based on the well-established APIOBPCS model (Dejonckheere et al., 2003, Disney and Grubbström, 2004). We refer interested readers to Lin et al. (2017) for details of the model and a comprehensive summary of its applications. Unlike previously published applications, we use R for the modelling work. The following assumptions apply to the model. We consider a one echelon supply chain model using an oreder-up-to policy where there are only e-retailer companies and their customers. Neither backlogs nor returns are permitted, which means the order rate and inventory is not negative. This is also consistent with previous literature (e.g. Sterman, 1989; Wang et al., 2012).

In day t, customers and companies perform the following event sequence:

(1) Firstly, D_t^a customers visit the platform, where $D_t^a \sim N$(μ,σ).

(2) All D_t^agenerate their expected utility with/without the influence of online review rating. Only D_t customers who have U_{it}^{e} (without online review) and U_{it}^{er} (having online reivew) greater than zero will choose to purchase the product.

(3) For companies' side, they first update their demand and then fulfil customers' order and n_t customers are fulfilled on a first-come-first-serve basis.

(4) Only customers who are fulfilled and willing to post provide an online review rating score and the rating for day *t+1* can be calculated based on equation.

(5) Companies update work-in-process (or goods in transit).

(6) Companies make forecast by using simple exponential smoothing.

(7) Finally, companies place their orders based on the rules in Dejonckheere et al. (2003) where no return constraint is applied:

$$O_t = MAX(0, (L+1) * \widehat{D}_t - I_t - WIP_t) = \mathrm{MAX}(0, (T_p+2) * \widehat{D}_t - I_t - WIP_t) \qquad (13)$$

O_t here will be rounded up/down to the nearest integer.

To test the influence of online review on supply chain dynamics, we designed a full factorial experiment. The summary of variable value selection is shown in Table 1.

Parameters	Value
Customer numbers	Round[N(100,σ^2)] per period
Demand smoothing parameter alpha	0.2
Probability of posting review	0.8 (and it follows a B(1,0.8) distribution)
Quality	2
Unit mismatch cost	8
Coefficient of variation of platform visitors (σ/μ, where μ=100)	30%

Tp (Lead time -1)	12
Independent variable	Value
Online review system	Yes (for using the system); No (for not using the system)
Dependent variable	
Bullwhip effect	Var(O)/Var(D)
INVamp	Var(I)/Var(D)

Table 1. Experimental design

We conduct 2 simulation experiment for online review using and not using. We replicated each experiment 5 times, with each time running 10000 periods. The first 500 periods are warm-up periods and removed when calculating bullwhip effect and INVamp.

SIMULATION RESULTS AND DISCUSSION

The effect of using or not using online review is presented in figure 2. Observing the results, we can identify that the bullwhip effect and INVamp are always higher when online review is used. The percentage increase value brought by online review is 1.8% for bullwhip effect and 4.9% for INVamp. The magnitude is not large, but it is notable. The online review just influences the demand pattern but does not essentially change the structure of supply chain model. The structure here means the exponential smoothing parameter value and lead time value are the main sources of bullwhip effect and INVamp, under the same structure of supply chain.

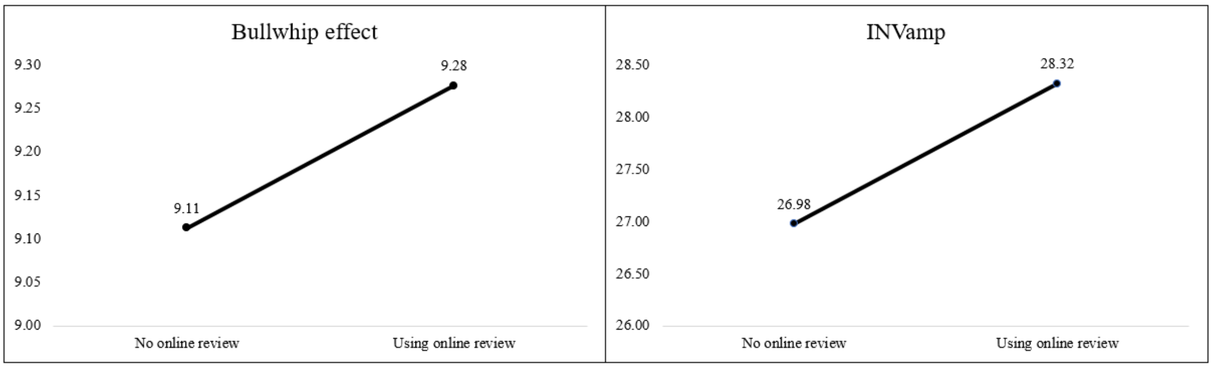

Figure 2. Influence of using/not using online review on bullwhip effect and INVamp

However, small percentage increase does not mean the influence of online review on supply chain dynamics should be ignored. Consider the following two scenarios. For one scenarios, a supplier has multiple retailers, and each retailer uses an online review system. Compared with other suppliers whose downstream retailers do not use online review system, this supplier will have around 2% and 5% percentage higher bullwhip effect and INVamp, but as the absolute demand is very large, this supplier can have a much more severe influence of supply chain dynamics induced from online review use. Another scenario is the dynamic influence amplification cross supply chain. Suppose a supply chain has four or more echelons, from manufacturers to distributors to wholesalers to retailers, even a small percentage increase can bring large difference in absolute terms on the bullwhip effect and INVamp to the upstream companies in supply chain. As Dejonckheere et al. (2004) observes, within a typical supply chain, each echelon can double the bullwhip effect. Therefore, companies should pay attention to the online review's influence on supply chain dynamics.

CONCLUSION

To conclude, this paper modelled a one echelon supply chain under the influence of online review. By conducting simulation experiment, this paper compared the bullwhip effect and INVamp value between supply chains using online review and those without online review. The results show that using online review will bring higher bullwhip effect and INVamp. This paper's contributions are at least two-fold. It contributes to the literatures about online review's research on supply chain and operations management from an inventory management and supply chain dynamics perspective. It also gives practitioners and companies more insights about the online review's influence on supply chain's operational performance, enhancing their understanding about the dynamics induced from online review use and support better decisions making.

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OPTIMAL ROUTING OF ORDER PICKERS IN THE LEAF WAREHOUSE

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Purpose
In manual picker-to-parts order picking systems, order pickers walk or drive through the picking area in the warehouse to retrieve the items requested by customers. The time order pickers spend on travelling through the warehouse accounts for almost 50% of the total order picking time. Therefore, reducing this non-value adding time will lead to a reduction in the total warehouse operating cost. Thus, the purpose of this paper is to develop a procedure for optimally routing order pickers through warehouses following the leaf layout.

Design/methodology/approach
The order picker routing problem in a warehouse is identical to the problem of finding the shortest picking tour in the graph representation of the warehouse. For optimally routing order pickers through the warehouse, we adapt the algorithms of Ratliff and Rosenthal (1983) and Roodbergen and de Koster (2001) that are based on an Eulerian graph and a dynamic programming procedure to the case of the warehouse layout investigated in this paper. The proposed procedure is evaluated in comprehensive numerical experiments.

Findings
The proposed solution procedure generates the minimum-length order picking tour and thus contributes to lowering the cost of warehousing. Its computational time is low, which enables warehouse managers to create efficient order picking routes quickly.

Value
The majority of the procedures developed for order picker routing are only applicable to conventional warehouses with parallel picking aisles. For non-conventional warehouses, only a few optimal algorithms have been developed so far, which makes it difficult to efficiently manage these warehouses in practice. This paper contributes to closing this research gap by developing an optimal order picker routing strategy for non-conventional warehouses following the leaf layout. The results of the paper at hand are valuable for warehouse managers that are interested in improving the efficiency of their order picking operations in the leaf warehouse.

Research limitations/implications
One limitation of our proposed algorithm is that it is only applicable to a warehouse with a leaf layout. To apply it to other warehouse layouts, a modification is required.

1. Introduction

Order picking is the process of retrieving a set of requested items from storage locations in a warehouse to prepare orders that are then shipped to the customers. It ranks among the most laborious tasks in warehousing and has a strong impact on the total warehouse operating cost. In manual order picking systems, the time spent by the order picker on travelling through the picking area for collecting items comprises around 50% of the total order picking time (De Koster et al., 2007; Tompkins et al., 2010; Öztürkoğlu and Hoser, 2019). Hence, reducing this unproductive and non-value adding time can lead to a substantial reduction in the total warehouse operating cost. The travel time required to complete an order is influenced by the order picker routing policy used in the warehouse. Thus, developing an efficient routing policy will lead to lower order picker travel times and consequently reduce warehouse operating cost. In a systematic review of the literature, Masae et al. (2019b) have shown that the majority of optimal routing algorithms are limited to single- or multi-block warehouses. An optimal order picker routing policy for the leaf warehouse has not been proposed so far. Motivated by their observation, the paper at hand intends to close this research gap by developing an optimal order picker routing algorithm to address the routing problem in the leaf warehouse. We adapt the solution procedures proposed in Ratliff and Rosenthal (1983) and Roodbergen and de Koster (2001a) that are based on an Eulerian graph and that apply a dynamic programming procedure. The remainder of this paper is structured as follows. Section 2 discusses the related literature on order picker routing. Section 3 provides a description of the problem investigated in this paper, and Section 4 develops an optimal order picker routing policy for the leaf warehouse. Numerical experiments are presented in Section 5. Finally, Section 6 concludes this paper and presents some interesting research opportunities.

2. Literature review

Order picker routing procedures proposed in the literature can be categorized into optimal algorithms, simple heuristics, and meta-heuristics (Masae et al., 2019b). In terms of optimal algorithms, the seminal work in this area is the one of Ratliff and Rosenthal (1983). They developed an algorithm that generates an optimal picking tour in a single-block warehouse using graph theory and dynamic programming. De Koster and van der Poort (1998) extended the algorithm of Ratliff and Rosenthal (1983) to a warehouse with decentralized depositing, where the start and end locations of a picking tour can be at the front of the picking aisles. Roodbergen and de Koster (2001a) also extended the algorithm of Ratliff and Rosenthal (1983) to a warehouse with a middle cross aisle. Recently, Öztürkoğlu and Hoser (2019) modified the algorithm of Roodbergen and de Koster (2001a) to find the optimal picking tour in a discrete cross aisle warehouse. Moreover, researchers have generalized the algorithm of Ratliff and Rosenthal (1983) to other order picking scenarios, such as order picking assisted by automated guided vehicles (AGVs) (see Löffler et al., 2018), dynamic order picking (see Lu et al., 2016), or order picking with turn penalties (see Çelik and Süral, 2016), for example. All aforementioned optimal algorithms were dedicated to rectangular warehouses with parallel picking aisles that are perpendicular to the cross aisles. A few optimal algorithms are applicable to other warehouse designs, such as the fishbone and flying-V (see Çelik and Süral, 2014) or the chevron warehouse (see Masae et al., 2019a). As to simple heuristics, the S-shape heuristic proposed by Hall (1993) is the most popular one because of its simplicity. Other routing heuristics that were frequently discussed include midpoint, largest gap (see Hall, 1993), return, composite (see Petersen, 1997), multi-block S-shape, multi-block largest gap, combined, and combined^{+} (see Roodbergen and de Koster, 2001b). Meta-heuristics have been mostly used for solving the combination of the picker routing problem with other order picking planning problems, e.g. a combined order batching and picker routing problem (see Chen et al., 2015; Lin et al., 2016; Li et al., 2017).

3. Problem description

This study considers manual order picking in a leaf warehouse as demonstrated in Figure 1. As can be seen, the leaf warehouse consists of two horizontal cross aisles, referred to as the front and back cross aisles, two vertical cross aisles, referred to as the left and right vertical cross aisles, and two diagonal cross aisles, referred to as the left and right diagonal cross aisles. It has a single depot in the middle of the front cross aisle. The leaf warehouse can be divided into four parts as labeled in Figure 1. We assume that parts 1 and 4 consist of the same number of picking aisles, n_s. Similarly, parts 2 and 3 are composed of the same number of picking aisles, n_t, where each picking aisle in both parts consists of two sub-aisles, namely a vertical and a diagonal sub-aisle. We also assume that the front end of a vertical sub-aisle intersects with the front end of a diagonal sub-aisle. Furthermore, we assume that all picking aisles are narrow that allow the order picker to retrieve the requested items (marked with black boxes) from both sides of the picking aisles without facing an additional travel distance for crossing the aisle. We further focus on a low-level order picking system, such that the requested items can be picked directly from the low storage racks without additional vertical travel. The order picking process in our case works as follows: The order picker receives a pick-list containing a set of items to be picked at the depot. S/he then walks through the aisles for retrieving items from their storage locations until all requested items have been obtained, and then returns to the depot.

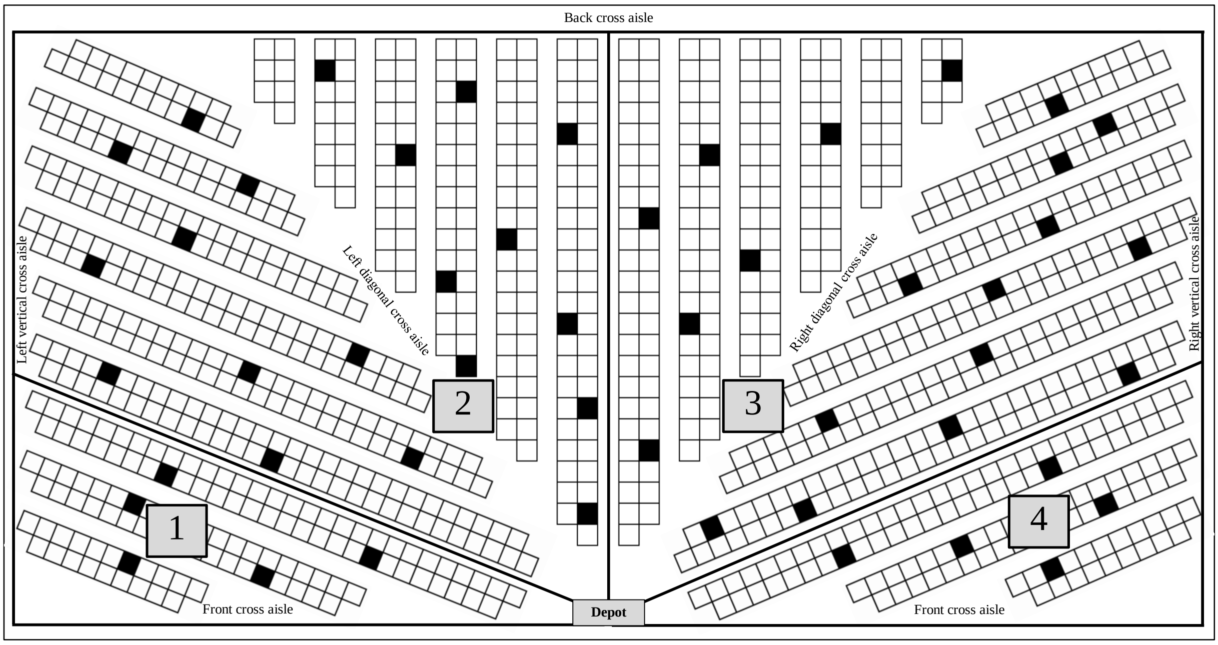

Figure 1. Leaf warehouse with 50 requested items.

4. Optimal routing algorithm

The order picker routing problem in the leaf warehouse is identical to the problem of finding the shortest picking tour in its graph representation. Therefore, we first construct the graph representation of the leaf warehouse. Secondly, we construct the minimum-length tour subgraph on it and then generate the optimal order picking tour from the minimum-length tour subgraph. The different steps of the solution procedure are described in the following.

4.1 Graph representation

The order picker routing problem corresponds to the problem of finding a picking tour in the graph representation of the given warehouse. Thus, we first define a graph representation, called graph G, of the warehouse with a set of vertices and edges as illustrated in Figure 2. The vertex v_0 denotes the depot's location, and the vertices $v_i, i = 1, 2, \dots, m$, represent the storage locations of all m items to be picked. We assume that the picking aisles in part 1 are labeled from the left to right, where the first picking aisle in this part is the left-most aisle from the depot. The picking aisles in part 4 are numbered from the right to left. The intersections of picking aisle j, $j \in \{1,2,\dots,n_s\}$, in part 1 with the left vertical and front cross aisles are denoted by the vertices $c_{j,1}$ and $b_{j,1}$, respectively. Similarly, the vertices $c_{j,4}$ and $b_{j,4}$ represent the intersections of picking aisle j, $j \in \{1,2,\dots,n_s\}$, in part 4 with the right vertical and front cross aisles, respectively. In terms of parts 2 and 3, the picking aisles are labeled from the back to the front. The vertices $a_{j,2}$, $b_{j,2}$, and $c_{j,2}$ denote the intersections of each picking aisle j, $j \in \{1,2,\dots,n_t\}$, in part 2 with the back, the left diagonal, and the left vertical cross aisles, respectively. The intersections of each picking aisle j, $j \in \{1,2,\dots,n_t\}$, in part 3 with the back, the right diagonal, and the right vertical cross aisles are represented by the vertices $a_{j,3}$, $b_{j,3}$, and $c_{j,3}$, respectively. We note that some vertices along the three aisles printed in bold coincide, including (1) $c_{n_s,1} = c_{n_t,2}$, (2) $c_{n_s,4} = c_{n_t,3}$, (3) $b_{n_s,1} = b_{n_t,2} = b_{n_t,3} = b_{n_s,4}$, and (4) $a_{n_t,2} = a_{n_t,3}$. Those three aisles connect the different parts of the warehouse. The vertices along these connections as well as the coincident vertices mentioned above need a special treatment in our solution procedure. The details of the solution procedure are described in the following section.

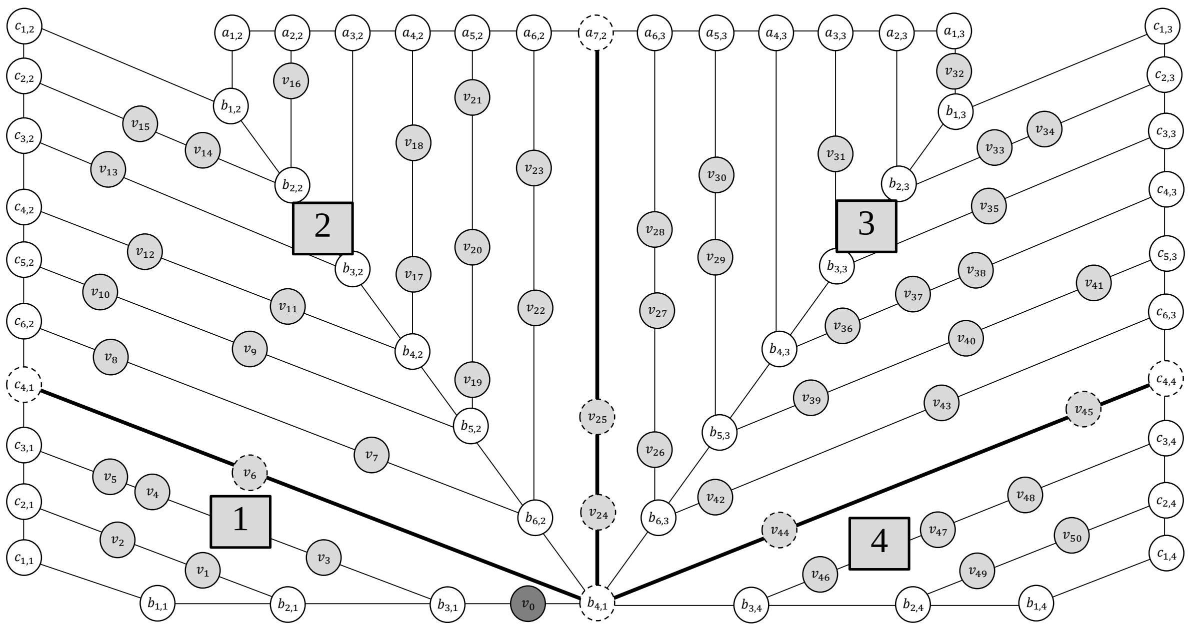

Figure 2. Example graph G of a leaf warehouse with $n_s = 4$, $n_t = 7$, and $m = 50$.

4.2 Constructing the minimum-length tour subgraph

The following definitions are used for constructing the minimum-length tour subgraph.

Definition 1 Let G be the graph representation with n_s, n_t, n_t, and n_s picking aisles in parts 1, 2, 3, and 4 of the warehouse (as defined in Figure 2), respectively. For $j \in \{1, 2, \dots, n_s\}$, we let

- $L_{j,1}^{-}$ be the subgraph (in part 1) of G consisting of the vertices $c_{j,1}$ and $b_{j,1}$ together with all vertices and edges in/connected to the aisles in part 1 of index lower than j,
- $L_{j,1}^{+}$ be the subgraph of G consisting of $L_{j,1}^{-}$ and all vertices and edges between the vertices $c_{j,1}$ and $b_{j,1}$,
- $L_{j,4}^{-}$ be the subgraph (in part 4) of G consisting of the vertices $c_{j,4}$ and $b_{j,4}$ together with all vertices and edges in/connected to the aisles in part 4 of index lower than j,
- $L_{j,4}^{+}$ be the subgraph of G consisting of $L_{j,4}^{-}$ and all vertices and edges between the vertices $c_{j,4}$ and $b_{j,4}$.

For $j \in \{1,2,\ldots,n_t\}$, we let

- $L_{j,2}^{-}$ be the subgraph (in part 2) of G consisting of the vertices $a_{j,2}$, $b_{j,2}$, and $c_{j,2}$ together with all vertices and edges in/connected to the aisles in part 2 of index lower than j,
- $L_{j,2}^{+l}$ be the subgraph of G consisting of $L_{j,2}^{-}$ and all vertices and edges between the vertices $b_{j,2}$ and $c_{j,2}$,
- $L_{j,2}^{+u}$ be the subgraph of G consisting of $L_{j,2}^{+l}$ and all vertices and edges between the vertices $a_{j,2}$ and $b_{j,2}$,
- $L_{j,3}^{-}$ be the subgraph (in part 3) of G consisting of the vertices $a_{j,3}$, $b_{j,3}$, and $c_{j,3}$ together with all vertices and edges in/connected to the aisles in part 3 of index lower than j,
- $L_{j,3}^{+l}$ be the subgraph of G consisting of $L_{j,3}^{-}$ and all vertices and edges between the vertices $b_{j,3}$ and $c_{j,3}$,
- $L_{j,3}^{+u}$ be the subgraph of G consisting of $L_{j,3}^{+l}$ and all vertices and edges between the vertices $a_{j,3}$ and $b_{j,3}$,

To simplify notation, we use the notation L_j to indicate that a result holds if we let $L_j = L_{j,1}^{-}$, $L_j = L_{j,1}^{+}$, $L_j = L_{j,4}^{-}$, or $L_j = L_{j,4}^{+}$ for $j \in \{1,2,\ldots,n_s\}$, and $L_j = L_{j,2}^{-}$, $L_j = L_{j,2}^{+l}$, $L_j = L_{j,2}^{+u}$, $L_j = L_{j,3}^{-}$, $L_j = L_{j,3}^{+l}$, $L_j = L_{j,3}^{+u}$ for $j \in \{1,2,\ldots,n_t\}$.

Definition 2 A picking tour in G is a directed walk that starts from v_0, passes through the vertices $v_i, i = 1,2,\ldots,m$, and ends at v_0, where each edge in G is traversed at most once. A subgraph T of G is a tour subgraph if it is the underlying graph of some picking tour in G.

Definition 3 (cf. Ratliff and Rosenthal, 1983) For any subgraph L_j of G, a subgraph T_j of L_j is an L_j PTS if there exists a subgraph C of G consisting of edges that are contained in G, but not in L_j, such that $T_j \cup C$ is a tour subgraph of G. The subgraph C is called a completion of the subgraph T_j.

Definition 4 (cf. Ratliff and Rosenthal, 1983) Two L_j PTSs, namely T_j^1 and T_j^2, are said to be equivalent if for any completion C_j of T_j^1 such that $T_j^1 \cup C_j$ is a tour subgraph, $T_j^2 \cup C_j$ is also a tour subgraph, and vice versa. In other words, the set of completions of T_j^1 and T_j^2 coincide.

The solution procedure for finding the minimum-length tour subgraph of the entire graph G consists of three main steps. In the first step, the algorithm of Ratliff and Rosenthal (1983) is used to construct the minimum-length $L_{n_s,1}^{+}$ and $L_{n_s,4}^{+}$ PTSs in parts 1 and 4, respectively. In the second step, the algorithm of Roodbergen and de Koster (2001a) is applied to construct the minimum-length $L^{+u}_{n_t,2}$ and $L^{+u}_{n_t,3}$ PTSs in parts 2 and 3, respectively. In the last step, the minimum-length L_j PTSs resulting from the previous steps are combined to connect the different parts of the warehouse. We assume that the vertices corresponding to the storage locations along the left and right diagonal cross aisles are contained in parts 1 and 4, respectively. The vertices corresponding to the storage locations along the vertical middle aisle are contained in part 2. Therefore, there are no vertices along the last aisle n_t of part 3 as shown in Figure 3(c).

For the first step, the equivalence classes of L_j PTSs in part 1 are referred to by the triple (degree parity of $c_{j,1}$, degree parity of $b_{j,1}$, number of connected components). In part 4, the equivalence classes of L_j PTSs are represented by (degree parity of $c_{j,4}$, degree parity of $b_{j,4}$, number of connected components). Similar to Ratliff and Rosenthal (1983), we apply a dynamic programming procedure to find the minimum-length tour subgraph by defining the states of the algorithm as the equivalence classes of L_j PTSs. The transitions between states are the addition of vertical or horizontal components to PTSs, and the cost in each transition is the sum of edge weights of the L_j PTS. Figures 3(a) and 3(d) show instances of $L^{+}_{4,1}$ and $L^{+}_{4,4}$ PTSs of G from Figure 2. In the second step, the equivalence classes of all L_j PTSs, $j \in \{1,2,\dots,n_t\}$, in parts 2 and 3 are denoted by (degree parity of $a_{j,2}$, degree parity of $b_{j,2}$, degree parity of $c_{j,2}$, number of connected components, connectivity) and (degree parity of $a_{j,3}$, degree parity of $b_{j,3}$, degree parity of $c_{j,3}$, number of connected components, connectivity), respectively. We construct the minimum-length $L^{+u}_{n_t,2}$ and $L^{+u}_{n_t,3}$ PTSs of each equivalence class by considering each aisle $j \in \{1,2,\dots,n_t\}$ in sequence. Figures 3(b) and 3(c) show examples of $L^{+u}_{7,2}$ and $L^{+u}_{7,3}$ PTSs of G from Figure 2. In the final step, we connect parts 1 and 2 of G at the connection aisle by combining the minimum-length $L^{+}_{n_s,1}$ PTSs in each equivalence class with the minimum-length $L^{+u}_{n_t,2}$ PTSs in each equivalence class. After that, we connect parts 3 and 4 by combining the minimum-length $L^{+u}_{n_t,3}$ PTSs with the minimum-length $L^{+}_{n_s,4}$ PTSs. We further combine the minimum-length PTSs that result from the combination of a pair of $L^{+}_{n_s,1}$ and $L^{+u}_{n_t,2}$ PTSs and the minimum-length PTSs that result from the combination of a pair of $L^{+u}_{n_t,3}$ and $L^{+}_{n_s,4}$ PTSs. The shortest PTS from the set of PTSs that are connected and possess even degree parity in the connection vertices is selected as the minimum-length tour subgraph of the whole graph G. Once the minimum-length tour subgraph of its graph representation has been constructed, we apply the picking tour construction algorithm presented in Ratliff and Rosenthal (1983) to our case.

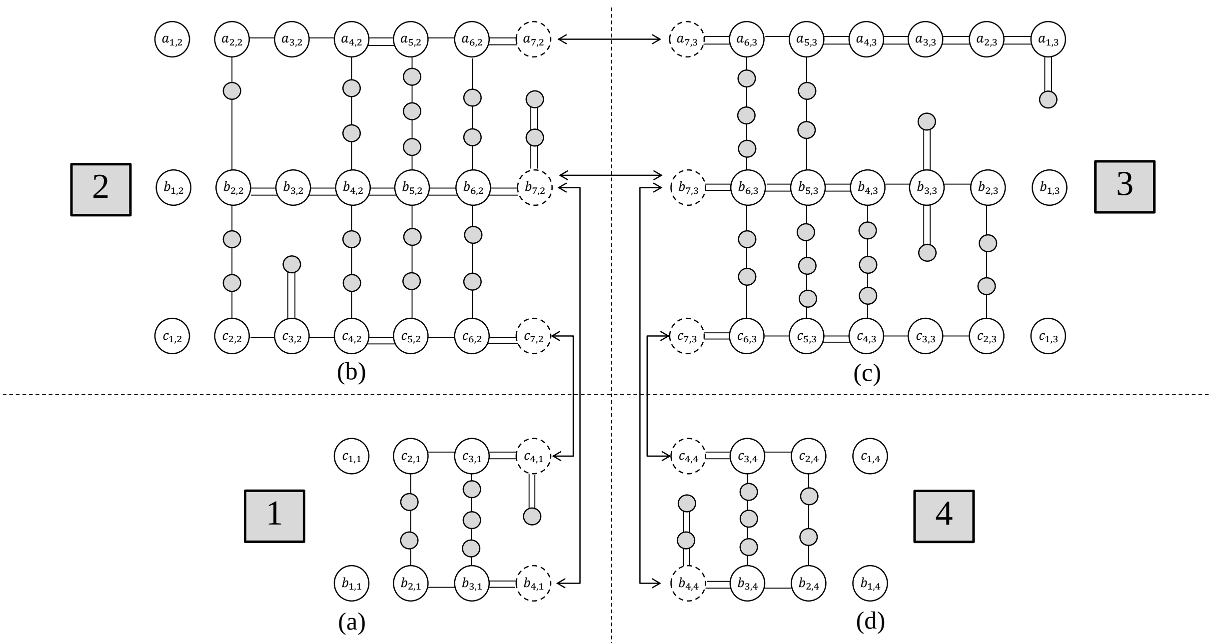

Figure 3. An L_j PTS in each part of G form Figure 2.

5. Numerical experiments

In this section, we evaluate the performance of the proposed optimal routing algorithm for the leaf warehouse by comparing the average length of the order picking tours produced by this method to the tours obtained using the *leaf S-shape* heuristic. In this heuristic, the order picker starts at the depot and moves to the left-most aisle of the left part that contains at least one requested item. S/he traverses this aisle completely and moves to the next aisle (in the same part) containing a requested item, and continues according to the same procedure until all requested items in the left part have been retrieved. S/he then moves to the left-most aisle of the middle part containing requested items and starts retrieving all requested items according to the same procedure until the right-most aisle of the middle part that contains at least one requested item has been completed. Afterwards, s/he continues picking all requested items stored in the right part from the back- to the front-most aisle containing requested items and then returns to the depot. In our experiment, we consider three different warehouse sizes; small, medium, and large. For each warehouse size and for each routing strategy, we vary pick-list sizes (number of items in an order) as 10, 20, 30, 40, 50, and 60 to investigate their effects on the relative performance of the picker routing strategies. Table 1 gives an overview of the average order picking tour lengths for the different routing policies and the average percentage gaps of the *leaf S-shape* heuristic from the optimal solutions. The results presented in Table 1 demonstrate that the proposed optimal algorithm clearly outperforms the *leaf S-shape* heuristic, and that it significantly reduces the average tour lengths in all cases. Moreover, we found that the warehouse and pick-list sizes have an impact on the optimality gap of the routing heuristic. Our numerical studies indicate that the optimal algorithm obtains tour lengths that are between 10.60% and 34.18% shorter than those generated by the *leaf S-shape* heuristic. These results emphasize that optimal picker routes should be the preferred policies to guide the order picker through the leaf warehouse.

Table 1. Average tour length per pick-list for the different routing policies and average percentage gaps from the optimal solution.

Warehouse size	Pick-list size	Average tour length per pick-list in the warehouse (meters)		% gap from the optimal solution
		Optimal algorithm	Leaf S-shape	
Small	10	115.57	136.03	17.70%
	20	149.49	178.11	19.15%
	30	171.20	198.02	15.67%
	40	184.53	208.11	12.78%
	50	193.10	214.91	11.29%
	60	198.67	219.72	10.60%
Medium	10	202.15	251.79	24.56%
	20	285.20	362.48	27.10%
	30	344.30	424.61	23.33%
	40	387.08	464.27	19.94%
	50	418.66	489.18	16.84%
	60	442.22	507.42	14.74%
Large	10	287.44	375.17	30.52%
	20	418.56	561.62	34.18%
	30	520.91	687.17	31.92%
	40	602.52	771.11	27.98%
	50	667.35	832.66	24.77%
	60	720.87	876.47	21.59%

6. Conclusion

This paper studied the problem of routing an order picker in a manual picker-to-parts order picking system that uses the leaf layout. We proposed an optimal order picker routing policy based on the solution procedures proposed by Ratliff and Rosenthal (1983) and Roodbergen and de Koster (2001a) that applied graph theory and a dynamic programming procedure. The paper at hand also proposed a simple routing heuristic, named *leaf S-shape*. The average order picking tour lengths resulting from the optimal algorithm and the *leaf S-shape* were compared to assess the performance of the optimal algorithm. The results of the paper indicate that the tours resulting from the optimal algorithm are 10.60% and 34.18% shorter than the tours generated by the routing heuristic. This emphasizes that an optimal order picking routing policy should be the preferred means of guiding the order picker through a leaf warehouse. For future research, it would be interesting to extend the current work by taking into account picker congestion. Furthermore, future research could also study the effect of different storage assignment strategies on the performance of the proposed routing policies.

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COORDINATING A TWO-LEVEL SUPPLY CHAIN WITH UNCERTAIN DELIVERY PERFORMANCE

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PURPOSE: This paper investigates the impact of coordinating a two-level supply chain, consisting of a vendor and multiple buyers, when delivery performance, unlike traditional models, is taken into consideration. Early and late deliveries, outside a delivery time window, introduce inefficiencies and additional costs into the supply chain.
DESIGN: We develop a mathematical model for each of the vendor and multiple buyers, and for the total supply chain costs, and with and without coordination scenarios. We analytically derive the optimal replenishment decisions for the buyer and vendor under each scenario. We analytically derive closed-form solutions when the delivery time window follows the Asymmetric Laplace distribution. The model is supported with numerical examples and sensitivity analysis.
FINDINGS: We show that traditional supply chain models that ignore the untimely delivery costs tend to underestimate the buyer's order size and overestimate the vendor's order. Accounting for untimely delivery costs can reduce supply chain costs by an average of 40%.
VALUE: This paper has significant practical implications. In today's global and competitive environment, companies compete to reduce costs, increase efficiency, and increase customer service level. Delivery performance is a critical supply chain performance measure that directly impacts customer satisfaction level. We show that when delivery performance is properly accounted for, it impacts the various players' decisions and improve the profitability of the supply chain. More importantly, we show applying traditional models in this case often result in biased and suboptimal decisions.

KEYWORDS: delivery window, lot sizing, supply chain, coordination.

INTRODUCTION

The delivery process in a supply chain is a key component of supply chain operations and a key strategic performance measure within a supply chain. The performance of the delivery process within a supply chain directly impacts sourcing decisions as well as customer satisfaction (Tanai and Guiffrida 2015). This paper investigates the impact of coordinating a two-level supply chain, consisting of a vendor and multiple buyers, when delivery performance is taken into consideration. Specifically, an earliness or a lateness delivery cost are incurred each time an order arrives early or late, outside a delivery time window. Early and late deliveries introduce inefficiencies and additional costs into the supply chain. Early deliveries contribute to additional inventory holding costs, while late deliveries may result in production interruptions, lost sales and loss of customers goodwill. To hedge against untimely deliveries, supply chain managers often make biased decisions. Our paper derives the optimal order decisions for a vendor and multiple buyers in the presence of untimely delivery costs, and show that traditional models underestimate (overestimates) a buyer's (vendor's) ordering decisions and reduce the profitability of a supply chain.

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Several research works have identified and analyzed delivery performance as a key supply chain performance measure (Guiffrida and Jaber, 2008; Tanai and Guiffrida, 2015; Bushuev and Guiffrida, 2012; Bhattacharyya et al. 2015; Bushuev, 2018; Guiffrida and Nagi, 2006; Shahriar et al. 2017). Our paper is the first to incorporate delivery performance into a two-level supply chain cost model in order to analyze the effect of delivery timeliness on supply chain inventory decisions made by the vendor and buyers. Additionally, we obtain analytical results when the delivery time window follows the Asymmetric Laplace distribution instead of the Gaussian distribution commonly used in the literature.

In fact, most of the supply chain delivery performance models that exist in the literature use the Gaussain probability density function to model the delivery timeliness distribution (Guiffrida and Nagi, 2006; Bushuev, 2018; Guiffrida and Jaber, 2008; Roy et al., 2013; Garg et al., 2006; Shin et al., 2009). Recent research studies (Tanai and Guiffrida, 2015) express concerns about using the Gaussian distribution to model delivery timeliness and suggest the Asymmetric Laplace distribution as an attractive probability density function for modeling supply chain delivery timeliness.

MATHEMATICAL MODEL

We consider a two level supply chain consisting of a vendor/manufacturer who manufactures the final product, and a number of n buyers/retailers. The supply chain undergoes a number of activities before the final product is delivered to customers in the last stage. The delivery lead time is the time from when the supplier receives the order to when the order is delivered to the final customer and is the summation of activity durations at each supply chain stage. Activity durations across and within supply chain levels are assumed to follow the Asymmetric Laplace distribution, as in Tanai and Guiffrida (2015); Bushuev and Guiffrida (2012).

We make the following assumptions: The time horizon is infinite; Demand is deterministic; Activity durations across the supply chain levels follow the Asymmetric Laplace distribution; No shortages are allowed; The lead time is zero. Buyer n places an order quantity of size Q_n every Tn period of time, $T_n = Q_n/D_n$. Let $[c_1, c_2]$ be the window of delivery timeliness. That is, if $c_1 \leq E(X) \leq c_2$ the product is delivered on time to the final customer. Otherwise, if $E(X) \in (-\infty, c_1]$, the product is early and buyer n incurs a holding cost $\hat{h}_n$ as the product is stored before it is being delivered to customers. We assume that the cost of early delivery is incurred by the buyer, and the earliness cost is computed per early delivered batch. If $E(X) \in [c_2, -\infty)$, the product is delivered late, incurring a penalty cost p_n per unit time of late delivery. The lateness cost is incurred by the vendor and is computed per batch of late delivery. We define the timeliness delivery window as $c_2 - c_1$ the difference between the latest acceptable delivery date and the earliest acceptable delivery date. The notation is summarized below.

Notation

Buyer

- D_n annual demand rate for buyer n (units/year)
- A_n order cost per cycle
- h_n holding cost per unit per year ($/unit/year)
- $\hat{h}_n$ cost of early delivery ($ per early delivery)
- p_n penalty cost per unit time of late delivery
- c_1 beginning of on time delivery of the buyer
- c_2 end of on time delivery of the buyer
- T_n cycle time (year)
- Q_n order quantity of buyer n (units) (decision variable)

Vendor

- A_v fixed order cost per cycle for the vendor ($)

h_v holding cost per unit (\$/unit/year)
S_n Fixed ordering cost for the vendor, dependent on buyer n
λ_n integer multiplier to adjust the order quantity of the vendor to that of the buyer (decision variable)

Next, we develop the cost functions of buyer n and that of the vendor assuming no earliness or lateness costs, then we incorporate the earliness and lateness costs into the supply chain model, derive the optimal decisions, and analytically obtain some sensitivity results.

Model without the untimely delivery cost

Buyer's Cost
The vendor needs to determine his/her order quantity, a multiple $\lambda_n$of the buyer's order quantity, in order to satisfy the demand of each buyer n. The annual cost to fulfill the request of buyer n is

$$C_v(T_n, \lambda_n) = \frac{A_v}{\lambda_n T_n} + \frac{h_v}{2}(\lambda_n - 1)D_n T_n + \frac{S_n}{T_n},$$

where the first term is the annual fixed ordering cost and the second term is the holding cost to satisfy the demand of buyer n. Note that the unit costs have no effect on the optimal decisions, thus we have omitted them from the formulation of the cost functions. However, they are used in the numerical analysis to compute the holding costs as a percentage of the unit cost. The total vendor's cost can thus be written as

$$C_v(T_n, \lambda_n) = \sum_{n=1}^{N} \left(\frac{A_v}{\lambda_n T_n} + \frac{h_v}{2}(\lambda_n - 1)D_n T_n + \frac{S_n}{T_n} \right)$$

The optimal replenishment cycle and the vendor quantity multiplier can be derived as

$$T_n^0 = \sqrt{2A_n/(D_n h_n)} \qquad \lambda_n^0 = \sqrt{2A_v/(h_n D_n T_n^2)}.$$

With Coordination
Next, we find the optimal buyer and vendor's decisions in the case of coordination. Here, we we assume the same cycle time T is set for all buyers, i.e. $T_1 = T_2 = \ldots = T_n = T$ as in Jaber and Goyal (2008), and λ_v to be the common integer multiplier. Then, the total cost of the supply chain under coordination can be written as

$$TC(\lambda_v, T)_{chain} = \sum_{n=1}^{N} \left(\frac{A_n}{T} + \frac{h_n}{2} D_n T \right) + \frac{A_v}{\lambda_v T} + \sum_{n=1}^{N} \frac{S_n}{T} + \frac{h}{2}(\lambda_v - 1)T \sum_{n=1}^{N} D_n.$$

The optimal replenishment cycle and the vendor quantity multiplier are found from the total supply chain cost function by using differential calculus as follows

$$T_{chain}^0 = \sqrt{\frac{2\left(\sum_{n=1}^{N}(A_n + S_n) + A_v/\lambda_v \right)}{h(\lambda_v - 1)\sum_{n=1}^{N} D_n + \sum_{n=1}^{N} h_n D_n}},$$

$$\lambda_{chain}^0 = \sqrt{\frac{2A}{T^2 h \sum_{n=1}^{N} D_n}}$$

Model with untimely delivery performance

Buyer's cost
The cost of early delivery is paid by the buyer. Referring to Figure 1, there is a cost incurred by buyer n whenever there is an early delivery arriving before the inventory level reaches

zero. In this case, the expected holding cost is found using the area of the rectangle with height Q_n and base the expected early delivery duration, $E(c_1 - x)$, where c_1 is the lower limit of the delivery window and x the delivery time. The retailer's total cost per cycle is the summation of the ordering, holding, and expected early delivery, and can be written as follows

$$C_n/\text{cycle} = A_n + h_n \frac{D_n T_n^2}{2} + \hat{h}_n \int_{-\infty}^{c_1} (c_1 - x) f(x) dx$$

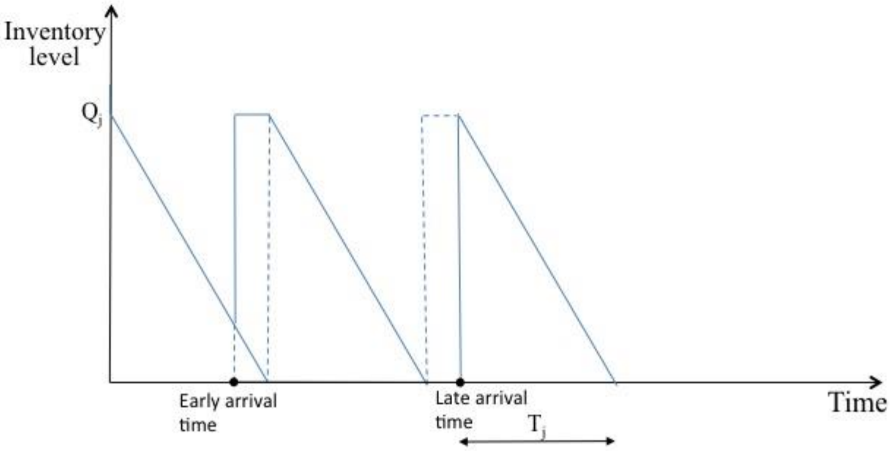

Figure 1: Inventory level for buyer j.

Then, buyer n's annual cost can be written as

$$C_n/\text{unit time} = \frac{A_n}{T_n} + h_n \frac{D_n T_n}{2} + \hat{h}_n \frac{\int_{-\infty}^{c_1} (c_1 - x) f(x) dx}{T_n}$$

Vendor’s cost

In case of late delivery, the penalty cost is paid by the vendor and is computed based on the expected late delivery, $E(x - c_2)$, where c_2 is the fixed upper limit of the delivery window. The vendor needs to determine its order quantity $\lambda_n Q_n$ to satisfy the demand of each buyer n. The annual cost to fulfill the request of buyer n is

$$C_v(Q_n, \lambda_{v,n})/\text{unit time} = \frac{A_n}{\lambda_n T_n} + \frac{h_v}{2}(\lambda_n - 1) D_n T_n + \frac{p_n}{T_n} \int_{c_2}^{\infty} (x - c_2) f(x) dx,$$

where the first term is the annual fixed ordering cost and the second term is the holding cost to satisfy the demand of buyer n. Note that the unit costs have no effect on the optimal decisions, thus we have omitted them from the formulation of the cost functions. We, however, use them in the numerical analysis section to compute the holding costs as a percentage of the unit cost. The total vendor's cost can thus be written as summation of the vendor’s cost for all n buyers, as follows

$$C_v/\text{unit time} = \sum_{n=1}^{N} \left(\frac{A_v}{\lambda_n T_n} + \frac{h}{2}(\lambda_n - 1) D_n T_n \right) + \sum_{n=1}^{N} \frac{S_n}{T_n} + \sum_{n=1}^{N} \frac{p_n}{T_n} \int_{c_2}^{\infty} (x - c_2) f(x) dx$$

Under no coordination, the buyer's cost function per unit time, C_n, given in in the above equation is convex in T_n. The optimal replenishment cycle for buyer n is given by

$$T_n' = \sqrt{\frac{2\left(h_n \int_{-\infty}^{c_1} (c_1 - x) f(x) dx + A_n \right)}{h_n D_n}}, \text{ and } T_n' \geq T_n^0.$$

Under no coordination, the vendor's cost function per unit time, C_v, given above is convex in λ_nThe optimal value of $\lambda_n$that minimizes the vendor's cost for buyer n is given by

$$\lambda'_n = \sqrt{\frac{2A_v}{hT'^2_n D_n}},\ \text{and}\ \lambda'_n \le \lambda^0_n.$$

With coordination
In this case, the buyer and vendors coordinate their decisions and share the costs of untimely delivery such that the total supply chain cost is minimized. The optimal decisions are the vendor's integer multiplier λ_v and buyer n optimal replenishment cycle T. Here we assume as Jaber and Goyal (2008) and Visnawathan and Piplani (2001) that $T_1 = T_2 = \ldots = T_n = T$. Then, we have the following supply chain cost function

$$\begin{aligned} TC(\lambda_v, T) &= \sum_{n=1}^{N}\Bigg(\frac{A_n}{T} + h_n\frac{D_nT}{2} + \frac{A_v}{\lambda_v T} + \frac{S_n}{T} + \frac{h_v}{2}(\lambda_v - 1)D_nT + \hat{h}_nD_n\int_{-\infty}^{c_1}(c_1 - x)f(x)dx \\ &+ \frac{p_n}{T}\int_{c_2}^{\infty}(x - c_2)f(x)dx\Bigg). \qquad (16)\end{aligned}$$

Lemma 1. *i) The total cost function under the coordinated supply chain model is jointly convex in T and λ_v.*

ii) The optimal decision variables that minimizes the coordinated supply chain cost in (16) are given by the following equations

$$T'_{chain} = \sqrt{\frac{2\sum_{n=1}^{N}\left(A_n + S_n + \hat{h}_n\int_{-\infty}^{c_1}(c_1 - x)f(x)dx + 2A_v/\lambda_v + p_n\int_{c_2}^{\infty}(x - c_2)f(x)dx\right)}{\sum_{n=1}^{N}h_nD_n + h_v(\lambda_n - 1)\sum_{n=1}^{N}D_n}} \qquad (17)$$

where $T'_{chain} > T^0_{chain}$, and the optimal vendor's decision λ_v is such that

$$TC_{chain}(T'_{chain}, \lambda'_{v-1}) > TC_{chain}(T'_{chain}, \lambda_v)\ \text{and}\ TC_{chain}(T'_{chain}, \lambda_v) < TC_{chain}(T'_{chain}, \lambda'_{v+1}).$$

ASYMMETRIC LAPLACE DISTRIBUTION FOR DELIVERY TIMELINESS
We derive sensitivity results for the optimal supply chain decisions. We assume the delivery window x follows the Asymmetric Laplace distribution. For reference on Asymmetric Laplace distribution, we refer the reader to Tanai and Guiffrida (2015), Bushuev and Guiffrida (2012), Kozubowski and Podgorski (2000). The probability density and cumulative distribution functions of the Asymmetric Laplace distribution are defined as follows:

$$f_{\theta,\mu,\sigma}(x) = \left(\frac{\sqrt{2}}{\sigma}\frac{k}{1+k^2}\right)\left\{\begin{array}{ll} e^{\frac{\sqrt{2}k}{\sigma}(x-\theta)} & \text{if } x \ge \theta \\ e^{\frac{\sqrt{2}}{\sigma k}(x-\theta)} & \text{if } x < \theta \end{array}\right\}$$

$$F_{\theta,\mu,\sigma}(x) = \left\{\begin{array}{ll} 1 - \frac{1}{1+k^2}e^{\frac{\sqrt{2}k}{\sigma}(x-\theta)} & \text{if } x > \theta \\ \frac{k^2}{1+k^2}e^{\frac{\sqrt{2}}{\sigma k}(x-\theta)} & \text{if } x \le \theta \end{array}\right\},$$

Where

$$k = \frac{\sqrt{2}\sigma}{\mu + \sqrt{\mu^2 + 2\sigma^2}}.$$

Then, using the Asymmetric Laplace distribution defined above, we can derive the following expressions for the earliness and lateness costs (for detailed derivations, we refer the reader to Tanai and Guiffrida, 2015)

$$C_{early} = \hat{h}_n \frac{e^{-\frac{(\theta-c_1)(\mu+\sqrt{\mu^2+2\sigma^2})}{\sigma_1^2}}(\mu^2+\sigma^2-\mu\sqrt{\mu^2+2\sigma^2})}{2\sqrt{\mu^2+2\sigma^2}}$$

$$C_{lateness} = p_n \frac{e^{\frac{2(\theta-c_2)}{\mu+\sqrt{\mu^2+2\sigma^2}}}(\sigma^2+\mu(\mu+\sqrt{\mu^2+2\sigma^2})}{2\sqrt{\mu^2+2\sigma^2}}$$

Then the optimal replenishment cycle under no coordination is

$$T_n' = \sqrt{\frac{2(C_{earliness}+A_n)}{h_n D_n}}$$

Similarly, the optimal replenishment decision under coordination is found as

$$T_{chain}' = \sqrt{\frac{2\sum_{n=1}^{N}\left(A_n+S_n+C_{earliness}+C_{lateness}+2A_v/\lambda_v\right)}{\sum_{n=1}^{N} h_n D_n + h_v(\lambda_n-1)\sum_{n=1}^{N} D_n}}$$

NUMERICAL ANALYSIS

For numerical analyses, we test a one-vendor and two-buyers system. We adopt the basic parameters from Jaber and Goyal (2008) and Bushuev and Guiffrida (2012). Closed form expressions for the untimely delivery costs are derived for asymmetric Laplace distribution of delivery time following Bushuev and Guiffrida (2012), Tanai and Guiffrida (2015). Parameter setting of the base problem is shown in Table 1 below.

θ	μ	σ	Δc	P	H	A	h	A_1	h_1	D_1	S_1	A_2	h_2	D_2	S_2
0	3	13	8	200	50	300	6	30	16	100000	45	50	14	75000	75

Table 1. Base Problem Parameters.

We perform extensive sensitivity analysis with respect to the model untimely delivery parameters. In each problem instance tested, only one parameter from the base setting is changed. For each problem instance, both uncoordinated and coordinated solutions are obtained for each of the cases where untimely delivery costs are considered or not. Thus, solutions of four models are reported for each instance. The benefit of coordination, i.e., the percent decrease in total system costs, is reported separately. We make the following observations:

- Under both coordinated and uncoordinated solutions when untimely delivery costs are considered, the replenishment cycle times of buyers, T_1 and T_2 under no-coordination, and T under coordination, increase. This implies that buyers order more when delivery performance costs are considered, even though buyers incur the cost of early delivery. In addition, the integer multiplier of the vendor for each buyer, and λ_1 and λ_2 under no-coordination and λ_v under coordination, decrease, which implies that the vendor orders less than in the model when untimely delivery costs are ignored. Vendor benefits from this solution, as he prefers less frequent orders because of his higher fixed costs. Thus, traditional supply chain models that ignore untimely delivery costs tend to underestimate the orders of the buyers and overestimate the vendor's orders.

- The benefit of coordination in percentage is much higher under untimely delivery costs. Coordination in the case when untimely delivery costs significantly achieves reduction in the supply chain cost, with an average of 40% reduction in cost.

CONCLUDING REMARKS

We formulate a two-level supply chain consisting of one vendor and multiple buyers that accounts for the delivery performance, an important performance measure in a supply chain. The model incorporates the earliness and lateness cost of untimely deliveries. We obtain a closed form expression of the vendor and buyer replenishment cycle and order quantity decisions, when the delivery time follows the Asymmetric Laplace distribution. We perform extensive sensitivity and numerical analysis. Our results indicate that traditional supply chain models underestimate (overestimates) a buyer's (vendor's) order quantity. To hedge against the uncertainty in the delivery performance, and assuming that the buyer bears the earliness cost while the vendor bears the lateness cost, we show that the buyer should increase the order size and the vendor should reduce its order size. We also investigate the impact of coordination in the presence of untimely delivery costs and show that significant savings are achieved. In fact, we observe in our extensive numerical analysis an average reduction of 40% in the total supply chain under coordination when the untimely delivery costs are incorporated, compared to 20% in the case when untimely delivery costs are ignored.

ACKNOWLEDGEMENTS

M.Y. Jaber thanks the Natural Sciences and Engineering Research Council of Canada (NSERC) for supporting his research activities, and the FEA Dean and the MIE Chair at Ryerson University for partially supporting his travel.

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ON CONSIGNMENT SALES FOR ITEMS WITH A SHORT SELLING SEASON

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Purpose
The purpose of this paper is to study the effectiveness of the consignment sales contract between the retailer and the manufacturer. The research intends to show how profitability and service level can improve both locally and globally through collaboration when supplying products with a short selling season. In particular, the paper aims to establish supply chain settings with respect to demand variability and cost structures under which consignment sales could be beneficial for stakeholders.

Design/methodology/approach
The paper builds on the newsvendor model to develop the optimal consignment sales policy in which the consignor (manufacturer) places the product at the consignee (retailer) to gain greater exposure to the market, whereas, the consignee physically stores the product and pays the consignor only upon the sales of the product. Using the traditional newsvendor model as the base case, this research conducts numerical experiments for sensitivity analysis as well as compares its results with the well-established optimal return policies proposed by Pasternack (1985) to assess the effectiveness of the consignment sales contract.

Findings
Analytical results for the consignment sales contract indicate that the optimal consignment stock is primarily contingent on the cost of goodwill and the commission rate to be negotiated between the parties. Further, initial results of the numerical experiments reveal that the higher the demand uncertainty, the lower the optimal commission rate determined for the overall system.

Value
The vast majority of existing literature on vendor-initiated replenishment is focused on the research of vendor-managed inventory. In comparison, the study of the consignment sales has been rather limited. Considering the fact that the consignment sales contract holds greater relevance for new products (uncertain demand with no sales history), seasonal products, or perishables, this paper contributes in filling research gap by identifying incentive aligned collaborative initiative via use of the newsvendor approach.

Research limitations/implications
Although this paper provides valuable insights on the benefits of the consignment sales, its structure of single retailer – single supplier can be considered a limitation. An extension for future research direction, thus, includes the study of the initiative under multi-retailer setting. Also, incorporating the impact of supply-side disruption should provide a relevant and interesting research avenue.

Practical Contribution
Assuming no legal ownership of the product and merely acting as the agent of the consignor, the consignee minimizes the financial loss from capital investment or the risk of overstocking under high demand variability and a short selling season. Further, consumers benefit from such an agreement as product availability improves as a consequence of the collaboration between parties.

INTRODUCTION

Businesses in the 21st centuries are witnessing a major trend dictating their performance in increasing complexity of dynamics in the global supply chain: namely, a transition from a decentralized view of business practices to a collaborative view of supply chain initiatives (Zhao et al., 2017; Han and Dong, 2015). In clear departure from the paradigm that governed business relationships of the past, companies have come to the realization that developing collaborative relationship among business partners has become an industry-wide mandate to be competitive in the global supply chain (Mesa and Galdeano-Gomez, 2015). Among major factors behind this transition to collaborative and integrative approach in decision framework is the growing importance of *time* over *cost and quality* as the primary competitive dimension in business arena in the last few decades (Olhager, 2013). Understanding the implications of shortened time dimension with respect to manufacturing and delivery lead time, product development time, and product life cycle is critical in designing conceptual framework of collaborative initiatives between supply chain partners (Beamon, 2008). In particular, due to prevalence of shrinking product life cycle or selling season for growing number of products, having an agile and mutually beneficial coordination mechanism in supply chain operations is now more crucial than ever before as each company is given only a small window of time to maximize its contribution to the overall supply chain potential.

In practice, there are as many successful implementations of supply chain coordination as there are failures due to lack of collaborations or misalignment of incentives among supply chain partners. Wal-Mart and P&G's Continuous Replenishment (CR) program based on the implementation of Collaborative Planning Forecasting and Replenishment (CPFR) clearly displayed how mutual trust and industry leadership based on information visibility can lead to coordination at strategic as well as at operational level in the retail industry (Fleidner, 2003). In a related supply chain contract, business partners engage in a vendor-managed inventory (VMI) agreement where, given information visibility between the vendor and its buyers, the vendor takes full responsibility of making replenishment and inventory decisions for its buyers in a coordinated and integrated manner (Darwish and Odah, 2010; Yao and Dresner, 2008). In such a contract, buyers (retailers) are primarily involved with consumer promotions and information sharing with the vendor (Waller, Johnson, and Davis, 1999). Both business practices and research have shown that, in general, the vendor is deemed to be in better position to make integrated decisions for the entire system given its upstream perspective in the supply chain granted that demand information is readily accessible to the vendor as illustrated in successful implementation cases of VMI contract between Walgreens and SC Johnson, at Campbell Soup, Nestle, and IKEA (Henningsson and Linden, 2005). On the other hand, numerous examples of supply chain coordination failure originate from lack of trust, incomplete information sharing, or inequitable benefits to be allocated between supply chain partners (Corsten and Kumar, 2005; Narayaman and Raman, 2004). In majority of cases where disparity in supply chain benefits are reported among stakeholders, greater benefits tend to be distributed to the buyer sides, often undermining long term trust with their suppliers (Ellegaard and Freytag, 2010).

Literature on vendor-initiated replenishment is heavily tilted towards the study on the VMI contract with its proven effectiveness in practice. It should be noted, however, that for a relatively newer product with a *short selling season*, buyers (i.e., retailers) may not want to make financial commitment by purchasing items for which they have little sales record, rendering conventional supply chain contracts less attractive for buyers despite the need for collaborations. For instance, as discussed in a study of Spanish horticultural exporting companies working with wide variety of European retailers, Mesa and Galdeano-Gomez (2005) show that under business circumstances defined by rather short time windows (e.g., perishables), supply chain partners look for steady and cooperative relationship to gain greater supply chain profitability. Understanding the need for collaborative efforts in such cases, this paper intends to address research questions related to vendor-initiated collaborative replenishment policy for business settings defined by uncertain demand and short selling season. In particular, the paper proposes the use of an agreement between supply chain partners, known as consignment sales and inventory contract, whereby the vendor (consignor) delivers its goods to the buyer (consignee or retailer in most cases) to be displayed and sold without being paid for the goods upon delivery (Zahran et al., 2016). The payment of the goods by the consignee to the consignor takes place only after the actual sales of the goods to the end customer: in such an agreement, the ownership of the items remains with the consignor and transfers directly to the end customer upon sales. The consignee rarely takes legal ownership of the goods throughout the whole process. In an earlier analytical paper, Braglia and Zavanella (2003) modelled consignment sales and inventory and discussed advantages and disadvantages of its practice. Their paper was followed by a number of other related research on industry cases of consignment sales contract (Valentini and Zavanella, 2003), revenue sharing applications (Wang et al., 2004), implications of storage and financial terms (Hung and Chen, 2009), coordination of a vertically separated system using VMI and consignment sales (Chen et al., 2010), and impact of stock-dependent demand (Zanoni and Jaber, 2015). New products with little sales history or products with limited life cycle are deemed to be a good fit for consignment sales because the retailers are generally more inclined to promote the products they carry on consignment as there is little financial commitment to be made on their end.

The paper uses newsvendor model to capture desirable features of supply contract between the consignor (manufacturer) and the consignee (retailer) for products with a short life cycle and uncertain demand for which traditional VMI contract does not provide much benefits due to financial investment expected for items with greater level of uncertainties. Although consignment sales contract has not been studied extensively in supply chain research relative to other vendor-initiated collaborations, such as the VMI, it holds relevance for new products, seasonal items, and perishables as it provides an attractive option for the retailer (consignee) whose potential investment loss due to lack of demand can be protected. This paper contributes in filling research gap in vendor-initiated supply chain collaboration by identifying incentive aligned consignment sales contract for products with a short selling season and uncertain demand using the newsvendor model.

OBJECTIVE AND RESEARCH QUESTIONS

The purpose of this paper is two-fold: to assess the effectiveness of the consignment sales contract between the consignor (manufacturer) and the consignee (retailer) to establish supply chain settings with respect to demand variability and cost structures under which consignment sales could be beneficial for all stakeholders involved. The paper shows how profitability and service level can improve both locally and globally through collaboration when supplying products with a short selling season. That is, the research identifies and proposes the use of incentive aligned collaborative initiative in the form of consignment sales contract while making a comparison with the well-established optimal return policy for perishables as recommended by Pasternack (1985). Using the traditional newsvendor model as the base case, the research conducts numerical experiments for sensitivity analysis and discusses dynamics within the supply chain when consignment sales contract is in place. The paper addresses the following research questions:

- How effective is consignment sales contract as a supply chain collaboration mechanism for products with a short selling season?
- What are business settings under which consignment sales contract could be beneficial to stakeholders in improving supply chain performance metrics?
- How do supply chain parameters (e.g., demand variability, cost of good will, and commission rate) affect incentive-aligned consignment contract between the consignor and the consignee?

CONSIGNMENT SALES CONTRACT IN A TWO ECHELON SUPPLY CHAIN

This paper studies a general two-stage supply chain setting in which a manufacturer supplies a retailer with a product as per consignment sales contract that features uncertain demand and a short selling season. Consignment is defined in the *APICS Dictionary* (2016) as "the process of a supplier placing goods at a customer location without receiving payment until after the goods are used or sold". This is different from conventional business transaction in which the buyer is obligated to make payment to the vendor for the delivery of goods within set period as per agreement. Under typical consignment sales agreement, the consignee (retailer) acts as the agent of the consignor (manufacturer) without assuming legal ownership of products, thus hedging significant financial risk associated with the purchase and storage of the products. The consignee physically stores the products and pays the consignor the proceeds from the sales less the commission fee. In such a contract, the consignee may prefer to carry a large inventory as a way to buffer against demand uncertainty at a little to no risk as unsold items at the end of the selling season are fully returned to the consignor, the legal owner of the products. On the contrary, the consignor can easily run into working capital problem if payments are not collected for a lengthy period of time (Williams, 2000). This situation calls for the right contract in which incentives for collaboration are properly aligned to balance risk and rewards between business partners.

Among supply chain framework exhibiting similarity to consignment sales is the supply contract with the return policy for perishable commodities (Pasternack, 1985). Pasternack (1985) showed that the optimality of the return policy in the multi-retailer setting is achievable when unlimited returns to the vendor for unsold items are allowed at partial credits. The wholesale price and the partial credit value are thus determined as part of this return-based coordination contract. In contrast, in the consignment sales contract studied here, the commission rate to be applied and paid to the retailer upon sales of the items is the main decision variable along with the consigned quantity.

For seasonal products or new products, the retailer will naturally display reluctance to invest in inventory due to either a short selling season or uncertain demand, whereas, the vendor (manufacturer) wants maximum exposure of its product in the marketplace. Understanding this, the vendor has clear incentive to propose consignment-based contract to the retailer to put the products on retail shelves to enjoy exposure to the market while allowing the retailer to hedge risk of making financial commitment. Following notations will be used to model consignment sales contract using the newsvendor model:

c = unit manufacturing cost
p = unit retail price
$gw(R)$ = unit goodwill cost incurred at the consignee (retailer)
$gw(M)$ = unit goodwill cost incurred at the consignor (manufacturer)
s = unit salvage value
r = commission rate, where $p \cdot r$ is the unit commission fee paid to the consignee
Q = consigned quantity owned by the consignor but stored at the consignee
x = market demand normally distributed with mean of μ and standard deviation of σ.

In consignment sales contract, the consignor and the consignee each faces understocking (C_u) and overstocking costs (C_o) respectively as follows under the premise that all unsold items will be fully returned to the consignor at the end of the selling season:

<u>Consignee (Retailer):</u>
$C_U(R) = p \cdot r + gw(R)$

$C_O(R) = 0$

<u>Consignor (Manufacturer):</u>
$C_U(M) = p \cdot (1 - r) - c + gw(M)$

$C_O(M) = c - s$

The expected profit at the consignee, $\mathrm{E}P_R(Q)$, is obtained in the following manner as per the newsvendor model:

If demand $x \leq Q$, consignee profit = $x \cdot pr$

If demand $x > Q$, consignee profit = $Q \cdot pr - gw(R)(x - Q)$

$$\mathrm{E}P_R(Q) = \int_0^Q x \cdot pr \cdot f(x)dx + \int_Q^\infty [Q \cdot pr - gw(R) \cdot (x - Q)] \cdot f(x)dx$$
$$= pr \cdot \mu - E(s)[pr + gw(R)] \quad (1)$$

where $f(x)$ and $F(x)$ are density function and distribution function of demand *x* and *E(s)* is the expected shortage.

From equation (1) above, $\frac{\mathrm{d}\mathrm{E}P_R(Q)}{dQ} = -[pr + gw(R)] \cdot (SL - 1) = 0$, which implies that the consignee has every incentive to stock (or consign) as much as possible with no risk involved with overstocking regardless of the commission rate.

Now from the overall system's perspective, the optimality condition is contingent not only on the consigned quantity but also on the commission rate to be applied to the retail price. Understocking cost, $C_U(T)$, and overstocking cost, $C_O(T)$, for the system are obtained as

$C_U(T) = p - c + g$ where $g = gw(R) + gw(M)$

$C_O(T) = c - s$

Expected profit for the whole system, $\mathrm{E}P_T(Q)$, can be simplified as in (2).

$$\mathrm{E}P_T(Q) = (p - s)\mu - (c - s)Q - (p - s + g)\sigma \cdot E(z) \quad (2)$$

with $P_{x<Q}(= SL) = {p - c + g}/{p - s + g}$ and optimal commission rate determined as

$$r = 1 - \frac{c-s}{p(1-SL)} - \frac{s-g}{p} \quad (3)$$

The commission rate to be determined for the consignment sales contract in (3) is expected to incorporate proper risk-reward allocation between the consignor and the consignee.

NUMERICAL EXPERIMENTS AND MANAGERIAL INSIGHTS

Designing Experimental Settings

Numerical experiments are conducted to perform sensitivity analysis and to understand dynamics among supply chain parameters. In particular, this paper investigates the impact of demand variability, salvage value, and goodwill costs on supply chain performance measures as well as on the commission rate. Range of parameter values and assumptions for the numerical experiments are summarized in Table 1 below.

The consignee faces market demand with an average of 500 units with the demand variability defined by standard deviation as per coefficient of variations (*cv*) which range from 0.1 (low variability) to 0.5 (high variability). Also, unit salvage values (s = \$0, \$3, \$6, and \$9) and unit goodwill costs at the consignee ($gw(R)$ = \$10, \$15, \$20, \$25, and \$30) are varied to investigate the impact on the expected system profit, service level, consigned quantity, and the commission rate. A total combination of 100 (= 5 x 4 x 5) business scenarios are studied. For each scenario, simulation runs are conducted and summarized for 500 cycles and over 2,000 replications.

Fixed parameters (per unit)	**Parameters (range)**
p = \$30.00	*cv = 0.1, 0.2, 0.3 0.4, 0.5*
c = \$10.00	*s = \$0, \$3, \$6, and \$9* (per unit)
r = TBD between 0 and 1	*gw(R) = \$10, \$15, \$20, \$25, and \$30* (per unit)
gw(M) = \$10.00	

μ = 500	**Assumptions**
σ = as per cv	Demand follows normal distribution
g = gw(R)+gw(M)	Unsold items at the consignee is fully returned to the consignor at the end of the selling season.
Q = TBD as per service level	

Table 1. Parameters and assumptions of simulation experiments

Discussions of Results and Managerial Implications

For all cases considered, consignment sales contract showed significant improvement in the expected supply chain profits over the base case defined in the numerical experiments as the traditional newsvendor model where stocking level is determined based on the optimal service level with given understocking and overstocking costs. As displayed in Figure 1, the expected supply chain profits show the largest percent improvement over the base case when the market demand exhibits higher variability (cv = 0.5) and when goodwill cost at the consignee is the lowest, which implies that the consignment sales contract effectively provides protection against demand uncertainty and stockout situations via collaborative risk hedging at the consignee level.

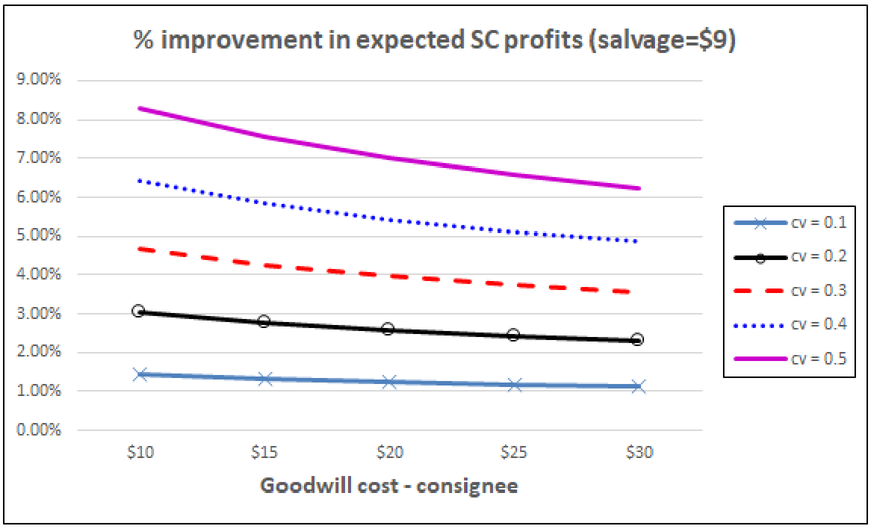


Figure 1. % improvement in expected supply chain profits (high cv)

As for the effect of salvage value on system profitability, it is clear that higher salvage value for items returned to the consignor at the end of the selling season commands much greater impact on profitability than does goodwill cost at the consignee. That is, higher salvage value of unsold items provides greater system profitability and better protection in overstocking situation. In fact, the impact of high salvage value (e.g., *s* = $9) is significant enough to nullify the impact of the goodwill cost at the consignee as illustrated in Figure 2.

Finally, optimal commission rate for the system with consignment sales contract is shown to be contingent on all three parameters: the salvage value for unsold items (*s*), goodwill cost at the consignee ($gw(R)$), and demand variability (*cv*) as observed in Figure 3.

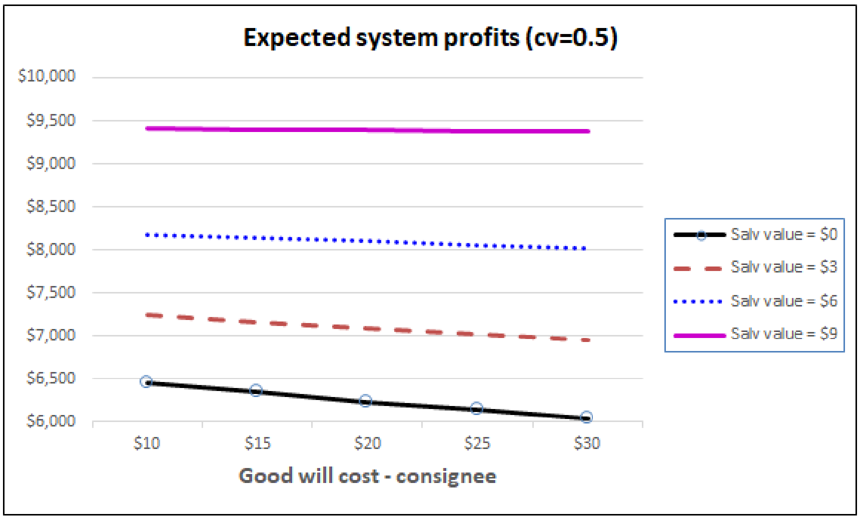
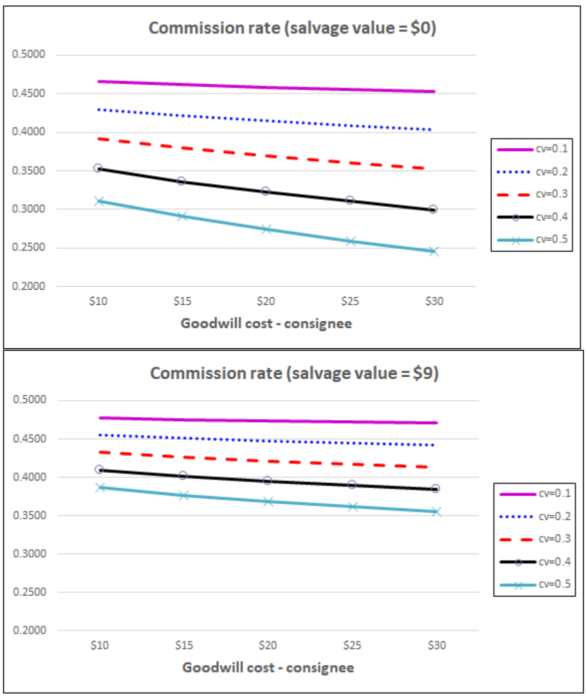


Figure 2. Expected supply chain profits with high demand uncertainty

With high salvage value for the returned items (*s* = $9), the consignor can afford to offer higher commission rate to the consignee, whereas, with greater loss of goodwill at the consignee level, say $gw(R) =$ $30, the optimal consigned quantity increases. As a consequence, the optimal commission rate offered to the consignee can go lower as the consignee should exhibit strong inclination to engage in consignment sales contract even with a lower commission rate. As for the impact of demand variability defined by the *cv* of demand, the consignee would be willing to accept a low commission rate when *cv* is high (e.g., *cv* = 0.5) as consignment sales effectively provides safety net under both understocking and overstocking scenarios with larger consigned quantity, *Q*.



No salvage value High salvage value

Figure 3. Commission rates with no salvage and high salvage values

CONCLUSION

This paper provides valuable insights on the benefits of consignment sales contract. It is noted, however, that the structure of the supply chain studied with a single consignor and a single consignee can be considered a limitation. A natural extension for future research, thus, includes the study of the initiative under multi-retailer setting. Also, incorporating the impact of supply-side disruption should further provide an interesting and relevant research avenue. Assuming no legal ownership of products and merely acting as the agent of the consignor, the consignee clearly sees the full benefit of engaging in consignment sales. Further, consumers generally benefit as well from such an agreement as product availability improves as a consequence of the consignment sales collaboration. Developing the right incentives for different variations of consignment-based contract will continue to provide a win-win partnership between stakeholders especially with shrinking time dimensions characterizing the current industry trend.

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IMPLEMENTING ASSOCIATION RULES FOR RACK REPLENISHMENT IN KIVA SYSTEMS

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ABSTRACT
Purpose – Kiva robots system is considered as the 8th generation of warehousing picking system by Amazon. The system utilizes Automated Guided Vehicles to pick up and carry racks to picking stations to realize goods-to-man picking operations and can save 2/3 of manpower in picking operations. One of the ways for efficient operations of the system is to have right assortment of goods on racks to reduce the number of rack move completing customer orders. This research looks into correlations of customer orders to study the goods allocation plan on racks that could effectively reduce the number of rack moves for shorter order completion time and less manpower used in picking operations.
Design/methodology/approach –This study aims at finding goods allocation plans considering correlations of customer orders for efficient picking operations. In calculating the correlation between and among orders, we used a priori association rules to compute the support and confidence of order items. We generate three batches of 10,000 orders with VBA, each referring to an EC company. We later implemented ABC classification and association rules to conduct different levels of order analysis. Considering put-to-light picking systems as in the Kiva systems, the correlations of order items and customer orders were computed with R programming software. The performance measure is the number of times to move racks to complete the customer orders. Different replenishment strategies for goods allocation on racks using product correlation values and order quantity ratios were implemented with simulation to find the optimal replenishment strategy.
Findings – We analyzed nine replenishment strategies and found that the best strategy among the nine could reduce the number of rack moves by 77.9% when compared to a randomly allocated strategy.
Value/Originality - Despite the growing application of Kiva systems in warehousing operations, there is only few studies look into operational improvement problems. This paper lies its originality in using association rules for rack replenishment strategy for efficient picking operations. The result show tremendous improvement in performance measures, which demonstrates the value of the paper.
Keywords: Kiva systems, movable racks, a priori, association rule, replenishment strategy

Category of the paper
Research paper

INTRODUCTION

Kiva robots system is considered as the 8th generation of warehousing picking system by Amazon. The system utilizes Automated Guided Vehicles (AGVs), so called Kiva robots, to pick up and carry racks to picking stations to realize goods-to-man picking operations and can save ⅔ of manpower in picking operations (Wurman et al., 2008). Each picking station is designed for put-to-light picking and may contain, depending on design and product characteristics, 6-30 cartons to fulfil 6-30 orders simultaneously. The movable racks can be packed tightly to spare space to stock more racks. The racks serve as inventory spots to store multiple kinds of products and depending on customer orders, racks are moved by Kiva robots to the picking stations. However, which racks are chosen to be moved and how many of them are moved to the picking stations to fulfill the wave of orders are some of the decision problems of the Kiva robots control system. Apparently, if proper racks are chosen, the number of racks moved to the picking station can be reduced. Further, because a rack can carry up a few hundred kilos of goods that occupy 1-2 m^3 of space, it can carry a variety of goods and their assortment affects how many racks are chosen for a wave of customer orders. Thus, one of the ways for efficient operations of the system is to have a "best" assortment of goods replenished on racks to reduce the number of rack moves required for completing customer orders.

As customer order contents is dynamic, it is hard to pre-determine what to replenish into racks. However, based on past order contents, including the product and the quantity as well the total sum etc., appropriate rack assortment suggestions can be given.

Figure 1 shows the control structure of a generic Kiva system via multi-agent modeling (Wurman et al., 2008). Multi-agent architecture has computational and organizational benefits. While the former deals with decomposition of computation across servers making the system robust to failures, the latter is on code compartmentalization for allocation of functions. The central control system of the multi-agent model of a Kiva system is the Job Manager (JM), which allocates resources and communicates with the WMS (warehouse management system) of the warehouse. A robot is modeled and embodied by the drive unit agent (DUA) and each station (for picking and possibly for replenishment as well) by the inventory station agent (ISA). As the JM receives customer orders to be fulfilled, it searches for available resources, including the racks, the robots, the inventory station etc. to make a reasonably good allocation decision based on a time-limit constraint. Besides the resource allocation, JM also works closely with DUA on both task planning and path planning, and with ISA on workflows. ISA, then, communicates with DUA on task planning, and DUA works with JM on path planning: DUA is also responsible for the motion planning of robots, while ISA also manages the pick-by-light controls. When a job is assigned in multi-agent modeling, which facilitates two-way communications, the job can be dynamically reassigned depending on the situation on the shop floor.

This research looks into correlations of customer orders to study the goods replenishment plan on racks because it affects the number of rack moves and, if planned well, could achieve the goal of less rack moves for shorter order completion time and less man-power used in order picking operations. It relates to one of the original metrics used by JM – the replenishment-task assignment. The replenishment of racks can happen at the picking stations or at specific replenishment stations. When both the required goods and the stations for replenishment are available, replenishment tasks begin to execute. The JM has to determine the product assortment to be replenished into the racks and this decision affects subsequent picking operations. By studying the correlations of customer orders, the JM could determine current good assortment plans for less rack moves as Figure 2 shows.

Unlike past research, which has only looked into put-away problems of stationary warehouses, this study aims at the replenishment strategy for movable racks. Each rack can be considered to hold a cluster of goods and the best scenario is for a pack of orders (a so-called "wave" from either a specific time window or a tranche of orders) to be picked with only one or a minimal number of rack moves to the picking stations. In order to achieve this, we plan to find the correlations among a pack of orders. Moreover, if each rack contains a better assortment of goods in terms of goods selection and quantity, the picking time per order could be reduced. We also expect that this improvement on rack replenishment could reduce the resources required for efficient operations of the warehouse.

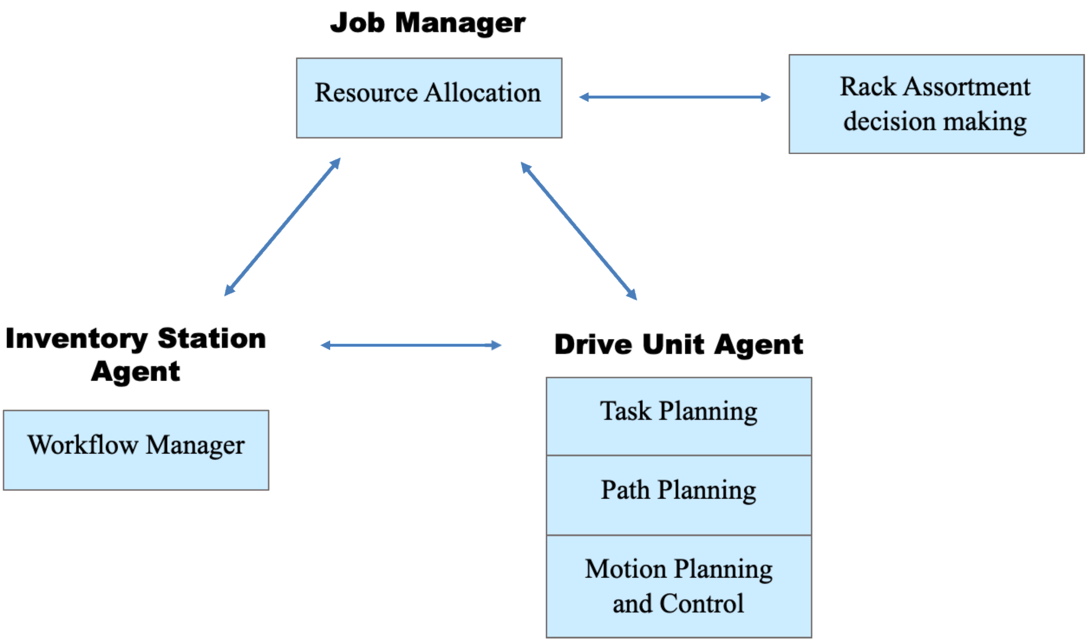

Figure 1: Rack assortment decision-making in a multi-agent architecture

METHOD

This study aims at finding goods allocation plans considering correlations of customer orders for efficient picking operations. For calculating the correlation between and among orders, we use a priori association rules to compute the support and confidence of order items (Agrawal et al., 1993; Hsu et al., 2004). Using Visual Basic for Applications (VBA), we randomly generated three packs of 10,000 orders referring to an EC company. We later implemented ABC classification and association rules to conduct different levels of order analysis. Considering put-to-light picking systems as in the Kiva system, the correlations between/among order items are computed with R programming software. The performance metric is defined as the number of rack moves to complete customer orders. Different replenishment strategies for goods allocation on racks using product and order quantity correlation values are computed with R programming language to find the optimal replenishment strategy.

The EC company has 26 types of products and each type features 10 to 60 products. DataSet1 contains 864 products. We assume each rack comprises 24 products without duplication and the assortment on a rack does not change. Thus, we need 36 kinds of rack assortments to hold all the products. We also assume that each customer order comprises 1-3 kinds of products and each is required 1-3 times. A picking station can hold 24 cartons at a time (4 bins x 3 rows x 2 sides), each representing an order, making a rack fulfill 24 orders at a time. When an order is completed, the respective carton is moved away and replaced by an empty one. Because picking and replenishment operations are usually separated, we further assume that the products on a rack will not be replenished next time the rack is called.

RESULTS

We designed nine rack replenishment strategies to form diverse assortments of products on a rack based on product correlation and ABC classification, Table 1. The performance metric is the number of journeys robots carrying racks to fulfill the orders and it is displayed in Figure 2 for DataSet1

Table 1 Rack Replenishment Strategy

Strategy	Description
ST1	Each rack holds products of either category (A, B or C) randomly.
ST2	Each rack holds 50% of category A products and other correlated category B and C products
ST3	Each rack holds 50% of category A products and other correlated category B and C products, also considering quantity correlation
ST4	Each rack holds 50% of category A products and other correlated category B and C products, and top 10% of hot sale products are distributed to multiple racks.
ST5	Each rack holds 50% of category A products and other correlated category B and C products considering quantity correlation, and top 10% of hot sale products are distributed to multiple racks.
ST6	Hold products on a rack sequentially based on correlation
ST7	Hold products on a rack sequentially based on correlation considering quantity correlation
ST8	Hold products with high correlation on a rack, and top 10% of hot sale products are distributed to multiple racks.
ST9	Hold products on a rack sequentially based on correlation considering quantity correlation, and top 10% of hot sale products are distributed to multiple racks.

In our study, we found that the two best strategies are ST5 and ST9 while BASE is the reference as the baseline which represents random assignment. From Figure 1, BASE performs similarly worse as ST1 (close to random assignment), which means any strategy proposed can improve the metric in some way or another. The best two strategies (ST5 and ST9) can reduce the number of rack moves by about 75% when compared to the BASE strategy.

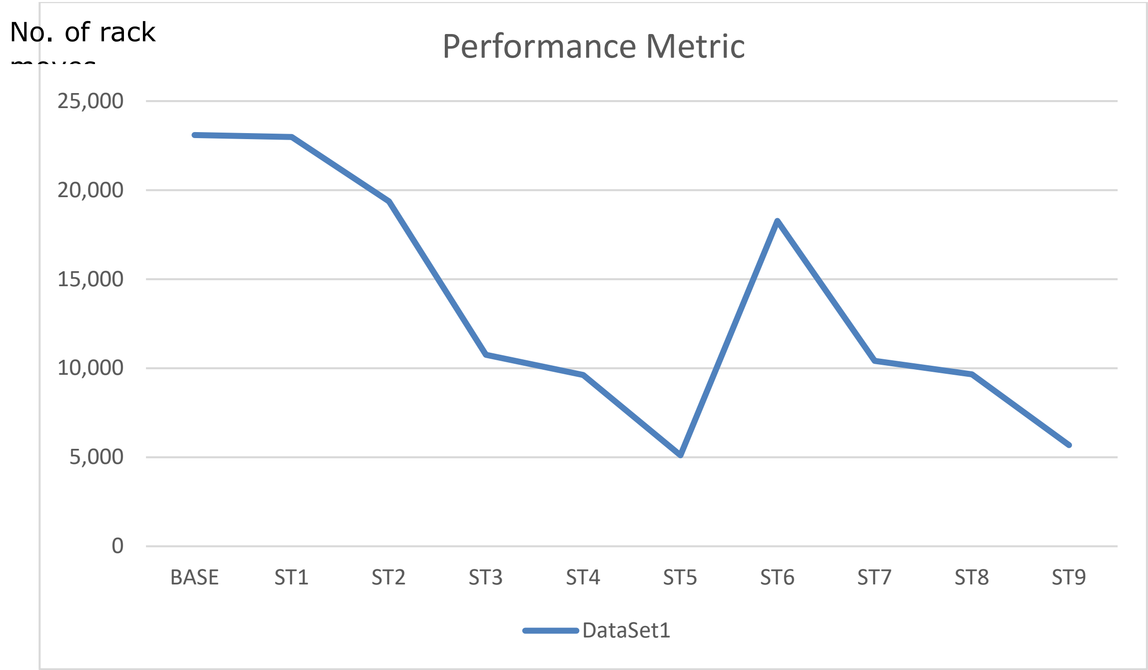

Figure 2: Performance Metric of DataSet1

CONCLUSIONS

In this study, we generated three kinds of order sets, each consisting of 10,000 orders. With a rack storage assignment strategy based on ABC classification, order association and order quantitative association rules, the result shows that implementing the association rules on rack replenishment has significant impact on the number of rack moves. Further, different replenishment strategies determine the assortment of products on a rack as Figure 2 shows. ST5 and ST9 can effectively reduce the number of rack moves, with ST5 reducing the number of moves by as much as 78% (from 23,000 for BASE to 5,100 for ST5). The result indicates the effectiveness of using association rules in order correlation and in order quantity correlation as well as distributing top sales items to diverse racks as ST5 and ST8 illustrate.

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Session 6: Supply Chain Performance Assessment

AN OPERATIONS-DRIVEN SIMULATION PLATFORM FOR THE ASSESSMENT OF FAIR SUPPLY CHAIN COSTS AND IMPACTS

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Purpose of this paper: Modern supply chains are characterized by large distribution networks spread over a globalized geography, multiple actors and stages, and lots of logistic operations, e.g. consolidation, packing and re-packing, storage, handling, delivery, typically performed by an extremely fractionated sector of carriers and logistic providers. In light of this, the real and objective full cost of a product which is sensibly affected by such operations is hard to be quantified.
This paper illustrates a simulation platform able to virtualize the supply chain operations of a generic logistic network and to allow quantifying costs and impacts associate to the logistic processes, thereby aiding a better and more fair product costing.

Design/methodology/approach: A flexible multithread simulation platform is developed with the attempt to virtualize a generic supply chain network as a group of production, storage and distribution nodes and to replicate the logistic operations i.e. processing, manufacturing, packing, storage, delivery throughout it. The costs and environmental impacts are then punctually quantified for each load of product (e.g. a piece, a carton or a pallet)as a consequence of the experienced processes (e.g. queues, delays and bottlenecks) and depending on the simulated order profiles, logistic capacities andthe undertaken decisional levers.

Findings: It comes out that even though each load experiences the same supply chain stages, the combination of exogenous conditions (weather, traffic, season), and endogenous aspects(congestions, bottlenecks) influences the logistic operations in a way that costs and impacts of the same product may result different.

Value: This paper explores the impact of the exogenous and endogenous conditions of supply chains on the economic and environmental performance of the logistic operations and on the determination of the proper and fair cost of a product.

Research limitations/implications: This research and the proposed operations-driven simulation platform pave the way for the implementation on real-scale of quantitative supply chain investigations trough advanced digital and information technologies as Internet-of-Things and Block chain architectures.

Practical implications: The determination of the proper, punctual and fair cost of a product as a consequence of the experienced specific logistic operations, with better visibility and transparency about price-making for the consumers and all the involved supply chain actors.

Keywords: Supply chain simulation, Virtual traceability, System dynamics, Flexible simulation model, Supply chain performance, Logistic operations.

1. INTRODUCTION AND FRAMEWORK

The integration of increasingly complex production and distribution systems throughout modern supply chain networks (SCNs) is an open challenge of this century. The intensification of demand and the widening of consumption areas, the customization of products, the enhanced distances between vendors and consumers, and the expectation of customers for price lowering, short delivering and quality of received products are among the main stressors of modern supply chains, whose management requires higher awareness of the operations behind, increased visibility and transparency of production and distribution tasks as well as quantifying and sharing metrics of performance among supply chain actors (Trienekens et al., 2011).

To deal with this complexity, the information sharing along the supply chain contributes to enhance visibility on characteristics of products, the requirements of tasks, the level of utilization of resources and of the production, storage and transport capacities, and other useful levers for the planning and control of the SCN.

Transparency and visibility of supply chain tasks and operations could result in improving the efficiency of logistics, the quality of products, the optimization of costs and of resource utilization, and quantifying the environmental impacts (e.g. emissions of air or water pollutants) associated to a specific task, with significant benefits for all actors and stakeholders (Yang et al., 2007).

Although theoretical intent, such visibility is poorly encouraged in practice by the supply chain actors themselves, who scare a loss of power in trading (Yao et al., 2008). Furthermore, barriers limit the diffusion of traceability and information sharing systems, which are expensive and requires expertise beyond most companies (Bottani and Rizzi, 2008; Bosona and Gebresenbet, 2013).

Traceability systems are indeed required to track the state of a product (i.e. *state variables*), to record the tasks experienced, the network's nodes visited, the conditions/disturbs it has been exposed to.To pursue this purpose, traceability systems, made by remote sensors, labels, information readers and recorders, and data repositories need to operate throughout extremely interconnected environments as SCNs are. Each node of the supply chain can be horizontally and vertically linked to others joining multiple production and distribution networks which evolve continuously. Meanwhile, each node manipulates products through its resources, occupies its capacities, modifies the *state variables* of products, being responsible to transfer such records' changes to the following nodes. Surveys on the topic confirm the gut feeling of a broken connection in the information sharing among supply chain nodes, mainly due to lack of standardization in information communication technologies, data architectures and the lack of awareness by companies of the potential benefits achievable through an integrated and comprehensive supply chain traceability (Wognum et al., 2011).

Practical solutions can be implemented by companies like strengthening the digitalization of information according to tailored data architectures (Accorsi et al., 2018), enhancing cooperation and information sharing among companies belonging to same supply chain, and exchanging technical details (e.g. capacities, throughputs, takt-time, number of resources) to enable coordinated planning and process optimization.

The point handled in this paper is the contribution that scholars and research might provide to aid companies toward such development. Instead of focusing on information technologies, or on the design of cost-effective and flexible traceability architectures, we approach to the purpose through the formulation of a generic supply chain model able to represent the entities, the operations and tasks manipulating products along a production and distribution network. This model, formulated through the system dynamics theory,includes the production, storage and transport operations carried out by a SCN in response to a customer order. The purpose of this model is to virtualize supply chain operations and quantifies the change of a product's *state variables* node by node, as well as the variation in the resources utilization (i.e. node's *state variables*) that the material flow would generate. The virtualization of the SC operations allows quantifying, tracing and controlling the value of products/nodes'*state variables*, thereby replacing the impact and effect that a real and physical traceability system would have (Feng, 2012). Thank to

this virtual (i.e. *simulated*) traceability systems, deduced information and records can be shared among companies, support coordinated planning and contribute to quantitatively assessing costs, impacts and supply chain performance.
System dynamics (Taylor, 2008) has been used to simulate and predict the behaviour and the performance of the supply chain as a wholefrom the comprehension of the behaviours of the single nodes operating along the production and distribution operations, and of the connections among these. The system dynamics model has been then implemented into a flexible simulation platform able to virtualize the characteristics of any supply chain (e.g. made of one-to-many nodes, stages, actors, products) thank to a tailored data entry.
The remainder of this paper sees the description of the supply chain model and the adopted theoretical approach in Section 2. Section 3 exemplifies how to run the system dynamics model through a tailored simulation platform developed to the scope. Section 4 comments on the potential applications of this work and claims future research developments.

2. SYSTEM DYNAMICS FOR SUPPLY CHAIN MODELLING

The management of SCNs entails the planning and coordination of many tasks and operations from the supply of raw materials, their processing and manufacturing, one-to-many stages of storage, and transport among nodes (Accorsi et al., 2017).
In the light of their implicit complexity, SCNs are affected by uncertainty which refers to the demand, the available (i.e. production, storage, transport) capacity at each node, the size of order and production batches, the production and distribution throughputs, the effectiveness of deliveries, and so on (Georgiadis et al., 2004; Rebs et al., 2019). In such environment the quantification and control of the wide sets of product's and node's *state variables* which result in costs, impacts and supply chain performance is unlike without the adoption of an integrated real-time traceability system.
With the purpose to address to the same target and to quantify the values of the *state variables* over time along supply chain operations, system dynamics approaches can be tried. Such techniques are able to study the dynamic of a complex system through the definition of the behaviour of the single entities, and the formulation of the non-linear and non-stationary interdependencies among these entities (Diaz et al., 2008).
For its nature, system dynamics is widely used to model supply chain processes (Langoodi and Amiri, 2016). In this paper a new supply chain model is formulated via system dynamics with the purpose of incorporating all the stages/tasks/operationsfrom suppliers to consumers (i.e. production, transport, storage, delivery)in a flexible and generic SCN made by one-to-many nodes per stage.
In comparison with the state-of-art (Kumar andNigmatullin, 2011) and the typical state variables (e.g. delay, capacity utilization) handled, the proposed model also incorporates product's variables that change with the state of perishable products (i.e. residual shelf-life, decay of quality) so that the losses of products due to spoilage along the supply chain are quantified accordingly. Furthermore, the proposed model incorporates node's variable reflecting the consumptions and impacts (e.g. energy consumption for refrigeration, water used for processing, etc.) resulting from handling both perishable and non-perishable products along the supply chain.
In the following these variables are introduced, while causal diagrams illustrated to show the interdependencies and to explain the transfer functions that rule the behaviour of each task.

2.1. Model's state variables

The state variables represent the conditions of a product or a supply chain stage/node and determine its performance over time. The definition of the sets of variables determines the parameters to control along the supply chain whose number reflect on the complexity of the traceability system to implement or of the virtual simulation model to develop. Table 1 summarizes some of these variables with the sets of indices that define their dominium.

Sets
$p \in P$ set of manufacturing nodes

$d \in D$ set of storage nodes $o \in O$ set of orders $m \in M$ set of trucks	
Stage/Node's variables	**Product's variables**
$ord_{p(d)}$: list of orders at node p (or d) Cap^{Prod}_{p} : Processing/manufacturing capacity of node *p* $Throughput_{p(d)}$: throughput of node *p (or d)* $Prod_p$: Production of node *p* Inv_d: Inventory of node *d* Cap^{Inv}_{d}: Storage capacity of node *d* *Waste:* Disposed order $Freight^{Load}_{m}$: Loading capacity of vehicle *m* $Costs_{p(d)}$: Cumulated costs of node *p* (or *d*) $Energy_{p(d)}$: Cumulated energy consumption of node *p* (or *d*) $Water_p$: Cumulated water consumption of node *p*	$t^{due}_{op(d)}$: due time of order *o* at node *p (or d)* t^{now}: current simulation time q_o: quantity of order *o* sl_o: residual shelflife of order *o*

Table 1. State variables.

2.2. Causal diagrams

The causal diagram illustrates the dynamics of the observed supply chain by connecting nodes and stages with dependency arcs. These arcs can be drawn for each *state variable* defined for a product or a node, whilst the sign of the arc (+/-) indicates the sign of the transfer function of a given *state variable* from the two vertexes. In comparison with published papers, hereby a flexible supply chain made of one-to-many nodes per stage and one-to-many stages is modelled and formulated through causal diagrams.

With the purpose to showcase how the complexity of a flexible supply chain affects the causal diagram and the simulation model behind, two examples of causal diagrams are illustrated in Fig. 1 and 2.

In Fig. 1 a simplified supply chain made of three single-node stages includes the manufacturer, and distribution centre and the retailer as well as two transport stages in between. When a customer order occurs, is inserted in the list of production orders i.e. ord_p, then after a time depending by the producer's throughput is shipped to the storage facility and inserted into the list of stored orders i.e. ord_d. Once an order is processed by a generic node the capacity (i.e. Cap^{Prod}_{p} or Cap^{Inv}_{d}) is released accordingly. Bottlenecks due to lack of capacities, queues throughout the nodes, or delays in transport phases may result in unexpected decay of product shelf life and accelerating its spoilage. Whether an order expires before is purchased by the customer at the retailer is sent to disposal.

The simulation model illustrated through Fig. 1. can be flexibly implemented on highly complex supply chains, as the one reported in Fig. 2. In the proposed model, different transfer functions are executed at each virtual node to control how a specific state variable will change.

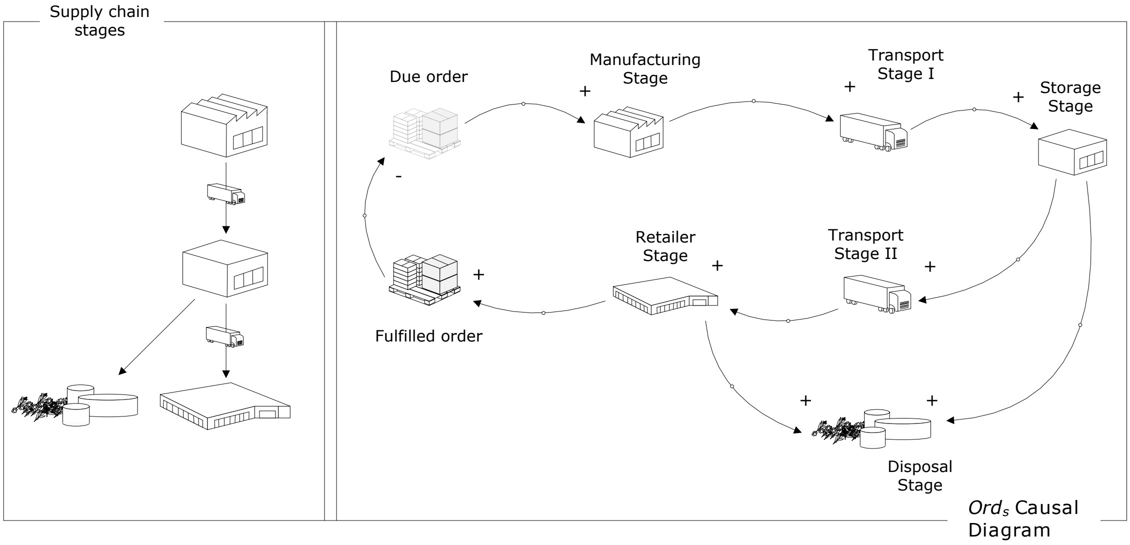

Fig. 1. Causal diagram of the variable ord_s(for the generic stage s) for a simplified supply chain made of three single-node stages.

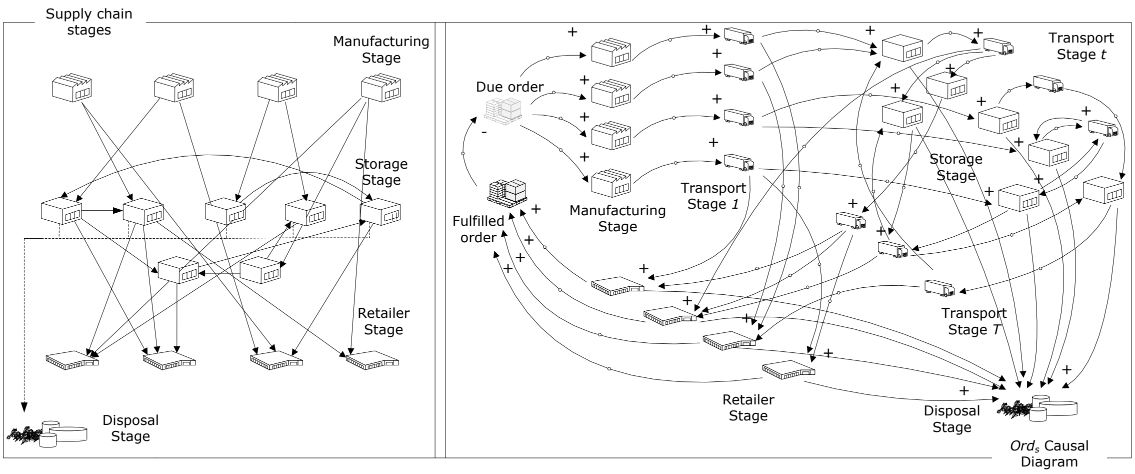

Fig. 2. Causal diagram of the variable ord_s (for the generic stage s) for a typical supply chain made of multiple multi-nodes stages.

2.3. Transfer functions

Transfer functions are simple algorithms able to determine how a state variable associated to products (i.e. orders) or nodes varies over time in agreement with the input parameters. While the behaviour of each node (or stage) can be easily simulated and predicted, the impacts of the whole sequence of non-linear transfer functions throughout all supply chain stages is hard to foresee.

In the following, two main algorithms are exemplified with the purpose to manage the arrival of new production orders and their processing (Alg. 1), and the quality control of order to be shipped at the storage node (Alg. 2).

For each p in P

  For each o in ord_p

    If $t^{due}{}_{op}$ <> 0 then

      $Cap^{Prod}{}_{p}$ -= q_o

    Else If $Cap^{Prod}{}_{p}$ >=q_o then

      $t^{due}{}_{op} = t^{now} + \left\lceil \frac{q_o}{Throughput_p} \right\rceil$

      $Cap^{Prod}{}_{p}$ -= q_o

$Prod_p$ += q_o
End If
Next
Next

Algorithm 1. Processing a new production order.

For each d in D
For each o in ord_d
If t^{due}_{od} >= t^{now} then
$Freight^{Load}_m$ += q_o
Cap^{Inv}_d -= q_o
Else If sl_o<= 0 then
Cap^{Inv}_d -= q_o
$Waste$ += q_o
End If
Next
Next

Algorithm 2. Shipping stored orders at a warehousing node and quality checking.

3. A NUMERICAL APPLICATION

The proposed simulation model has been tested with a multiple nodes and multiple stages supply chain of perishable products. The observed supply chain lacks of a shared traceability system able to track orders state variables and performance of production, storage and distribution operations, and simulation was hereby applied to quantify supply chain impacts, to identify criticalities and provide a benchmark for future improvements. The studied supply chain is made by nine production plants *p*, nine storage facilities *d*, and twenty retailers, and around 30 orders cumulating more than 540 tonnes of fresh fruits are analyzed. Some of the input parameters for the nodes and the orders are reported in Table 2 and 3 respectively.

P	Cap^{Prod}_p [kg]	$Throughput_p$ [kg/hour]	d	Cap^{Inv}_d [m3]	$Throughput_d$ [m3/day]
3	150000	*3000*	*0*	800	*50*
4	400000	*1200*	*1*	1000	*35*

Table 2. Parameters of some production and storage nodes.

o	$ord_{p(d)}$ [kg]	sl_o [days]
0	1000	20
1	200	5
2	1500	8
3	400	8
4	100	15
5	100	9

Table 3. Parameters of some orders.

The output form simulation are reported in the following charts and figures. Among the wide set of state variables and economic and environmental impacts resulting from the supply chain operations, we report the distribution of the capacity utilization for the production nodes (Fig. 3), and the energy consumptions per each production (Fig. 4) and storage node (Fig. 5) resulting from the manufacturing and handling operations on the simulated orders.

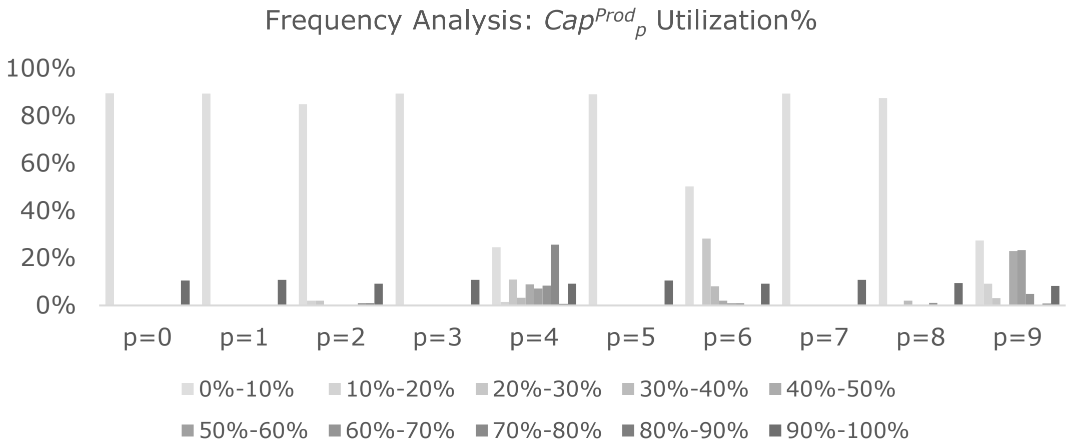

Fig. 3. Capacity utilization of the production nodes.

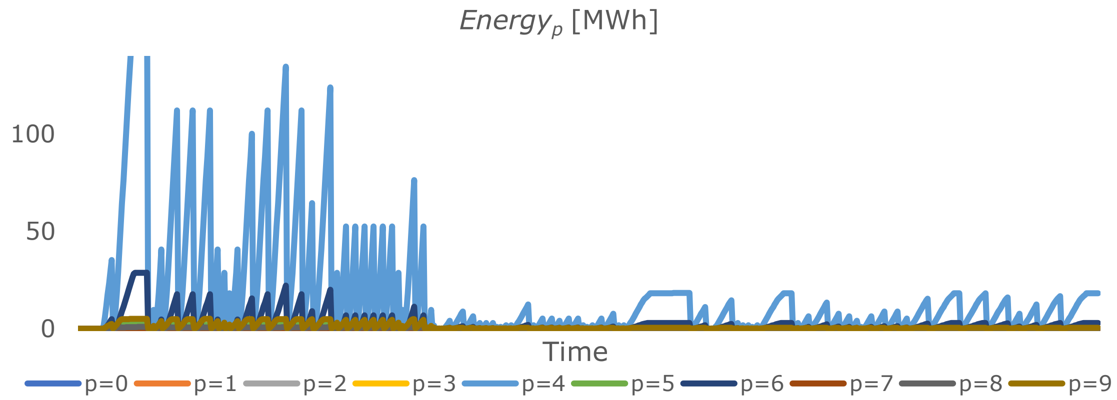

Fig. 4. Energy consumption of the production nodes.

3.1. Discussion

By observing these charts, the planners may assess, predict and quantify the contribution of each node to the overall supply chain performance, which node is exploited the most, which are the consumptions and the costs accounted by each stage of the supply chain to the specific order. Furthermore, the analyses of such impacts contribute to quantify precisely the costs and externalities resulting from the production and distribution of a specific order, enabling a more fair pricing which may vary in agreement with the delays, the bottle necks experienced, the efforts on the supply chain infrastructures, the congestion of the supply chain, the opportunity for shipments consolidation, the distribution of the network and the distance between specific producers and customers, and so on.

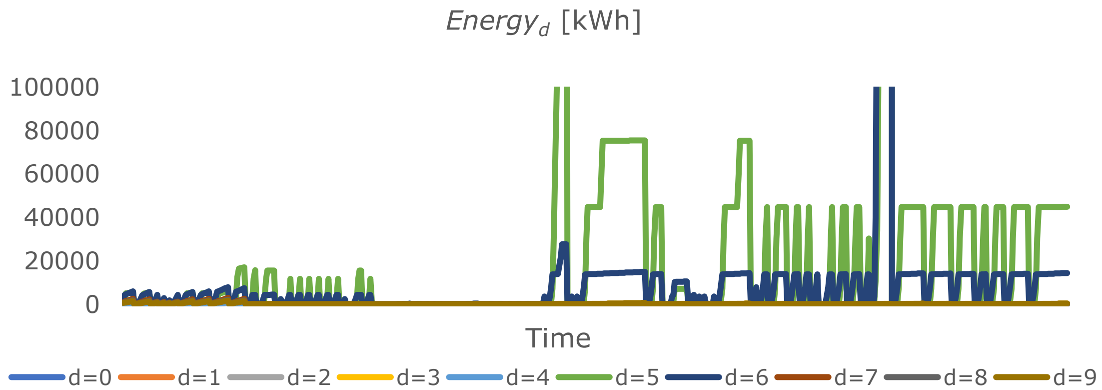

Fig. 5. Energy consumption of the storage facility.

4. APPLICATIONS AND CONCLUSIONS

While the control of supply chain performance and the accurate management of production and distribution operations are crucial in determining the success of companies and the long-term sustainability of the supply chain operators, the advent of Internet-of-Things paradigm represents a huge opportunities of development (Rong et al., 2015; Ng nd Wakenshaw, 2017). Nevertheless, the lack of shared traceability and information systems infrastructures still limit the exploitation of such opportunities.

Meanwhile, advanced simulation tool can be implemented to virtualized supply chain systems, and predict their performance through the analysis of digital twins.

In this paper a flexible simulation tool for the virtualization of a multiple nodes and stages has been implemented through a system dynamics approach. This tool can be adopted by both scholars and practitioners to investigate the impacts of a single entity (i.e. an order, a node) upon the whole system performance, to punctually quantify the costs and environmental impacts associated to an order resulting by the operations experienced, to obtain the same benefits achievable by a traceability system in term of KPIs control, and to simulate the impacts of new collaborating scenarios among actors (Ramanathan, 2014) or new network design decisions (Bosona et al., 2013).

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AN INTERPRETIVE STRUCTURAL MODELING (ISM) APPROACH FOR ANALYZING BARRIERS TO SUSTAINABLE SUPPLY CHAIN MANAGEMENT IMPLEMENTATION IN EGYPTIAN INDUSTRIES

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Abstract
Purpose:
Since sustainability and supply chain management are currently gaining more importance in the research fields. This study aimed to explore relationships among barriers to sustainable supply chain management (SSCM) implementation in Egyptian industries, and their influence on each other in order to provide a structured model for interrelationships between barriers and offer solutions or recommendations to deal with these barriers.

Design/methodology/approach:
This study is an empirical study with a descriptive research approach using qualitative methodology to collect data about barriers to SSCM implementation in Egyptian industries and ways to overcome these barriers through interviewing experts engaged in sustainability implementation within supply chain functions from different organizations representing four different industries followed by interpretive structural modeling (ISM) for barriers to SSCM to develop an overall structured model representing possible interrelationships between barriers.

Findings:
ISM analysis helped in shaping barriers into a structured model with clear identification of relationships among these barriers. ISM analysis for barriers to SSCM implementation in Egypt helped in prioritizing barriers that would help in providing solutions for most important barriers that would help in overcoming barriers to SSCM implementation in Egypt.

Value:
This study is considered among the very first studies to implement ISM for barriers to SSCM on data collected from Egypt which is considered a constructive addition which would help in developing strategies to overcome these barriers.

Research limitations and implications:
Future researches might consider developing ISM analysis for smaller number of barriers to minimize its complexity hence maybe reaching different results. Moreover since ISM analysis technique is known to be highly dependent on the experience and knowledge of experts' opinions, validation of ISM through the use of structural equation modeling or linear structural relationship approach to test the validity of such hypothetical model is recommended.

Practical implications:
This study provides insights for managers about barriers to SSCM implementation in Egypt, and recommendations on how to deal with these barriers.

Keywords:
Sustainability, Supply chain, Social sustainability, Economic sustainability, Environmental sustainability, Barriers, and Interpretive structural modeling.

INTRODUCTION

Over the last few years, sustainability is increasingly recognized as one of the most important strategic goals. This increased importance of in business practices can be explained by the greater attention towards environmental and social movements since the 1960s in addition to organizations' awareness about their significant impact on the ecosystems (Giunipero et al., 2012). The concept of sustainability has been integrated into multiple disciplines such as engineering science and operations management. Yet, there exists a divergence in such topic which can be clarified by considering the topic still in the evolution stage (Winter and Knemeyer, 2013). After Brudtland's report in 1987, sustainable development and sustainability have been increasingly implemented into multiple governmental policies and corporate strategies (De Brito et al., 2008). In view of that, sustainable supply chain is defined as incorporating the social, environmental, and economic dimensions in all supply chain activities (Diabat et al., 2014; Walker and Jones, 2012; Giunipero et al., 2012). Despite the evidence of benefits of implementing sustainable supply chain management, organizations are still reluctant to adopt sustainable practices due to internal and external barriers in terms of organizations boundaries (Esen and Elbarky, 2017; Elbarky and Elzarka, 2015). Internal barriers are organizational related obstacles and are known to be of a higher impact than external barriers (Sajjad et al., 2015; Walker et al 2008).

There is an increasing demand for sustainability research within the supply chain field. Although there is a well-developed previous literature about barriers of sustainable supply chain management, research of such field in Egypt is still limited. Hence this study aims to explore the relationships among barriers to SSCM implementation in Egypt and their influence on each other to provide a structured model for interrelationships between barriers. This research study is structured as follow; first a literature review including background about SSCM barriers, and how to overcome barriers, then research gap, research methodology, followed by the results and discussion, and finally the conclusion, limitations and recommendations for future research.

LITERATURE REVIEW

Sustainable Supply Chain Management

The term sustainability first appeared in the literature only 20 years ago, and over the years academics and practitioners have proposed many ways of defining sustainability (Winter and Knemeyer, 2013). The most commonly used definition of sustainability was suggested by Brundtland Report in 1987, "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (Ashby et al., 2012). The inclusion of sustainability in supply chain management is based on the triple bottom line approach (3BL) which combines three dimensions for sustainable supply chain management; environmental, social, and economic rather than the single focused sustainability that is most probably considering environmental dimension leading to the idea of green supply chain management (Touboulic and Walker, 2015; Beske and Seuring, 2014; Walker and Jones, 2012). Accordingly, SSCM can be defined as managing materials, information and flow of capital in order to improve organizations economic, environmental, and social performance taking into consideration all stakeholder's expectations (Kannan et al., 2013).

Barriers to SSCM

In review of literature about sustainable supply chain management, it was reported that significant fewer studies have been discussing the barriers to SSCM (Sajjad et al., 2015). The reason behind that can be explained as researchers sometimes prefer reporting positives rather than negatives or due to social desirability bias where organizations participating in such studies highlight drivers (Walker et al., 2008). Table 1 presents a summary of barriers to SSCM implementation based on previous literature.

Internal Barriers to SSCM Implementation	
Financial constraints: high initial costs, non-availability of loans supporting sustainability programs, high capital investment with lower return and high implementation costs.	Mangla et al., 2017; Esen and Elbarky, 2017; Ghadge et al., 2017; Elbarky and Elzarka, 2015; Sajjad et al., 2015; Elbarkouky and Abdelazeem, 2013; Mathiyazhagan et al., 2013
Lack of top management support: lack of interest by top and middles managers or lack of commitment of responsible actors.	Esen and Elbarky, 2017; Sajjad et al., 2015; Elbarkouky and Abdelazeem, 2013; Mathiyazhagan et al., 2013
Lack of SSCM Awareness: lack of knowledge about sustainability benefits.	Esen and Elbarky, 2017; Mathiyazhagan et al., 2013
Lack of organizational encouragement: lack of training courses and workshops and poor employees' commitment.	Esen and Elbarky, 2017; Elbarky and Elzarka, 2015; Mathiyazhagan et al., 2013; Elbarkouky and Abdelazeem, 2013
Poor quality of human resources: higher costs/ lack of access to trained expertise.	Mangla et al., 2017; Esen and Elbarky, 2017; Mathiyazhagan et al., 2013
Operationalization of sustainability: complexity of sustainability measurement systems and lack of effective tangible/financial metrics.	Mangla et al., 2017; Touboulic and Walker, 2015; Sajjad et al. 2015; Mathiyazhagan et al., 2013; Elbarkouky and Abdelazeem, 2013
Resistance to change: traditional practices, or technology advancement.	Esen and Elbarky, 2017; Elbarkouky and Abdelazeem, 2013
External Barriers to SSCM Implementation	
Lack of government support: Poor legislations and regulations or lower emphasis on environmental aspects or inadequate incentives to support SSCM implementation.	Mangla et al., 2017; Esen and Elbarky, 2017; Ghadge et al., 2017; Sajjad et al., 2015; Elbarkouky and Abdelazeem, 2013; Walker and Jones, 2012; Walker et al., 2008
Poor suppliers' commitment: lack of suppliers' awareness, lack of collaboration with suppliers, and difficulty in monitoring suppliers' practices.	Mangla et al., 2017; Ghadge et al., 2017; Elbarkouky and Abdelazeem, 2013; Mathiyazhagan et al., 2013; Walker et al., 2008
Unawareness of Customers: lack of customers' pressures concerning green practices, and unwillingness to pay more.	Mangla et al., 2017; Sajjad et al., 2015; Elbarkouky and Abdelazeem, 2013; Mathiyazhagan et al., 2013
Other Barriers: Culture difference, and industry specific barriers	Esen and Elbarky, 2017; Sajjad et al. 2015; Giunipero et al. 2012; Walker et al., 2008

Table 21: Barriers to SSCM implementation

Overcoming SSCM Barriers

Relatively, a little number of articles has focused on ways to overcome SSCM barriers (Rauer and Kaufmann, 2015). Although adopting SSCM or green supply chain management practices is complex and challenging (Deepak et al., 2014). Since organizations might face difficulty in attempting to eliminate all barriers simultaneously, it is recommended to first critically analyze all barriers, prioritize them, and work on the most influential and important barrier first then another (Ghadge et al., 2017; Deepak et al., 2014).

RESEARCH GAP

By reviewing previous literature about sustainability and supply chain management, it was found that the majority of research conducted on barriers for sustainable supply chain management is theoretical in nature (Seuring and Gold, 2013). Thus there is a great emphasis on analyzing empirical data collected from companies (Ageron et al., 2012). Additional studies for low income countries is recommended as well as supply chain managers there are facing more challenges due to limited distribution or communication infrastructure that may hinder the ability of organizations to have a SSCM (Seuring and Gold, 2013). Esen and Elbarky (2017) mentioned that although a well-developed literature about barriers and consequences of SSCM exists, yet the research of such field in Egypt is limited.

Accordingly, this study aims to explore the relationships among barriers to SSCM implementation in Egypt and their influence on each other in an attempt to provide a structured model for interrelationships between barriers, in addition to provide recommendations to manage such barriers. The choice of Egypt was due the lack of previous research of similar topics, and the increasing importance of sustainable development issues in Egypt.

Consequently, the research questions for this study are; RQ1: What are the possible interrelationships between barriers to SSCM implementation in Egypt? And RQ2: How can companies overcome barriers to SSCM implementation in Egypt?

RESEARCH METHODOLOGY

The primary instrument used for data collection was semi-structured interviews with an interview protocol developed on the basis of previous literature to enhance reliability of such instrument. Interview questions were developed using questions from Walker and Jones (2012), Walker et al. (2008), and Rauer and Kaufmann (2015) in addition to some questions developed by the researcher in accordance to literature review.

Research population included all industrial companies operating inside Egypt. And focusing on industrial sector is known to be a historical trend in studying SSCM (Hassini et al., 2012). This research used a non-probability -purposive judgment- sampling technique which suggests selecting sample according to a certain criteria set by the researcher serving the research objective, and the criteria was that organizations; represent multiple industries, have direct and observable impact on external environment (environmentally, socially, and economically), relatively similar size companies, and had implemented or planning to implement SSCM practices. The final sample included 14 organizations representing four different industries with 22 experts engaged in sustainability implementation within supply chain functions being interviewed.

Afterwards, qualitative data analysis traditional phases - data reduction, data display, and drawing conclusions- were followed performed Data reduction was done through deductive coding process where codes are generated from previous literature, and coding was performed using N-Vivo qualitative data analysis computer software. Followed by data display, and conclusions were drawn about barriers and how organizations could overcome such barriers which answer the three research questions addressed in this study.

INTERPRETIVE STRUCTURAL MODELING PROCEDURES

The researcher decided on the use of ISM for barriers to SSCM implementation in Egypt to identify possible relationships among those barriers and identify the most important and influential barriers to recommend solutions for those barriers which would help organizations to overcome barriers to SSCM implementation in Egypt. ISM technique is frequently used when there is large number of variables influencing a specific topic being studies and the relationships between these elements are complex and unclear which transfers unstructured models into clearly defined and understandable models (Attri et al., 2013). Additionally ISM was previously used by multiple researchers to identify barriers to SSCM implementation (Mathiyazhagan et al., 2013; Luthra et al., 2011; Ravi and Shankar, 2005). Similar to any modeling analysis, ISM includes multiple steps to be followed as suggested by Warfield in 1974 (Diabat et al., 2014; Attri et al., 2013; Mathiyazhagan et al., 2013; Jadhav et al., 2013; Luthra et al., 2011; Ravi and Shankar, 2005). These steps are:

(1) Identifying the factors related to topic of interest: for this research, barriers were identified according to analyzing data collected from interviewing organizations operating in Egypt that are implementing SSCM strategies from different industries to enhance representativeness of the results. Summary of internal and external barriers to SSCM in Egypt is in table 2.

(2) Contextual relationships between barriers: five experts were interviewed to identify the nature of relationships among barriers to SSCM implementation in Egypt; two experts were from the academia with previous research experience in the same field, and three experts from the industry.

(3) Structural self-interaction matrix (SSIM): converting contextual relationships between barriers into a single matrix using four symbols; **V** (i influences j), **A** (j influences i), **X** (i and j influence each other), and **O** (no relation) shown in table 3.

Internal Barriers	External Barriers
B1: Financial constraints **B2**: Lack of interest/ commitment of top management **B3**: Lack of organizational encouragement **B4**: Employees' resistance to change **B5**: Lack of employees' experience **B6**: Lack of awareness about sustainability among employees **B7**: Lack of availability of standardized sustainable measurement systems	**B8**: Lack of government support **B9**: Lack of sustainability awareness among customers **B10**: Lack of sustainability awareness among suppliers

Table 22: Barriers to SSCM implementation in Egyptian industries

(4) Reachability matrix from SSIM: transferring SSIM into an initial reachability binary matrix (0, 1). Then final reachability matrix is developed through updating the initial reachability matrix with transitivity that requires adjusting some of initial reachability matrix cells according to researcher's inference.

(5) Classification of factors according to driving and dependence power: in order to identify key factors for the topic being studied, factors are clustered according to driving power and dependence power providing a classification for factors into; driver factors, dependent factors, linkage factors, and autonomous factors as shown in figure 1. Findings suggest that driver/independent barriers are financial constraints and lack of government support with strong driving power, yet weak dependence power. Linkage barriers are lack of interest/commitment of top management, lack of employees' experience, lack of awareness about sustainability among employees, lack of availability of standardized sustainable measurement systems, and lack of sustainability awareness among customers with high driving and dependence power thus any action with regard to such factors would significantly impact the overall structure. Dependent factors are lack of organizational encouragement, employees' resistance to change, and lack of sustainability awareness among suppliers with low driving power and high dependence. No autonomous factors, confirming that all SSCM barriers reported in this research paper are related to each other.

6) Partitioning of barriers into levels: based on final reachability matrix, reachability sets, antecedent set, and intersection set are developed hence levels are concluded as shown in figure 2.

(7) Finalizing ISM model: finally ISM based model is created to visually present the interrelationships between barriers as shown in figure 2.

S.N (i)	Barriers (j)	10	9	8	7	6	5	4	3	2
1	Financial constraints	O	A	A	V	V	O	O	V	V
2	Lack of interest/ commitment of top management	V	A	A	A	X	O	V	V	
3	Lack of organizational encouragement	O	O	O	A	V	V	V		
4	Employees' resistance to change	O	O	O	A	A	A			
5	Lack of employees' experience	O	O	A	A	X				
6	Lack of awareness about sustainability among employees	O	O	A	A					
7	Lack of availability of standardized sustainable performance measurement systems	O	O	A						
8	Lack of government support	V	V							
9	Lack of sustainability awareness among customers	O								
10	Lack of sustainability awareness among suppliers									

Table 23: SSIM for contextual relationships among barriers

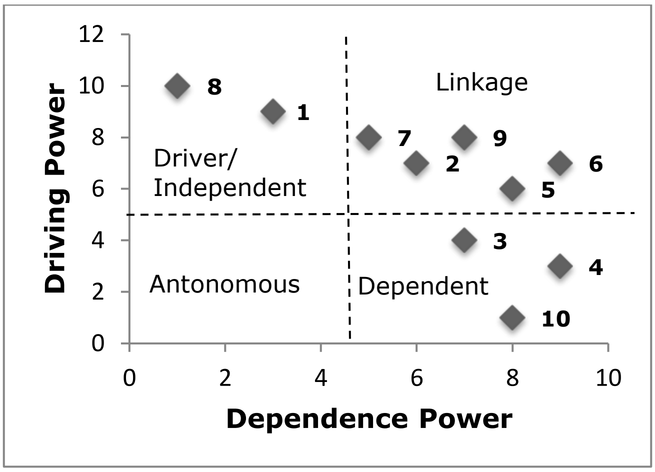

Figure 46: Driving and dependence diagram of barriers to SSCM implementation in Egypt

DISCUSSION

Discussion of Interpretive Structural Modeling Results

Since it was mentioned that organizations might face difficulty in attempting to eliminate all barriers simultaneously, and it is recommended to first critically analyze all barriers, prioritize them, and work on the most influential and important barrier then the second most important and so on (Ghadge et al., 2017; Deepak et al., 2014). ISM analysis for barriers to SSCM implementation in Egypt was very beneficial as it would help to prioritizing the barriers.

Results confirmed that no autonomous factors meaning that all barriers reported in this research paper are related to each other and there are interrelationships among those barriers. Moreover five barriers fall in the category of linkage barriers which are lack of interest/commitment of top management, lack of employees' experience, lack of awareness about sustainability among employees, lack of availability of standardized sustainable performance measurement systems, and lack of sustainability awareness among customers. These barriers are considered of high importance because they have strong driving and dependence power and any change occurring to them will have an effect on other barriers thus impacting the overall system, therefore these barriers are considered unstable barriers that need extra attention and have to be managed carefully. Additionally, lack of organizational encouragement, employees' resistance to change, and lack of sustainability awareness among suppliers are dependent barriers meaning that these barriers are with weak driving power thus would not have a huge impact on other barriers yet high dependence power so that they are easily affected by other barriers. Finally for driver/independent barriers; both financial constraints and lack of government support are the only independent barriers. These barriers have strong driving power, yet weak dependence power so they can impact other barriers yet not affected by them.

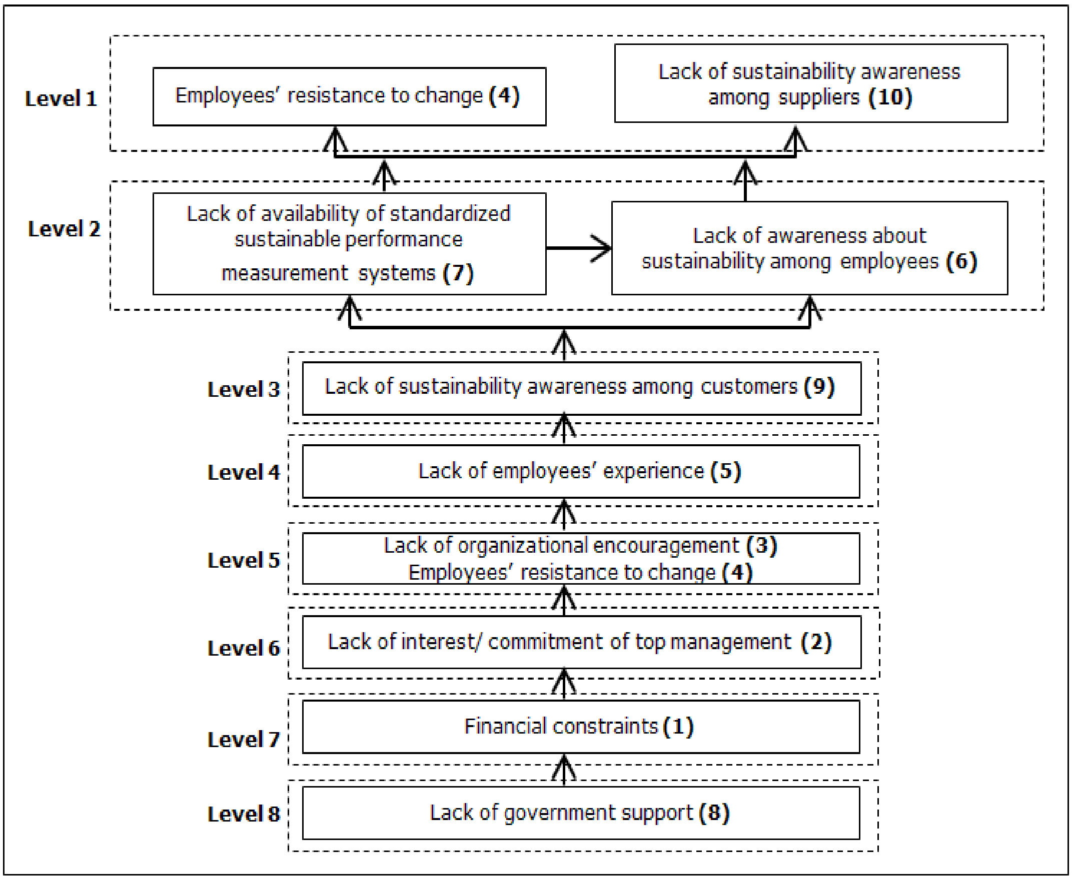

Figure 47: ISM based model for barriers to SSCM implementation in Egypt

Furthermore according to ISM based model developed for barriers; lack of government support and financial constraints are two driver/independent barriers at the base of the model of barriers meaning that these barriers are of high influence on all other barriers and are not influenced by any other barriers. Thus overcoming these two barriers would influence other barriers as well, thus reducing the barriers to sustainability implementation. To conclude ISM had helped in categorizing barriers according to their importance where barriers with highest importance are dependent barriers at the bottom of ISM based model which have high influence on other barriers and are not influenced by any other barriers. Barriers with moderate importance are still considered important barriers because they have huge influence on other barriers in the system. Also, barriers with lowest importance are easily adjusted by managing other barriers.

Overcoming Barriers to SSCM Implementation in Egypt

This research recommended that organizations focus on barriers according to their importance, so that plans set to manage barriers with highest importance would affect other barriers in the system as well and provided importance categorization for barriers according to dependence and driving powers, and levels of ISM based model in table 4.

	Internal Barriers	External Barriers
Highest	Financial constraints	Lack of government support

Moderate	Lack of interest/commitment of top management Lack of employees' experience Lack of awareness about sustainability among employees Lack of availability of standardized sustainable performance measurement systems	Lack of sustainability awareness among customers
Lowest	Employees' resistance to change Lack of organizational encouragement	Lack of sustainability awareness among suppliers

Table 24: Importance categorization of barriers to SSCM implementation in Egypt

CONCLUSION

This study aimed to explore relationships among barriers to SSCM implementation in Egyptian industries, and their influence on each other in order to provide a structured model for the interrelationships between these barriers and offer recommendations to deal with them. This research have managed to reach a categorization for barriers to SSCM implementation in Egyptian industries according to their importance based on ISM analysis, suggesting that barriers with highest importance are financial constraints and lack of government support. These barriers, having the highest impact on other barriers, are considered independent or driving barriers, and are at the base –bottom levels–ISM based model. Barriers with moderate importance are lack of interest of top management, lack of employees' experience, lack of awareness about sustainability among employees and customers, and lack of availability of standardized sustainable performance measurement systems. Those barriers are considered linkage barriers having high dependence driving power and are found in the middle levels of ISM based model. Finally barriers with lowest importance as employees' resistance to change, lack of organizational encouragement, and lack of sustainability awareness among suppliers, are dependent barriers which have high dependence power so they are easily shaped by other barriers.

This research study is considered among very few studies discussing SSCM issues in developing countries as Egypt. Additionally this study is considered among the first studies to implement ISM for barriers to SSCM implementation on data collected from Egyptian industries which is considered a constructive addition as such model helped in setting a clearer framework for interrelationships among barriers which would help in offering solutions to deal with these barriers. On the practical side, this study provides valuable insights for managers about barriers to SSCM implementation, as well as categorizing barriers according to their importance and their impact on each other based on interpretive structural modeling analysis results, additionally it offers valuable suggestions and recommendations for managers on how to deal with barriers.

As for all research studies limitations are always valid, hence future researches might consider developing ISM analysis for smaller number of barriers to minimize its complexity and maybe reaching different results. Moreover, since interpretive structural modeling analysis technique is known to be highly dependent on experience and knowledge of experts' opinions. Moktadir et al. (2017) and Jadhav et al. (2013) have recommended validation of interpretive structural modeling through the use of structural equation modeling, or linear structural relationship approach to test the validity of such hypothetical model.

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Session 7: Complexity, Risk and Uncertainty

A RESPONSIBLE BUSINESS LOGISTICS SYSTEMS DESIGN METHODOLOGY

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ABSTRACT
The paper presents a methodology for designing business logistics systems. It starts by examining a range of factors that illustrate internal and external influences on the logistics system and the interfaces to operational logistics decisions. The paper outlines and then details the steps in the methodology and proposes a way to evaluate the methodology, and illustrates, without examining in detail, how the methodology relates to wider logistics and environmental issues. One of the strengths of the proposed methodology is its simplicity. The methodology proposes combining systematic procedures with flexibility concerning the design objectives, and simultaneously using top-down and bottom-up procedures.

KEY WORDS: Logistics design and methodology, performance measures, top down and bottom up performance, responsible logistics.

1. INTRODUCTION

This paper proposes and discusses a methodology for designing responsible logistics systems (RLS), by building on earlier research. In brief, Jaber and Bonney (2011) argued that to design RLS one should consider new performance measures, models and structures alongside the traditional ones. This was followed by developing an activity matrix (AM) that represented the transformation of an organization's inputs into outputs (I-O) to reflect economic, environmental and social needs (Jaber and Bonney, 2013). A concurrent engineering (CE) approach was also elaborated that split the system into sets of activities and attributes starting by system requirements and ending with analysing system performance. Jaber and Bonney (2014) proposed a methodology that uses an activity matrix (AM) to produce a problem matrix (PM) from which they developed a research matrix (RM) and subsequently a research agenda (RA). Starting with the system requirements, the methodology of this paper shows how to develop and then implement the proposed system. Using feedback loops, the methodology discusses performance measures and identifies problems and concerns that may be the basis for continuous improvements projects.

2. BACKGROUND

Many papers describe common ways to design logistics systems, while others address specific aspects of logistics system design. Most existing research, however, did not take a microscopic approach to detailing activities of logistics systems; they were always macroscopic, resulting in parsimonious models with few variables (e.g., Daganzo et al. 2012). Many firms have embraced concurrent engineering (CE) to coordinate product design activities with their associated manufacturing and logistics systems (Hatch and Badinelli, 1999). However, micro level empirical investigations and calculations are poorly researched, even more so when it comes to considering environmental issues, which are as important as time and cost when designing logistics systems (Aronsson and Brodin, 2006).

The design and management of a logistics system thus affects both the environmental and economic performance. There are actions and trade-offs related to designing environmentally responsible logistics systems. Wu and Dunn (1995), with examples from different industries, subdivided a logistic chain into stages, which are raw materials acquisition, inbound logistics, transformation, outbound logistics, marketing, after-sales service, transport, and reverse logistics. They stressed that when considering the stages of a logistics system, it is important to consider the effect that the output from one stage has on a subsequent one. Feedback loops are necessary to fine-tune and synchronize the stages with one another.

Logistics systems also have to be socially responsible towards their employees, customers, and the communities within which they operate. Murphy and Poist (2002) conducted a survey-questionnaire of about 400 logisticians of manufacturers (55%) and retailers (45%) practicing or planning to practice socially responsible logistics. The respondents identified 10 strategies to manage 13 social responsibility issues.

As noted earlier, this paper is part of an ongoing responsible logistics project that is examining the environmental implications of the inventory, manufacturing and logistics systems functions. The methodology for logistics systems design discussed in this paper offers business logistics systems designers a flexible process that will iteratively produce economically, environmentally and socially excellent logistics systems. The proposed iterative sequence of steps which help to define the system's attributes is an important part of the methodology and means that the designer can steadily improve the proposal. The flexibility of the methodology allows designers to adopt priorities that they think are appropriate for the situation. The methodology uses a diagrammatic representation of logistics systems modules and also suggests using some of the systems approaches that the authors developed as part of the wider responsible logistics project while simultaneously adopting top-down and bottom-up system design methodologies.

3. THE RESPONSIBLE LOGISTICS DESIGN METHODOLOGY

The terms top-down and bottom-up are used in many fields including product design (usually the design of physical items), the design of computer systems or models (the design of software, or mathematical, simulation or computer models), and organisational design. The methodology suggests using top-down and bottom-up approaches together to design responsible business logistics systems. Broadly, top-down design is a hierarchical approach that starts with a macro view of what needs to be done and considers relatively few variables. In this paper, top-down (macro) models are strategic, are usually approximate and can be the basis of choosing high level system performance measures. By being parsimonious in their description, top-down models provide a clear focus to consider the proposals. By contrast, bottom-up models are often operational level models that deal with the detail of running an activity, such as physically handling items in a loading bay and providing and processing data. In many cases, data are aggregated to produce estimates of the higher-level system performance variables. Bottom-up organisational analysis usually describes and then records those actions. A business environment of a logistics company defines the aims and objectives of the logistics system, which has many operational factors, such as business, finance, environmental, social, among others. These factors affect inventory, logistics, and manufacturing systems plans and operational activities. The methodology suggests a cyclic approach, that is determine how a top-down approach affects plans and operational activities, then setting what is considered to be the best plans and operations and see, using a bottom-top approach, how the objectives and aims of the logistics system are affected. Adjustment are made in a cyclic (top-down-bottom-up, etc.) manner until, the best solution/design is achieved. A strategic logistics design must consider market influences, corporate social responsibility, environmental concerns, required system performance, that all affect, sequentially, logistics decisions, planning, operations, and performance feedback. Coordinating the top-down and bottom-up approaches can reveal facts such as resource incompatibility in the system design that might not be detected by either method alone. Figure 1 presents the proposed methodology as a sequence of steps provided by coordinating both approaches.

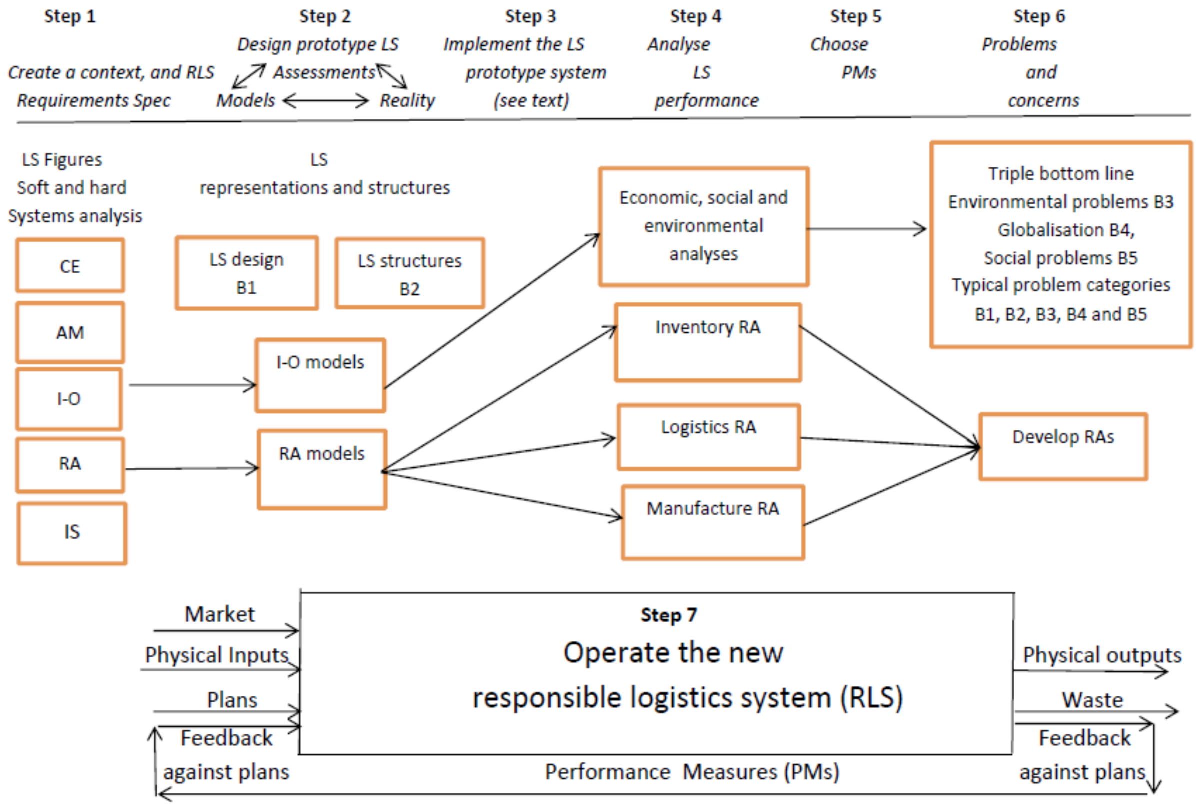

Figure 1. The business RLS design methodology

Column 1 lists some of the concepts and supporting approaches that could be particularly useful to the logistics systems design:

- CE is the concurrent enterprise and lifecycle representation of the company chosen to encourage designers to treat logistics as an integrated system.
- AM is the Activity Matrix representation of the logistics system that considers all activities.
- I-O is the input-output representation of the tiers of the logistics system. The Input-Output model(s) can be used to determine outputs from a tier's chosen inputs.
- RA is a methodology that produces Research Agendas and activity implementation sequences that prioritise logistics system research and development activities.
- IS, information system, aims to provide competitive advantage, e.g., future demand and delivery data relating to before and after the current tier in a chain.

Figure 1 shows that the output from one stage of an operational logistics system, as well as new demands, are the starting point for producing the plans for the next time interval.

Figure 1 develops an appropriate sequence of steps for designing responsible logistics systems and additionally shows some of the inter-relationships between various logistic systems functions that may identify where there are underlying problems that need further study to improve understanding of the logistics systems and logistics systems performance.

4. STEPS IN THE ITERATIVE LOGISTICS DESIGN METHODOLOGY

Figure 1, Table 1 and the notes below show that the methodology consists of seven steps.

Table 1. The 7 steps of the iterative logistics systems (LS) design methodology

Design step number	Key Actions	Explanatory notes
1. Create the requirements specification (RS) i.e. the essential and desirable needs of the logistics system (LS)	• Use systems analysis and design to clarify objectives and define the LS context • Define the planning actions needed to form the RS	1.1 Define the LS design context 1.2 Produce the RS 1.3 Move to steps 2-7 to create a LS that matches the RS
2. Design a prototype logistics system	• Describe the design in terms of modules. • Use an iterative procedure to create a more realistic representation of reality using module models • Assess performance to create a better prototype LS • Simulate the performance of the prototype LS	2.1 Represent the LS to an appropriate level of detail (reality) 2.2 Define the LS modules needed to represent 2.1 2.3 Develop models of the modules to produce a LS simulation 2.4 Use the simulation to analyse the LS performance, i.e. detail steps 2.1, 2.2 and 2.3 to obtain the realism required to represent a prototype LS
3. Develop, implement and operate the prototype LS	Approve, resource, install, test and evaluate the prototype LS	3.1 check the performance of the prototype modules 3.2 Modify the modules as necessary
4. Analyse the prototype LS performance	Use data from step 3 to measure and analyse the system performance. Steps 2, 3 and 4 are part of the same iterative procedure	Choose PMs to analyse and control economic, environmental and social aspects and problems of logistics design
5. Investigate measures (PMs) to assess the prototype LS performance	Investigate and choose PMs to measure the prototype system performance	Choose the PMs systematically or based on personal preferences
6. Identify poor performance and overcome system problems	Identify possible problems. Overcome the problems and/or improve understanding	If the actions to take are not obvious, use research agenda (RA) approach
7. Design, implement and operate the operational version of the LS	Use the iterative procedure (Step 2) to improve the LS design, then approve, resource, implement and operate the system	Use feedback to control the system and to check the suitability of the PMs chosen in Step 5

The RLS design methodology aims to help logistics designers match the organisation's resources and system requirements to the needs of the market in a responsible way. These needs include, for example, transporting the desired products taking account of special requirements (e.g. temperature control, hazardous items, heavy items, delicate items, and specific geographic locations), time constraints, and the volume of products to be moved. The methodology is an iterative and flexible way to design logistics systems that allows designers to systematically improve the logistics design until it meets the economic, environmental and social requirements specified plus the needs of the designers, operational users and potential customers. Steps 2, 3 and 4 produce a prototype system, whose performance needs to be measured. This iterative process may need several attempts to obtain satisfactory results. The prototype, possibly modified, may then be used in steps 5, 6 and 7 to produce the full logistics system.

Step 1: Create the requirements specification for the RLS design, where designers start by stating what they are trying to achieve using hard and soft systems analysis methods. The methodology also suggests using CE, AM, I-O, RA and IS that emphasize focussed aspects of the new RLS. A possible outline requirements specification for the RLS could be to 'create a logistics system that collects, transports and delivers the designated goods that meets the customers' needs and satisfies the company's economic, social and environmental objectives.'

Step 2: Develop a prototype logistics systems (LS) design iteratively by developing: (1) approximate representations of the modules or sub-systems of the real system and produce preliminary performance measures, (2) models of the modules, and (3), progressive representations that could be verbal statements, computer and mathematical representations, to describe the physical and system manifestations of the proposed logistics system. The iterative design procedure systematically considers the modules or sub-systems of the total RLS. It produces a model (or models) of each module in order to be able to evaluate various aspects of the module's performance and gradually develops the total system design.

Step 3: Develop, implement, operate and evaluate the prototype RLS design produced in Step 2. If satisfactory, then the prototype design is implemented and used to evaluate the system and its performance, and to train personnel. It will also identify need for modifying the design to meet the desired requirements.

Step 4: Measure and analyse the performance of the prototype RLS (post–implementation). Step 4 provides data to analyse the economic, social and environmental performance of the prototype RLS. The resulting system performance is obtained by comparing bottom-up data with top-down model predictions. Poor performance could mean further evaluation using steps 2 and 3, and perhaps modifying the prototype before fine-tuning the system.

Step 5: Identify appropriate performance measures (PMs). It uses the data from Step 4 to investigate which PMs are suitable to analyse and control the proposed logistics system. Ideally, the PMs should include both top-down and bottom-up PMs. For example, bottom-up models describe an energy system from primary energy sources via multiple processes of conversion, transport, and distribution to final energy use. This approach neglects the potential interactions of the energy sector and the rest of the economy. On the other hand, a top-down approach comprehensively captures market interactions and inefficiencies. This approach typically lacks technological details that could be relevant for setting an energy policy (e.g., Böhringer and Rutherford, 2008). Each results in a different set of

PMs, which makes feedback loops necessary to fine-tune the two approaches and reduce the gap in their performance outputs.

Step 6: Identify system problems and concerns; investigate and/or overcome. It evaluates outstanding system concerns and problems, and identify where individual modules need improving or detailing. The assessments could be made as part of the research agenda/system development approach. The feedback loop at the foot of Figure 1 is important for this process to identify continuous improvement opportunities.

Step 7: Develop, approve, implement and operate the full system. The iterative procedures in Step 2 and equivalent evaluations in steps 3 to 6 are used to design, develop, test, approve, invest resources, implement and operate all system modules. The inputs into the designed operational system are the physical inputs, plans and feedback from the system operation including economic, social and environmental performance data. The outputs, including measurements of system performance against plans, are recorded and then, possibly summarised, are fed back as, possibly modified, inputs into the system together with any additional planned inputs. These plans provide the initial conditions for operating the system over the next time-period.

5. INTERPRETING THE METHODOLOGY TO EXAMINE LOGISTICS ISSUES

Figure 1 presented a 7 step methodology for RLS design. Step 2 includes the consideration of RLS designs and structures, including selected operational logistics activities and their relationships. This encourages an initial intuitive choice of module locations that is almost a hierarchical top-down RLS design proposal. The performance measures chosen in step 5 may help to identify additional design concepts and problems and concerns that could be further investigated. Steps 6 and 7 develop and partially test all system modules and so guide the full systems design, which is effectively a detailed and extended version of the reality described in Step 2. Step 3 relates to system implementation and Step 5 relates to choosing performance measures. Both are important for producing the company's requirements specification. The RLS design procedures must achieve compatibility between a strategic (top-down) need to match the investment in logistics systems and resources (people and equipment) with the resource utilisation that is required to achieve appropriate profitability. The system design must also satisfy the bottom-up requirement that the system meets the delivery needs of the customers and the operational needs of the system designers and operators.

The design procedures of many organisations frequently use both top-down and bottom-up approaches. Ideally, their results should be relatively consistent. However, inconsistent results can and will occur if the top-down model does not contain the level of detail to enable the constraints to be realistically assessed. This may mean that the results that the system achieves may differ from that expected from the top-level plan. For example, if the top-down model does not plan adequately for the appropriate resource requirements, consequential resource shortages could mean that items are produced late or in the wrong quantity. In other words, although a bottom-up operational level model may often achieve what it is set up to achieve, its performance may be inconsistent with the original top-down model. The design procedures should check consistency to within a planned, possibly arbitrary, level.

Performance measures provide operational feedback. However, strategic logistics problems (Bonney and Jaber, 2011, 2013, 2014), require feedback over a longer time scale. Of particular interest is that the various models that Step 2 develops and tests when producing the prototype system and Step 7 when producing the full system also provide a way to evaluate system performance. Further, any misinformation that comes with them in terms of errors, emissions or delays will cause a directly attributable decrease in system performance. These parameters thus provide the basis of a class of top-down PMs that can be analysed in their own right to determine the desired accuracy of the PMs. Another obvious example is the traditional economic order quantity model, which depends on the demand, the ordering costs per batch and the stockholding costs. Modelling and PMs thus provides a means to unify top-down and bottom-up approaches to systems design for logistic systems.

6. DISCUSSION AND CONCLUSION

The methodology for designing responsible logistics system presented in this paper has several potential strengths, including:

- The representation is general and the number of logistics modules is not restricted other than by the need to include all modules that affect the requirements specification.
- The proposal is flexible (e.g., the system designer can choose the sequence in which to evaluate the logistics system modules).
- The iterative design process (Step 2 for the prototype and Steps 2 to 6 for the full methodology) provides an unconstrained look at design possibilities and using computer and simulation models cross check the PM analyses and physical module results.
- The process allows a designer to determine the importance given to environmental, social, and traditional design factors.
- The modules initially focus on broad topics, but, as with structured analysis, the investigation is hierarchical and the approach encourages more detailed studies.
- The approach encourages designers to use both top-down and bottom-up PMs to evaluate performance. This provides robust performance checking and also provides a scientific basis to learning about logistics systems.

A potential weakness of the methodology is its great flexibility. However, flexibility is also a positive feature and, although more experience is needed on how best to use it, its consistency with the scientific method suggests that it has great potential. This is one reason that the ideas are presented before many obvious but time-consuming aspects of detailed testing have been undertaken. Testing, good practice and performance assessment, particularly about how the methodology relates operational design to wider logistic and environmental issues such as globalisation, choosing logistics system structures and investigating environmental and social problems are all ongoing. Hopefully, they will be the subject of another paper. In practice, logistics system designers frequently will have a clear idea of their system design intentions, including the basic concepts and many of the detailed features. If so, simple logistics designs may not need to use every detail of the methodology. However, formal procedures are highly desirable for complex systems design, particularly when there are novel design problems to solve and when there is a need to consider environmental and social factors. For completeness, therefore, any iterative design example should include some relatively trivial analysis that deliberately emphasises the importance given to the iterative nature of the design activity, where several models (physical, computer and verbal representations of reality) are used together steadily to improve the realism of the developing design. The combination of formalised rules with great flexibility in their use offers many promising possibilities.

ACKNOWLEDGEMENTS

The first and second authors thank Attila Chikan, Peter Kelle and Henk Zijm for their feedback on an early version of this. The second and third authors thank the Natural Sciences and Engineering Research Council of Canada (NSERC) for supporting his research. The second author thanks the FEA Dean and the MIE Chair at Ryerson University for partially supporting his travel.

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DISTRIBUTION COMPLEXITY AND ITS IMPACT ON PERFORMANCE: A CASE STUDY

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Abstract
Purpose
Drivers of distribution complexity can be variety of products that needs to be delivered, the uncertainty in demand, the number and geographical spread of customers (Gerschberger et al., 2012; Wu et al., 2013). There is limited research on quantifying the complexity in distribution and to assess the impact of such complexity on the performance. Hence, the purpose of this paper is to answer the following research questions
1. How to estimate the distribution complexity in an industrial gas distribution company
2. How does complexity impact the performance of the company?

Design/methodology/approach
Data on the number of customers, number of products, silo size, daily demand and standard deviation of demand were collected along with performance measures like distribution cost and number of close to stock-out situations (NCSO) from the case company. These were supplemented by interviews with people from the case company for understanding the current state of operation, the degree of information sharing between the company and its customers, and for confirmation of the findings. The collected data were used to create the complexity index by considering weights of the individual factors using Analytical Hierarchy process (AHP). Statistical analysis was then conducted to understand the impact of the complexity on the performance measures.

Findings
The results showed that performance measures showed no significant difference for different complexity levels. However, a change in the weight of the standard deviation of demand a little resulted in a significant difference on performance between low and high complexity levels. Considering the individual factors of complexity, cost performance were significantly affected by standard deviation of demand while the number of close to stock-outs was significantly affected by both the silo size of the customer and standard deviation of demand.

Value
Creation of a distribution complexity index and assessment of impact of complexity index and individual drivers of complexity on distribution performance are the contributions of this paper.

Research limitations/implications
The research is based on data from a single company and hence the results cannot be generalised. The research implies that there is a need of better understanding of various factors that drive complexity but also their impact on performance.

Practical Contribution
Companies are usually unaware of the negative effects of complexity and their costs increase as well as their ability to service customers suffers. Hence, companies should proactively analyse the impact of complexity on performance and potentially assess the

cost of additional complexity on business performance so that corrective actions can be taken to either reduce complexity or make improvements in the supply chain to handle complexity.

Introduction

Complexity in distributing products can negatively impact the performance of a company. Drivers of distribution complexity can be variety of products that needs to be delivered, the uncertainty in demand, the number and geographical spread of customers (Gerschberger et al., 2012; Wu et al., 2013). All of the above could potentially increase when more customers enter the system. For example, with increase in the number of customers, the number of possible routes to serve them will increase. This will make the route planning more complex, as more solutions are to be considered and more customers require different products and services (Gerschberger et al., 2012a; Wu et al., 2013).
There is limited research on quantifying the complexity in distribution and to assess the impact of such complexity on the performance. Without such quantitative assessment, it will be difficult for companies to take any corrective action to address complexity.
Hence, the purpose of this paper is to answer the following research questions

1. How to estimate the distribution complexity in an industrial gas distribution company
2. How does complexity impact the performance of the company?

Literature Review

Definition of complexity

Complexity in distribution is an increase in difficulty to manage the system, as the number of nodes increase. This can include different factors such as the variety of products that needs to be delivered, the uncertainty in the demand and the geographical components that affects the system etc. (Gerschbergeet al., 2012; Wu et al., 2013). Manuj & Sahin (2011) described complexity as a linear change in a part of a system that can lead to a nonlinear and unexpected change in another part of the system. An increased complexity in the supply chain can cause disturbances. This will eventually cause bullwhip effects in the system leading to bad performance and higher supply chain costs (Giannakis & Louis, 2016; Wu et al., 2013). As an example of this, lack of visibility in the supply chain and demand variance increase the uncertainty of the system. This leads to a need for a higher inventory and will thereby affect the cost of the system (Collins,et al., 2010; Szmelter, 2017).
There can be three different types of complexity: static, dynamic and mixed states of complexity (Sterman, 2000; Szmelter, 2017). The static approach include the number of nodes in the system, where complexity increases as the number of nodes increases, as more management of these nodes is required (Craighead, et al., 2007). The dynamic complexity is the interaction between the nodes and the learning of the system. The dynamic view of the complexity means that everything is in a constant evolvement and that everything is uncertain (Sterman, 2000; Szmelter, 2017a). The dynamic complexity involve the feedback loops, which can either be reinforcing or balancing (Sterman, 2000; Windt, Philipp, & Böse, 2008). The mixed approach is where both static and dynamic complexity are present (Szmelter, 2017a).

Estimation of complexity

Complexity measurement should include an assessment of the different factors from the people who are actually working with the system, that needs to be measured (de Leeuw et al., 2013; Gerschberger et al., 2012a). Few authors have presented methods for calculating the level of complexity in supply networks (Gerschberger et al., 2012a; Sivadasan, Smart, Huaccho Huatuco, & Calinescu, 2010; Wu et al., 2013).
Complexity measurement consist of three steps:

1. Identify the factors in the industry
2. Define each factor and the impact on complexity to the system
3. Conceptualize a model to calculate the complexity

Gerschberger et al., (2012) introduces a generic model where companies can include their own factors in the model to determine the complexity of the system. The factors used in the complexity calculation are the number of customers and the number of different products. The third factor used is uncertainty, which could be measured in different ways including for instance volume volatility. This factor was measured for each customer and the final score in this case was calculated as the maximum value of this factor (Gerschberger et al., 2012). The complexity factors are multiplied by a subjective weighting factor, resulting in the final index score. This model proposed different complexity factors in the calculation and should be built on industry specific requirements and that the subjective considerations should be included in the weightings (Gerschberger et al., 2012).
De Leeuw et al., (2013) used a comparison method to measure complexity. In this study, eight factors are used to measure the complexity on a group of wholesalers:

- Uncertainty
- Diversity
- Size
- Variability
- Structure
- Speed
- Lack of information
- Lack of cooperation

Both the methods by Gerschberger et al., (2012) and De Leeuw et al., (2013) seems to provide good solutions on how to measure the complexity within a company. Gerschberger et al., (2012) differentiate in the way that this method provide a single complexity index with the complexity factors being weighted in relation to one another. This makes it easier to get an overview on how well the system is performing. On the other hand, De Leeuw et al., (2013) provides a more detailed calculation on each individual complexity factor. Also, the method De Leeuw et al., (2013) is more focused on the specifics of the warehouse industry. This is a good indication of how a detailed model should be tailored within a specific industry.

Methodology

Data on the number of customers, number of products, silo size, daily demand and standard deviation of demand were collected along with performance measures like distribution cost and number of close to stock-out situations (NCSO) from the case company. These were supplemented by interviews with people from the case company for understanding the current state of operation, the degree of information sharing between the company and its customers, and for confirmation of the findings. The collected data were used to create the complexity index by considering weights of the individual factors using Analytical Hierarchy process (AHP). Statistical analysis was then conducted to understand the impact of the complexity on the performance measures.

Distribution complexity measurement: a case study

Stage 1: Identification of factors:
Based on the literature review and in discussion with experts in the case company, six factors, which can be used to determine complexity within the gas distribution industry were identified.

- **Number of customers:** Adding a customer increases the complexity in two ways. First of all, the planner has an additional inventory to monitor and prevent from going stock out. Secondly, the extra demand will decrease the capacity flexibility of the truck, which could have been used for preventive refills at adjacent customers.

- **Number of products:** The number of products create a need for more trucks to be allocated because the trucks are only able to carry one product type at a time.

- **Silos size:** Companies are by regulations only allowed to set up silos at the size of 10.000 gas index units . The size of the silo have an impact on how much inventory that can be carried at the customer, and as discovered earlier, inventory is a method for reducing the complexity in the system. This advocates that the smaller the silo size, the higher complexity level.

- **Daily demand:** The daily demand [d] for a product [i] by customer [c] is an important determinant of complexity. As customers use more of the product on a daily basis, they will also need to be replenished and monitored more frequently than customers with a lower consumption.

- **Demand variability:** The standard deviation [σ] of the demand affects the complexity, as an increase in the uncertainty increases the safety stock needed at the customer inventory. If there is a higher uncertainty in the system, it is more difficult to manage and thereby the complexity of the planning will increase. A high uncertainty also demands a high flexibility in the system, as the planner has to react to sudden changes.

As these factors were derived from the literature review, the researchers of this paper validated the findings by an interview, ensure no additional factors were missing or no misinterpretations had occurred.

Stage 2: Determining the weights of each factor:
The weights used in the complexity index calculation is based on the planner's subjective comparison between the factors. The Analytical Hierarchy Process (AHP) developed by Saaty, (1980) is here used as a tool to calculate the total weights of each factor. Further, the consistency of the data should be calculated, to see if there is a consistency between the pairwise comparisons and the proportional relationship to the weights.
First step of the AHP is to do a pairwise comparison of each factor involved in the system. This is done by using the scale, shown in table 1. The calculated weights are shown in Table 2.

Importance (absolute scale)	Definition
1	Equal importance
3	Moderate importance of the one factor over the other
5	Essential or strong importance over the other factor
7	Very strong importance over the other factor

9	Extreme importance over the other factor
2,4,6,8	Intermediate values if it is in between two of the judgements.

(Saaty & Vargas, 2012)
Table 1: Scale for calculation of weights

Complexity factors	Weight
Number of customers	0,06
Silo size	0,20
Daily demand	0,12
Deviation of the demand	0,62

Table 2: Calculated weights for the complexity factors

Stage 3: Conceptualization of model for the complexity index:
The determination of complexity index and the index score is based on the knowledge from de Leeuw, Grotenhuis, & van Goor, (2013) & Gerschberger, Engelhardt-Nowitzki, Kummer, & Staberhofer, (2012).
When using the maximum value within the industry in the following calculations, the maximum value within the company was used instead. This was due to the researchers not being able to conduct the required data in other companies within the same industry. However, it is recommended to do an industry analysis in future research.
The number of customers is calculated as the total number of customers divided by the maximum number of customers in the industry:

$$Customer\ complexity\ score\ (c) = \frac{\sum_{c=1}^{n} c_{Focal\ company}}{\sum_{c=1}^{n} c_{\max in\ industry}}$$

The calculation on product complexity score is based on the mean number of products for all customers divided by the maximum number of products in the product portfolio, which is four different types of gasses.

$$Product\ complexity\ score\ (c,i) = \frac{\left(\frac{\sum_{c=1}^{n} i(c)}{n}\right)}{i_{max}} = \frac{\overline{\iota(c)}}{i_{max}}$$

Silo size complexity is measured as one minus the mean value of the siloes for each product at each customer divided by the industry maximum size. The reason for this is that it is more complex to replenish when the customer has a smaller silo size.

$$Silo\ size\ complexity\ score\ (c,i,S) = 1 - \left(\frac{(\sum_{c=1}^{n}\sum_{i=1}^{j} S(ci))/\sum_{c=1}^{n} i(c)}{S_{max}}\right) = 1 - \left(\frac{\overline{S(c,\iota)}}{S_{max}}\right)$$

The demand complexity is calculated as the mean demand for each customer and product, divided by the maximum demand in the industry:

$$Demand\ complexity\ score\ (c,i,d) = \frac{\left(\frac{\sum_{c=1}^{n}\sum_{i=1}^{j} d(ci)}{\sum_{c=1}^{n} i(c)}\right)}{d_{max}} = \frac{\bar{d}(c,i)}{d_{max}}$$

The Demand deviation (σ) complexity score is calculated as the mean deviation of each product, and for each customers divided by the maximum deviation in the system:

$$Demand\ deviation\ complexity\ score\ (c,i,d,\sigma) = \frac{\left(\frac{\sum_{c=1}^{n}\sum_{i=1}^{j}\sigma(dic)}{\sum_{c=1}^{n} i(c)}\right)}{\sigma_{max}} = \frac{\bar{\sigma}}{\sigma_{max}}$$

The final index score is calculated as the sum of all parameters multiplied with the equivalent subjective weight found in stage 2. This will give a final score between 0 and 1 (Gerschberger et al., 2012b). A score of 1 is the most complex state in the network and 0 is that there is no complexity in the network. The index is calculated as:

$$Complexity\ Index = \left(\frac{\sum_{c=1}^{n} c_{Focal\ company}}{\sum_{c=1}^{n} c_{\max in\ industry}}\right) \cdot W_c + \left(\frac{\bar{i}}{i_{max}}\right) \cdot W_i + \left(1 - \left(\frac{\bar{S}}{S_{max}}\right)\right) \cdot W_s + \left(\frac{\bar{d}}{d_{max}}\right) \cdot W_d + \left(\frac{\bar{\sigma}}{\sigma_{max}}\right) \cdot W_\sigma$$

As previously stated, this specific model is only applicable within the same industry and setting, as the factors are directly suited for this industry and case. The model also focus on the outgoing part of the supply chain and does not look at the entire flow and complexity of the supply network. For calculating the weights of each factor, the subjective opinion from the focal company is used, which could be different from each company within the industry.

Impact of distribution complexity on performance

The analysis of impact of distribution complexity was done in two steps The first compared the complexity index to the distribution cost and the second compared the complexity index to the Number of close to stock out situations (NCSO). For each of the two tests, a sensitivity analysis was performed, changing all weights to see how the result is affected. A structured approach is used in order to perform this analysis.

Complexity index with AHP distributed weights compared with cost:

Figure 1 illustrates the relationship between the calculated complexity index and the measured distribution cost for that same period.

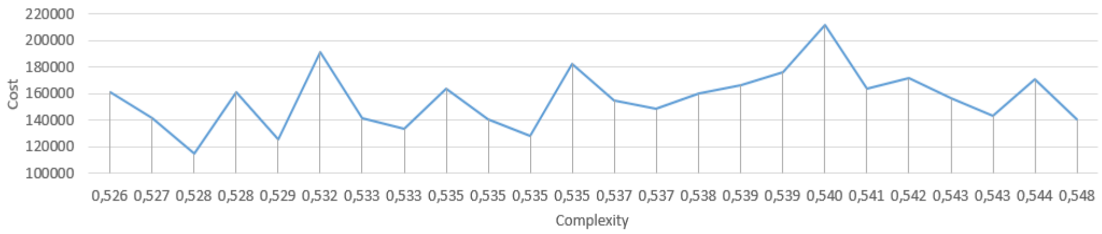

Figure 48 - Relationship between cost and complexity index

The results show that there is no significant difference in distribution cost with varying levels of complexity. One of the reasons for this finding is that the distribution cost is based on an aggregated cost of all four products. In the data provided by the company, the cost for each product is calculated based on a cost allocation key each period. Therefore, all the variations that occur one product will be split on all four products instead. In order to make a more comparable analysis, the cost should be calculated for each product, where variations can be detected.

Sensitivity results:

By changing the level of the Deviation of demand by +0,09 and the other factors by -0,03, a significant difference was discovered, as can be seen in the analysis below, see Table 9.

Anova: single factor

RESUME

Groups	Population	Sum	Avg.	Varians
L	8	1114995	139374,3	2,71E+08
M	8	1296302	162037,7	3,06E+08
H	8	1340382	167547,7	5,23E+08

Anova

Source of variation	SK	fg	MK	F	P-value	F krit
Between groups	3,57E+09	2	1,78E+09	4,863	0,0183	3,466
Within groups	7,7E+09	21	3,67E+08			
Total	1,13E+10	23				

Table 3 - Anova test on variation of distribution cost by levels of complexity

This analysis indicates that the deviation on demand might have a greater influence on the cost performance than the other factors. Further two tests on Deviation of demand were performed to see when the performance showed a significant difference between the levels of complexity. The result started showing a significant level, when the Deviation of demand weight was changed by 0,0225 and the others -0,0075 each. This analysis is therefore very sensitive for a change in the weight of deviation of demand. This might indicate that there is a stronger link between the cost and complexity of managing a distribution system with a high Deviation of demand.
The other sensitivity analysis did not show any significant difference between the performances at the different complexity levels.
Complexity index with AHP distributed weights compared with NCSO:
Figure 2 illustrates the relationship between the calculated complexity index and the measured NCSO for that same period.

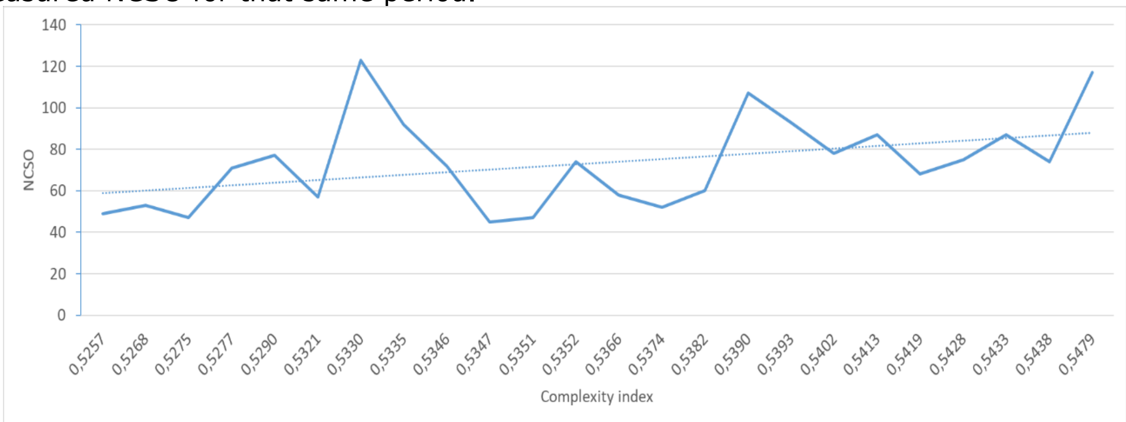

Figure 49 - Relationship between NCSO and complexity index

Sensitivity results:
A sensitivity analysis is also done on these measures in order to see how the result change at different weights for the four factors, see Table 4.

Anova: single factor

RESUME

Groups	Population	Sum	Avg.	Varians
L	8	446	55,75	143,92
M	8	639	79,875	644,98
H	8	678	84,75	234,21

Anova

Source of variation	SK	fg	MK	F	P-value	F krit
Between groups	3858,083	2	1929,042	5,656	0,0108	3,4668
Within groups	7161,875	21	341,0417			
Total	11019,96	23				

Table 4 - Anova test on sensitivity analysis for variation of NCSO with complexity levels

This sensitivity test showed a significant difference on the performance between the low complexity level and the high complexity level as p-Value = 1,1% < 5%. In this test, deviation of demand was changed by +0,09 and the other factors were changed by -0,03 each. In order to find an interval where the change occurred, another test was performed by changing the deviation weight by only 0,045 and the other factors by -0,015. This showed no significant difference between the different levels. The test is therefore set up to this level and changes somewhere in-between a change of the deviation weight by [0,045;0,09] and the other weights accordingly. The other parts of the sensitivity analysis did not show any different result on a significant level, but had a tendency to have higher NCSO at higher levels of complexity index in general.

Testing the effects of individual complexity factors:
In order to see if the individual complexity scores have an impact on the performance, the impact of each of the four complexity scores on cost, and on stock out situations are tested. It is tested if the individual complexity factors have a significant impact on the cost performance.

Customer complexity, silo size, demand do not have a significant impact on the cost performance by itself on the tested levels of complexity. Deviation of demand does significantly affect distribution cost. The gas distribution should therefore be aware that large deviation of the demand result in higher costs. When the deviation reaches a level equivalent to 113,3 - the average cost of the system will increase with approximately 27.000 DKK compared to deviations reaching from 86,9 to 104,9.
Figure 3 shows how the deviation of demand affects the cost of the distribution

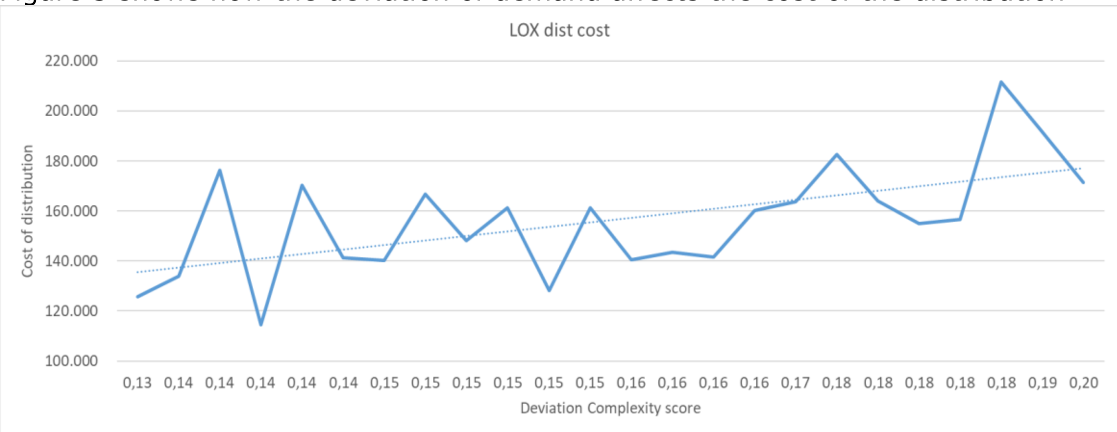

Figure 3 – Deviation of demand and cost

The figure shows that the cost of the system gets higher when reaching a complexity level on 0,17 and above.

Customer complexity and daily demand does not affect NCSO but silo size complexity and deviation of demand do impact NCSO.

To summarize, the results showed that performance measures showed no significant difference for different complexity levels. However, a change in the weight of the standard deviation of demand a little resulted in a significant difference on performance between low and high complexity levels. Considering the individual factors of complexity, cost performance were significantly affected by standard deviation of demand while the number of close to stock-outs was significantly affected by both the silo size of the customer and standard deviation of demand.

Conclusion

Creation of a distribution complexity index and assessment of impact of complexity index and individual drivers of complexity on distribution performance are the contributions of this paper.

Companies are usually unaware of the negative effects of complexity and their costs increase as well as their ability to service customers suffers. Hence, companies should proactively analyse the impact of complexity on performance and potentially assess the cost of additional complexity on business performance so that corrective actions can be taken to either reduce complexity or make improvements in the supply chain to handle complexity.

The research is based on data from a single company and hence the results cannot be generalised. The research implies that there is a need of better understanding of various factors that drive complexity but also their impact on performance.

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THEORETICAL MODEL OF SUPPLY CHAIN ACTOR ICT CAPABILITIES TO BUILD RESILIENCE A DELPHI STUDY OF EUROPEAN LOGISTICS EXPERT

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Abstract
Purpose
European Commission Horizon 2020 project 'Architecture for European Logistics Information Exchange' (AEOLIX), ventures to improve visibility across supply chain networks via development of a digital platform for data management, sharing, and distribution. This paper sets out to establish the market potential of such a platform considering the opinions of academia, technical experts and industry stakeholders.

Design/methodology/approach
This research employed the Delphi technique to compose a list of issues focusing on building resilience into supply chains through collaborative visibility. Delphi methods have proven to be an efficient survey method when only a limited amount of data is available or the topic is previously unexplored. It [Delphi] further permits alternate viewpoints to elicit information and validation of opinions to arise, or alternatively, identify discrepancies which can in turn be investigated.

Findings
Preliminary research has identified the current market state to be dominated by out-of-the-box solutions, comprising at least 57% of the market stakeholders. This percentage increases when considering market share held by these stakeholders [logistics organisation] as they are typically larger adopters of out-of-the-box solutions. Therefore, any disruptive technology in this area must be demonstrably more useful and cost-effective than the currently on-market alternatives. However, in gaining collaborative end-end supply chain visibility, integration and SME adoption was found to be a critical issue stifling logistics innovation in ICT solutions. Additionally, any innovative logistics solution that permeates through academic research or SME design suffers minimal market penetration due to the 'closed source' approach of larger ICT logistics suppliers.

Value
This research paves the way in identifying effective routes to, as well as the barriers of entry, to this market via assessment of client expectations and requirements as to successful integration and use of emergent solutions to data management, sharing and distribution across supply chains.

Research limitations/implications
A potential barrier to work of this nature is ascertaining as wide of a perspective as possible in order to mitigate variations in opinion across geographic regions. By working with AEOLIX we have access to a multitude of European supply chain stakeholders across multimodal transportation requirements. This provides a diverse range of expert opinions

within the Delphi allowing for the identification of a general-case basis of requirements for emergent and disruptive technologies.

Practical Contribution
This research will drive new approaches in the design and development of logistics and supply chain solutions through the identification and provision thereof client expectations and requirements for the uptake of new technologies

INTRODUCTION

Information and communication technology (ICT) has become an integral part of business management, permitting the alignment of actors in a supply chain to one common goal through synchronising information flows permitting agility, visibility and risk reduction to be achieved when implemented correctly (Jeffers et al., 2008). In recent years solutions pertaining to value add within logistics have been purported to meet these aforementioned benefit's, through deployment of but not limited to Electronic data interchange (EDI), Enterprise resource planning (ERP), warehouse management systems (WMS), Transport management systems (TMS), and Radio frequency Identification (RFID), and more recently internet based solutions such as Blockchain.

Despite this widespread adoption of technology within the logistics and supply chain industry, there still appears to reside huge inefficiencies within the sector (Chapman et al., 2003; Li et al., 2009). As such, there is a call by academia to have greater research exploring the divergence between logistics and supply chain efficiencies with the much-needed adoption of ICT and supply chain risk mitigation (Bienstock & Royne, 2010; Marasco, 2008; Fassam & Dani, 2017; Marchet et al., 2009).

Therefore, this research paper will utilise a systematic literature review of existent academic and practitioner literature against Delphi study outputs from the European Commission Horizon 2020 project 'Architecture for European Logistics Information Exchange' (AEOLIX). In doing so, this paper sets out to establish an understanding of benefits a collaborative data sharing platform has, considering the opinions of academia, technical experts and industry stakeholders through the research question:

'what barriers to successful logistics ICT data sharing exist'?

LITERATURE REVIEW

Supply chain risk management & visibility

With complexity, as seen with the global supply chain, comes uncertainty and with uncertainty comes risk (Bacon, 2014). One simple production flaw occurring many tiers upstream could lead to significant consequences downstream (Hall, 2014). To mitigate against this challenge across the multi-tiered supply chain, a 'software tsunami' developed by a myriad of highly specialised suppliers has enveloped the industry, which has arguably complicated an already complex environment. Much of these softwares do not integrate well with each other, and to further complicate matters, lack of holistic supply chain adoption [multi-tier] has led to risk mitigation strategies such as lean and just in time not being realised (Carvalho et al., 2013; MacDuffie and Fujimoto 2010; Liker, 2004). Hall (2014) summarises this well in saying that constant trimming and lack of standardisation has made supply chains "wonderfully efficient on one hand, yet woefully vulnerable on the other".

With an identified rising occurrence of cost and risk associated with supply chain vulnerability, it is surprising that such little scholarly research exists in understanding the gap between information sharing and risk mitigation (Skold & Karlsson, 2007; Wickenberg et al., 2011). Some authors such as Hetzner (2014) have identified a correlation between extended supply chains and issues around recalls, with a finding that the bigger the chain of actors, the larger the product recall could be. However, there is little empirical evidence to support how this can be mitigated. Furthermore, leading researchers on the topic of software integration, only briefly touch on the risk associated with scope of complexity and risk adversion, with little discussion on how this may be mitigated (Liker, 2004; MacDuffie & Fujimotor, 2010; Womack et al., 2011).

			Example Disruption	Researchers
High Likelihood, Low Impact	**Internal to OEM**		**Production Facility Failure**	Manuj and Mentzner (2008); Sodhi and Lee (2004); Zsidisin *et al*. (2000)
			Product Quality Issues	Dani and Deep (2010); Manuj and Mentzner (2008); Pyke and Tang (2008);
			Forecasting Errors	Faisal *et al*. (2007)
			Product Recall	NHTSA (2014); Sodhi and Tang (2012)
	External to OEM, internal to SC	**Demand Side**	**Distribution Network Breakdown (NSC/ dealer issues)**	Stecke and Kumar (2009)
			Demand Volatility	Chopra and Sodhi (2004); Tang and Tomlin (2008)
Medium Likelihood, Medium Impact		**Supply Side**	**Material Quality Issues**	Chopra and Sodhi (2004); Wu *et al*. (2006); Zsidisin *et al*. (2000)
			Supplier Delay	Blackhurst *et al*. (2008); Tang and Tomlin (2008); Wu *et al*. (2006)
			Supplier Breakdown (Bankruptcy)	Zsidisin *et al*. (2000)
		Transportation	**3PL Bancruptcy**	Stecke and Kumar (2009)
			Transportation Delay	Manuj and Mentzner (2008); Blackhurst *et al*. (2008)
			Port Strike	Stecke and Kumar (2009)
Low Likelihood, High Impact	**External to OEM and SC**		**Regulatory Risk**	Chopra and Sodhi (2004); Stecke and Kumar (2009); Zsidisin *et al*. (2000)
			Security Risk (e.g. terrorism)	Sheffi and Rice (2005); Stecke and Kumar (2009)
			Infrastructure Breakdown	Blackhurst *et al*. (2008); Faisal *et al*. (2007)
			Political/ Economic Instability	Manuj and Metzner (2008)
			Natural Catastrophes	Stecke and Kumar (2009); Behdani *et al*. (2012)

Table.1 Key areas of risk within supply chain

Highlighting the largely fragmented body of existent literature, table.1 synthesises researchers' views on the steps of risk identification, classification and assessment. While the majority of academic publications focus on very specific risk classifications, only few authors have researched the broader picture of risks associated with a lack of ICT integration. However, many of the risks identified are arguably avoidable if known, and mitigation strategies of collaborative data being a tool for reducing risk is not mentioned within the literature, although arguably implied.

That said, an area for this generalised lack of discussion on mitigation strategies could be related to risk and its associated causes, often being a default action applicable across many disruptive risks and associated causes (Sodhi and Lee, 2004). Additionally, risk acceptance is often created when the cost of a solution would outweigh the assessed disruption impact, highlighting an issue of short termism with logistics and supply chain sectors (Tomlin, 2006). That said, when choosing to mitigate against risk supply chain actors choose areas such as business continuity plans, flexible transportation, inventory management, supplier screening, performance-based contracting or security improvements (Manuj and Mentzer, 2008; Sodhi and Lee, 2007; Tomlin, 2006). However, all of these mitigation metrics are only of use when connected and collaborative data be gleaned, arguably giving supply chain managers a false security blanket with risk mitigation strategies by not having connected and visible data interchange.

The above identified risk challenges are subject to constant change, with globalised supply chains undergoing continuous change, which means some risk will be eliminated and as a consequence others [risks] appear (Sodhi & Tang, 2012). Monitoring these changes in network, technology, competition or location and consequently updating the risk assessment is a critical part of supply chain risk management (Pyke & Tang, 2010).

However, despite its importance, risk monitoring through connected logistics ICT is not a well-researched topic, with out-dated techniques requiring significant manual updating of systems often resulting in a non-deliberate unawareness of risk monitoring arising (Manuj, 2008). This arguably will be due to missing supply chain visibility leading to inaccurate and meaningless tools and techniques being made available.

Additionally, because historical data of holistic supply chain disruptions is limited or non-existent, companies cannot adequately quantify and therefore assess the risk exposure and balance cost of mitigation around same (Behdani et al., 2012; Levi-Simchi et al., 2002). However, it is suggested that use of expert judgement can compensate for the lack of historical data (Deleris & Erhun, 2011). But, Kleindorfer and Saad (2005) contradict this argument stating expert judgements about sudden disruptions are too vague and likelihood of human error is all too likely.

Another issue in managing supply chain risk is missing visibility and knowledge across long and complex logistics chains. A good example can be seen with European supply chain OEMs whom work with around 3,000 direct and known suppliers, with their [OEM] sub-suppliers [Tiered] are almost completely unknown to the OEM (Blackhurst et al. (2008). One such OEM, BMW Group, cites a supplier base of circa 12,000 known direct and indirect suppliers across two tiers and in 70 countries (BMW Group, 2013). Yet, when going further upstream to the extraction of raw material, this number is more than likely to be much higher. The missing visibility with upstream suppliers contributes to 51% of all Automotive supply chain disruptions, with this [disruption] occurring below tier-1 suppliers, highlighting a significant problem space for downstream supply chain actors (Blackhurst et al., 2008; Zurich Insurance, 2014). Therefore, we can conclude that 51% of supply chain disruptions cannot be predicted, are not measured with connected data and suffer at the hand of OEM's not having visibility of their multiple tiers of suppliers.

Strategies to address proactively managed supply chains

As previously discussed, existent literature has highlighted a significant 'problem space' between the increasingly complex web of supply chain management, which in itself is causing vulnerabilities to overall supply chain surplus through lack of visibility. When reviewing the case study of automotive OEMs [BMW] and the 51% hit rate on disruptions occurring below tier 1 suppliers, an emphasis must be placed on technology bridging the divide between human and data with interpretation. However, there is little in way of existing body of knowledge that supports the notion of mitigating supply chain disruptions with 'how to' approaches from industry.

Despite the benefits of collaborative data interchange to mitigate risk, there are a few scholars whom disadvantage use of a collaborative information-sharing ecosystems, such as the deployment of anti-competitive behaviours arising (Huck et al., 2000). However, despite this potential of anti-competitive behaviour arising, the benefits of supply chain flexibility mitigating impacts of risk occurrence are far outweighed (Deloitte, 2013; Goh, 2010).

The industry linkage is important, as human factors play an incredibly important role in decision making, and at times interpretation is key in determining likelihood of occurrence (Tang & Tomlin, 2008; Zsidisin et al., 2000). However, reducing the likelihood of supply chain risk occurrence is argued as impossible due to cost factors (Kleindorfer & Saad, 2005; Wu et al., 2006). Despite this prevalence of negativity toward risk mitigation in scholarly research, a proactive supply chain strategy can reduce the impact of disruption when the unthinkable happens, by enabling supply chain flexibility in reduced time frames (Carvalho et al., 2013; Kleindorfer & Saad, 2005; Punter, 2013; Tang & Tomlin, 2013).

The following supply chain flexibility strategies have been synthesised from research by (Carvalho et al., 2013; Kleindorfer & Saad, 2005; Punter, 2013; Tang & Tomlin, 2013):

- Use of multiple suppliers
- Engaging adaptive production processes
- Embracing dynamic supply contracts
- Adopting upstream supplier collaboration.

To achieve a flexible supply chain, organisations need to share information, a strategy that is espoused as significantly improving supply chain performance, and for small to medium enterprises being a catalyst to increased efficiency (Christopher & Lee, 2004; Simchi-Levi et al., 2002; Towill, 1998). Furthermore, collaboration through data interchange is seen as a win-win scenario for all actors in being able to lower inventory costs, arguably one of the most significant risk factors facing supply chain actors in todays complex trading environment (McClellan, 2003). This inventory management benefit is seen as a bi-product of much needed data sharing across the complete supply chain (Christopher & Lee, 2004; Sodhi & Tang, 2012).

In closing, despite a lack of connected literature relating to ICT and supply chains with reducing risk, there are four core elements of supply chain collaboration that have been identified in literature:

- Collaborative culture with openness, trust and communication (Barratt, 2004)
- Common strategic goals, objectives and KPIs (Sodhi and Tang, 2009)
- Supply chain information-sharing (Lee et al., 2000; Yu et al., 2000)
- Collective response planning (Stecke and Kumar, 2009)

These four elements are concatenate with good supply chain risk management and largely connected to the auspices of connected supply chain infrastructure systems such as AEOLIX, therefore relevant to understanding the process of collaborative data interchange across supply chain partners.

METHODOLOGY

There has been little academic knowledge creation around ICT theoretical frameworks in the area of logistics and supply chain, with a particular focus on risk mitigation (Bienstock & Royne, 2010). This was confirmed through an existent literature review into deployment of ICT and logistics service providers, with findings showing a lack of understanding of technology, implementation and use (Marasco, 2008). This study intends to develop an understanding of key metrics related to ICT implementation with use of a systematic literature review and Delphi study of European supply chain experts. This dual approach of research method was deployed as it has been upheld by scholars as espousing more reliable results whilst reducing bias (Bahri, 2009; Salanova et al., 2004).

The research had two objectives:

1. Identify existent literature relating to ICT risk reduction with logistics
2. Formulate an expert opinion of issues associated with ICT adoption.

Therefore, this paper takes a triangulated methodology (fig.1), firstly undertaking a systematic literature review (SLR) of current academic and practitioner thinking in relation to models of ICT to support logistics and supply chain innovation, identifying existent gaps allied to best in class thinking of business across Charted Association of Business Schools journals. It then builds upon the identified gap analysis, leveraging a Delphi study research across logistics, transportation and supply chain users, to build the perception of ICT implementation in logistics and supply chain now and in the future. Lastly, the research then undertakes a review of the outputs to proffer a model of key metrics affecting the implementation of ICT in logistics.

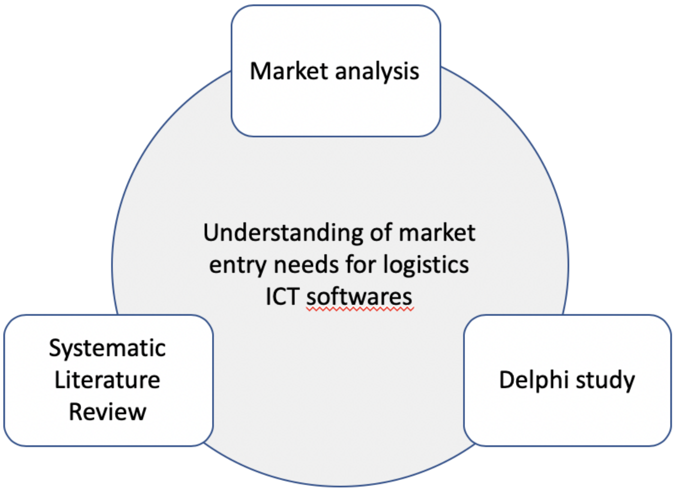

Fig.1 Methodology process

Systematic literature review

The systematic literature review (SLR) process employed in this research, provides a structured understanding and research gap identification for prospective researchers (Denyer & Tranfield, 2006). Further supporting the need for adopting the SLR approach, Tranfield et al (2003) claim that masses of subjective and often inconsistent literature resides within fields of study and through this process [systematic literature review] clearer identification of gaps and data will become prevalent. In doing so, systematic classification of current literature was carried out which deployed an iterative process of define, interpret and perfect across many databases manually assessing significance of literature (Clark & Oxman, 2001; Tranfield et al, 2003).

The keywords used for the Supply chain ICT literature search were "Logistics", "Supply chain", "Resilience", "Risk" and "Traceability" all prefixed by the term "ICT". These keywords were selected owing to the authors preceding experience in the supply chain risk management discipline, coupled to wider dialogue with academics and practitioners within the Supply chain field of operation.

In the case of this Systematic literature review (SLR) a variety of databases and journals were initially screened and in order to maintain relevance to the subject field, inclusion criteria was concentrated on the Association of Business Schools (ABS) journal listings due to their global acceptance, impact and standing in business research.

Delphi study

In addition, this research employed the Delphi technique to compose an understanding of the research question 'what are the 10 most important factors to consider when integrating new technologies within existing systems?' Delphi methods have proven to be an efficient survey method when only a limited amount of data on a topic is available (Linston & Turoff, 1975; Riggs, 1983; Rowe, Wright & Bolger, 1992), and therefore chosen by the authors due to limited research available in the area of ICT and supply chain market integration and take a practitioner approach to research validation (Fassam & Dani, 2016; Kache & Seuring, 2017). Previous research has utilised experts to form judgement panels about the likelihood of future events and recurrence of same occurring, therefore building an assumption that the wide range of responses would be distilled and converge toward a mid-range distribution (Johnston, 1976; Ng, 1984). Furthermore, Delphi is recognised as a process flow for collecting expert opinion permitting researchers access to previously unexplored issues (Garrod & Fyall, 2005; Green et al., 1990; Padel & Midmore, 2005).

Research reliability is reinforced by eliciting the opinions of the experts, allowing each expert to review the opinions of other participants with an assurance of anonymity which avoids issues of bias or coercion that may be presented during focus group or discussion scenarios (Ogden et al., 2005). Furthermore, to increase the validity of the received data, reduce research fatigue and mitigate respondents dropping from the research study, the authors deployed a 'live' Delphi approach which facilitates an almost immediate feedback loop (Gnatzy et al, 2011; Geist, 2010). Each expert member provides individual recommendations or opinions on the central issues of 'what are the 10 most important factors to consider when integrating new technologies within existing systems?' These issues and opinions were then circulated to the other participating members so that a consensus may be formed through collaborative review. Because of its quantitative, expert-based nature, the Delphi technique is useful in situations where statistical options are not practical. The technique also allows respondents time to reflect and provides them an equal opportunity to contribute.

Selecting Delphi experts

Critical to the success of the Delphi is the selection of panel experts, as per the Rowe et al (1991) methodology. The panel for this research study consisted of representatives from firms that are acknowledged experts in the practice of supply chain ICT management across Europe, drawing on a variety of practitioner sources including:

- Representatives from leading logistics and supply chain bodies (i.e. Chartered Institute of Logistics and Transport, Chartered Institute of Procurement and Supply)
- Members of European Commission supply chain projects
- Employees of top 100 FTSE food supply chain firms

In total 19 global supply chain experts were engaged in the Delphi process (Table.2) delivering a sample size accepted as robust and relevant to delivering appropriate outcomes (Kache & Seuring, 2017).

Job title	**Participants**
Director, Supply chain	4
Director, ICT systems	3
Plant manager	3
Operations manager	5
Consultant	4
	19

Table.2: Delphi participant role

Delphi expert participants not only came from differing roles within ICT and supply chain organisations (Table.2), they further came from differing sectors within the supply chain. The authors chose to have a mixed representation from different food supply chain nodes (Table.3) in order to get a representative holistic view of the challenges with ICT and supply chain.

Industry	**Participants**
Manufacturer	4
Retailer	4
Distributor	5
ICT design	3
Consulting	3
	19

Table.3: Delphi participant sector

Data collection process and response rate

The Delphi study data collection was undertaken between the period of December 2018 to April 2019. Throughout this time frame the three data collection processes [Delphi stages] were undertaken via email, with the research team checked for consistency and duplication measures with supply chain experts contained within the research team, which is suitable for ensuring reliability of research (Gracht and Darkow, 2010). All nineteen participants gave written consent for inclusion, and the study suffered zero dropout rates, thus delivering a 100 percent response rate.

Delphi process

To address the research question posed at the beginning of this paper, a three-phase Delphi research methodology was developed, aligned to the thinking that greater differentiation of results is not seen by adding further rounds of questioning and proven to permit expert feedback from participants to mitigate research fatigue and foster greater reliability (Kauko & Palmroos, 2014; Okoli & Pawlowski, 2004). Across the three rounds individual frequency distribution was evaluated to gain understanding of expert views to thematic relevance. Additionally, a mean value (μ) was calculated for each thematic area to permit a mean value to be achieved for each question.

The first phase contained the foundations of identifying critical issues pertaining to ICT and supply chain management. This phase given the limited research into this area was undertaken by the Delphi participant group by asking all members to supply allied to their extensive professional experience the top 10 metrics associated to the challenges of ICT and supply chain. The second phase involved the research team reviewing the 190 responses, removing duplication and aggregating into groups using qualitative cluster analysis (Revelle, 1979). These 46 aggregated topics were re-distributed to the 19 Delphi participants, where each was scored against a LIKERT scale 1-5 (1 strongly disagree – 5 strongly agree) with the degree of fit with supply chain resilience and food criminality. The Delphi results were returned and analysed by the research team and ranked in order of highest LIKERT score attained. Third and final phase of the Delphi was undertaken with the top 10 answers scored against the Likert scale in phase 2, which was re-distributed to the 19 participants for re-scoring against the same criteria and LIKERT scale as the previous two rounds.

In order to utilise the process of understanding when to cease further rounds of the study, known as the stopping rule, the authors used a Coefficient of variation, a recognised statistical test to ensure completeness and robustness of outcomes, while indicating the end point of a survey (English & Kernan, 1976; Yang, 2003). Furthermore, the coefficient of variation is the ration of standard deviation (Ω) to its corresponding mean (μ), noted as the most reliable tool for ensuring statistical relevance with a Delphi study (Shah & Kalaian, 2009), by using the formula:

$$CV = \Omega / \mu$$

In all cases the coefficient of variation was below 0.2, which according to Dajani (1979) is a minor difference and therefore concludes that stability was reached in the research outputs, with no further rounds of Delphi being required.

Results

Systematic Literature Review - outputs

The keywords used for the ICT Supply chain literature search were “Logistics”, “Supply chain”, “Resilience”, “Risk” and “Traceability” all prefixed by the term “ICT”. These keywords were selected owing to the authors preceding experience in the SCRM discipline, coupled to wider dialogue with academics and practitioners within the Supply chain field of operation.

Initial results returned 2,901 journal articles, which the research team reviewed for duplication. The next step included only results which were peer reviewed, returning 1,391 and the final step saw the team utilize only journals contained within the Chartered Associated of Business schools listing, acknowledged for its global relevance for publication of leading logistics and supply chain literature for business operations, returning a total of 144 papers.

Subject Category	Occurrences	Frequency (%)
Solution Design	58	40%
Connected Logistics	25	17%
Commercial agreements	15	10%
Outsourcing	13	9%
Digital infrastructure	11	8%
Renewables	9	6%
E-business	6	4%
Waste & Recycling	4	3%
Metadata	2	1%
RFID	1	1%
Other	144	

Table.4 Systematic literature review key themes

The appearance of solution design, a mathematical discipline focused on creating algorithms that can be incorporated into software for logistics planning, as the most common subject of an individual article is a reflection of the strengths of the academic community. However, the appearance of connected logistics in second place is notable, since it reflects a substantial funding stream across Europe for a single issue.

In the second stage of our analysis, we looked at the consistency of publications of articles covering these main subjects over time. Table 5 shows the frequency of publication from 2015 until April 2019.

Keyword	2015	2016	2017	2018	2019 (4 months)
Solution Design	10	9	12	20	7
Connected logistics	4	8	7	4	2
Digital infrastructure	1	3	4	2	1

Table 5: Longitudinal analysis of key publication subjects, 2015 – 19

From this analysis, we can observe that the output on the subject of connected logistics is increasing whilst the output on the subject of solutions design is reducing, while digital infrastructure appears to be remaining static in review across the academic literature. This is a significant result, as the funding available for logistics research is generally under pressure, suggesting that connected logistics is an area of research that finds particular favour with grant-awarding bodies.

Bibliometric Analysis of the Trade Press and Media

An initial analysis of the trade press and media was undertaken using the advanced search functions provided by Google with the keywords 'Supply chain ICT', with manual intervention to remove duplicates and eliminate hits due to alternative meanings of the relevant search terms.

A sample of 120 hits (representing 284 articles due to multiple reporting) was analysed to identify the key stories published in the media in the twelve months from March 2018 to April 2019.

Subject Category	Hits
Company Performance	59
Blockchain	21
Digital architecture	14
Skills Shortages	9
ICT	6
Trends / Reviews	4
Decarbonisation	2
Fraud	2
Rail	1
Ports	1
Supply chain	1

Table 6: Subject Analysis of 284 articles from 12 months to April 2019 (Google)

The mainstream press can be clearly seen to concentrate on company performance, blockchain and on digital architecture. Reports in the specialist press are rarely reported by the general press, leading to a phenomenon whereby the most published articles are often not the most important from a whole industry perspective.

Delphi Study – outputs

The results of the Delphi process gave an insight into challenges associated with ICT and supply chain infrastructure integration, an important metric to understand when developing ICT for supply chains risk mitigation.

Key themes across the top 10 evolved, namely areas associated to availability and ease of use regarding logistics ICT softwares, and is an important consideration for developers wishing to enter the marketplace. This is understandable as the complex nature of businesses require systems that integrate with ease and cause little complexity to existing systems. Often, additional layers of complexity mean operational procedures get stifled and issues within business occur, predominately by opening gateways of data in-security within a supply chain context. This desire for ease of integration can also be correlated to the challenges outlined in the literature review of cost and complexity (Kleindorfer & Saad, 2005; Wu et al., 2006). If a software is not easily integrated, it quite often requires middle ware, which in itself exposes risks of additional gateways for criminality to explore, and is a significant cost to bolt on to legacy systems. Furthermore, with the free text comments seen from the expert panel, it is this issue of complexity that is forcing supply chain managers away from integrated data interchange solutions.

This [gateway of data] can be correlated as another key theme set of integrity of data, data exchange and GDPR, that come out strong in the responses. One assumes to see this within a globalized supply chain context as trust and data sharing are the key aspects to supply chain collaboration (MacDuffie & Fujimotor, 2010; Womack et al., 2011). Within the literature the mitigation of risk through data interchange was stifled by use of data in an anti-competitive way. The risk of GDPR legislation is an added complexity to this [anti-competitive behaviour], and a key consideration by the expert panel. Furthermore, the outputs of the Delphi are closely allied to the academic literature, particularly in terms complexity and data with logistics ICT services and aforementioned issues around data sharing, which are embedded in the experts comments pertaining to a certified data exchange for securing data streams between supply chain actors. This would imply that supply chain managers would in fact share data to create better resilience, but it would need to be through the use of a third party that would not use data for own financial gain.

Answers	Round 1	Round 2	Round 3	MEAN	STD DEV	CV	Comments
Always Available	4.7	4.8	4.8	4.8	0.08	0.02	Visibility is key for AEOLIX success with integrated supply chain resilience building
Ease of Use	4.3	4.9	4.9	4.7	0.32	0.07	Solution is deemed as not easy to use or integrate
Network Security	4.5	4.6	4.6	4.6	0.05	0.01	Respondents feel security of data sharing is critical
Traceability of Information	4.3	4.6	4.4	4.4	0.14	0.03	Abilities for stakeholders to trace information as it moves through actors is critical
Reliable Technology	4.4	4.4	4.5	4.4	0.05	0.01	Reliable 'always on'
Legal Framework	4.2	4.3	4.2	4.2	0.04	0.01	Sharing agreements needed, would give greater collaboration opportunities with data
Data Privacy (GDPR)	4.3	4.1	4.2	4.2	0.12	0.03	Lack of knowledge of this metric created nervousness with respondents, especially those in the global marketplace
Integration into Existing Systems	4.2	4.2	4.2	4.2	0.02	0.00	Integration was seen as critical, and was linked to the issues around ease of use
Feasible Implementation Strategy	4.3	4.1	4.1	4.2	0.09	0.02	Lack of feasibility was noted as a critical issue with supply chain software's
Certified Data Exchange	4.0	4.1	4.2	4.1	0.08	0.02	Secure and certified sharing of information would be needed for seamless data sharing

Table.7 Delphi outputs

However, what is prevalent across the expert participation are concerns around existent technologies and their lack of integration with IT architecture. This would explain why there is a lack of uptake with existing supposed 'out of the box' connected visibility systems and furthermore, a lack of connected infrastructure across globalized supply chains. In addition, a recurrent theme within the research was data sharing agreements, particularly as data is shared upstream to tiers of supply that downstream partners have no visibility of. This scenario creates significant nervousness with supply chain actors and ratifies the need for centralized, impartial certified data exchange that can be seen within the AOELIX platform. This would further be connected to legal frameworks for data sharing and is a consideration when reviewing globalized chains, as not all legislation in Europe is covered in global markets. Therefore, certified data exchange would need to take the global lens, and not a local European approach.

In summary, the outputs of the Delphi study into issues associated with logistics ICT all point to three key themes:

- Ease of use and implementation
- Data exchange agreements
- Traceability

The majority of these areas all pertain to softer side of business research and people behaviours, rather than the physical ICT infrastructure itself. Much of the processes involved with AEOLIX pertain to these areas, and the research is indicating that successful implementation of connected ICT systems must address these three metrics.

Conclusion
Despite there being a lack of academic and practitioner information pertaining to ICT and logistics implementation, the methodology of systematic literature review and Delphi study have given clear direction to a 'capability map' approach to ICT software implementation that currently does not reside in academic or practitioner circles.

The results show academic literature to be broad and diverse, with the appearance of solution design making up the majority of academic research, a mathematical discipline focused on creating algorithms that can be incorporated into software for logistics planning, as the most common subject of an individual article is a reflection of the strengths of the academic community. However, the appearance of connected logistics in second place is notable, since it reflects a substantial funding stream across Europe for a single issue.

Identified implementation barriers		
Near real-time supply chain visibility	Willingness to collaboratively share information	Cost associated with implementation of proactive supply chain risk management
Visibility vs transparency	Supplier collaboration vs increased competition	Cost of reactive operations vs proactive risk strategies
Data analytics vs human interpretation of risk	Collaborative information security	Shared centre of risk management expertise

Table.8 Identified implementation barriers

Key barriers to implementation are summarised in table.8, and it is apparent from the literature that collaboration, information sharing, transparency all feature strongly in the literature, and the Delphi panel, meaning there is a convergence of view on what is needed for robust ICT delivery. Furthermore, platform strategies, software integration and other complexity drivers are ultimately leading to a steady erosion of margin for production facilities and the cushion in case of a nature-made or man-made disruption. This means that platforms to act as a collaborative data interchange to mitigate supply chain risk such as AEOLIX, need to be sure to address the aspects outlined in table.11 in order to be aligned to market needs and ensure good profitability can be achieved by all supply chain actors.

The fact that 51% of supply chain disruptions occur below tier-1 suppliers highlights a significant problem space (Zurich Insurance, 2014). This challenge creates significant issues around overall supply chain profitability, and is a critical issue known for a number of years within logistics circles. Having platforms that connect to other systems [AEOLIX], means mitigation of risk and greater profitability of organisations can be achieved through proffering connected and collaborative visibility.

Another critical element of ICT implementation in logistics pertains to collaborative information sharing ecosystems and the trust that resides with same. In order to remain relevant and address this key and arguably most important metric of supply chain resilience, platforms [AEOLIX] must leverage their position as a neutral certified information exchange, building trust and overcoming the major issues of culture that reside within supply chains. However, research platforms such as AEOLIX must understand the legislation and cultural changes that reside not just within Europe, but with the wider global marketplace. Failure to address this will evoke a lack of market uptake for those organisations operating on the global stage, which is a significant market share of logistics players.

Lastly, ease of use and integration aligned to understanding the marketplace of existent ICT logistics systems is a must for the connected data interchange platforms. It is a recommendation from the research that attention is paid to the ability for data interchanges to engage with leading softwares such as ORACLE and SAP without 'work arounds' or 'middle wear', which in the themselves leave supply chains open to vulnerabilities [security] and see the platform working against the expert panel needs of ease, data and traceability.

Given the current body of knowledge and direction of technical development the key trends these are as follows:

- Collaborative culture with openness, trust and communication (Barratt, 2004)
- Common strategic goals, objectives and KPIs (Sodhi and Tang, 2009)
- Supply chain information-sharing (Lee et al., 2000; Yu et al., 2000)
- Collective response planning (Stecke and Kumar, 2009)

Allied to aforementioned issues around data sharing are comments from the experts pertaining to a certified data exchange for securing data streams between supply chain actors.

Always Available	Legal Framework
Ease of Use	Data Privacy (GDPR)
Network Security	Integration into Existing Systems
Traceability of Information	Feasible Implementation Strategy
Reliable Technology	Certified Data Exchange

Table.9 Capability matrix of logistics ICT success

In summary, for successful implementation, the authors suggest that connected data interchange needs to develop succinct key performance indicator allied to the 'capability matrix' (table.9) that addresses the ten key elements pertaining to software introduction into supply chain operations. It is notable from the body of academic and practitioner knowledge, alongside expert Delphi panel review, that in order to mitigate challenges with uptake and ensure that the available market share is opened up to platforms that are allied to the three needs of ICT logistics:

1. Ease of use and implementation
2. Data exchange agreements
3. Traceability

If this can be achieved connected supply chains could reverse the old adage that supply chains are:

“wonderfully efficient on one hand, yet woefully vulnerable on the other”.

ACKNOWLEDGMENTS (where applicable)
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SUPPLY CHAIN RESILIENCE FROM AN OUTSOURCING PERSPECTIVE: A CRITICAL LITERATURE REVIEW ON 3PL NETWORK DESIGN STRATEGIES AND SUPPORTING QUANTITATIVE OPTIMIZATION METHODS

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Abstract

Complex networks of suppliers, customers and third party service providers, as well as, large interdependencies among multiple organizations make inter-organizational coordination of risks a critical requirement. In the last 20 years, supply chain management practices have been developed toward more lean process approaches, in order to increase supply chain effectiveness by reducing costs and eliminating inefficiencies. On the contrary, the increasingly dynamic and volatile market environment has elevated the importance of handling risks that can emerge from the customers or demand side, the suppliers' side, manufacturing processes and control systems. In such a context the supply chain capability to assure continuity can be expressed in terms of resilience. Resilience is a new approach to the design of supply chains and business processes. It is derived from the study of resilience in biological systems, which have a variety of mechanisms for sensing and responding to disturbances or threats. Efforts to identify and mitigate supply chain risks have traditionally focused on operational risks and familiar sources of potential disruption that have caused trouble in the past. However, risks are constantly evolving and can strike from almost anywhere, including sources that are new and unexpected. In addition, as soon as more companies are outsourcing their supply chains to 3PLs to focus on their core competences, at the same time, supply chain risks and uncertainties are also shifted to 3PLs. Therefore, the primary objective of the paper is to look on research considerations regarding the development of resilient 3PL supply chain networks through the utilization of OR/MS methods. After extensive literature review a framework is developed for better understanding of effectiveness, disturbances and resilience in supply chain designing process from a 3PL perspective. Additionally, the study adds to the literature by offering a future research agenda.

1. Purpose

Global supply chains are dynamic, complex systems vulnerable to numerous risks due to their interconnectedness and interdependent relationships. Competitiveness has driven companies to outsource their logistics activities to third-party logistics (3PL) providers.

Managers have designed supply chains on the assumption that the world market is a relatively stable and predictable place (Kearney, 2003). In contrast, the increasingly volatile market environment has elevated the importance of handling risks that can emerge from the customers or demand side, the suppliers' side and manufacturing processes (Mason-Jones, 1998). For example, when Thailand experienced severe flooding in 2011, the crisis not only caused tremendous losses locally but also paralyzed the supply of automobiles, electronics, and other products in markets half a world away. The impact of Thailand's floods persisted into early 2012 and more than 1,000 factories were impacted, with subsequent insurance claims reaching US$ 20 billion. As a result of the flooding, Thai GDP growth projections decreased from 2.6% to 1% (WEF, 2013). Further, the evolution of traditional supply chains into digital supply chains due to the latest technological advantages and innovation, has led to the introduction of new cyber risks. On June 2017, Maersk Line, APM Terminals and TNT suffered from the ransomware Petya cyber-attack throwing global container supply chain into chaos. Maersk Line was averaging around 210,000 FEU a week at the time of the attack with an estimated cost of combating the virus, mainly to the carrier, at $200m-$300m (The Loadstar, 2017).

At the same time, supply chain risks and uncertainties have also shifted to 3PLs. Thus, 3PLs networks should be designed to maintain equilibrium and succeed even through the unexpected.). At the same time supply chain risks and uncertainties have also been shifted to 3PLs.This paper aims to conduct systematic and structured review of relevant publications from 2008 to 2018 we provide a framework of the 3PLs network design strategies and modelling approaches.

2. Design/Methodology/Approach

The primary motivation of the research is to identify existing research related to OR/MS methodologies for the design of resilient supply chain networks from a 3PL perspective. Taking into consideration that companies, through outsourcing rely on 3PLs, not only the transfer of responsibilities and tasks but also all uncertainties and risks to them. Hence, 3PL supply chain networks must be designed to foresee, absorb, and overcome disruptions. As a result, 3PL supply chain networks opportunity for businesses to improve customer service, respond to competition must be maintained even if things won't always go according to plan. Thus, 3PLs networks should be designed to maintain equilibrium and succeed even through the unexpected. Simultaneously, supply chain risks are constantly evolving and can strike from almost anywhere, including sources that are new and unanticipated (Deloitte, 2013).

Due to the explorative nature of the field, it makes sense to conduct a Systematic literature review (SLR). SLR is a procedure of selecting papers and reviewing the existing literature (Wilding and Wagner 2014, Barbosa-Povoa et al. 2017). To identify and collect the published research we adopted a two stage approach. Initially, we used Web of Science and Science Direct as a search database and selected a sample of search keywords based on the terminologies used in supply chain risk management. Subsequently, we performed a content analysis through the scanning of abstracts, conclusions as well as the whole article to identify those that fully satisfy our requirements.

Through a systematic procedure of selecting papers and reviewing the existing literature (Wilding and Wagner 2014, Barbosa-Povoa et al. 2017), the aim of the paper is to provide a 3PL supply chain resilience framework and answer the following research questions:

1. How resilience has been addressed in 3PL supply chain networks design?
2. What are the strategies proposed to 3PL providers in terms of resilience?

3. What type of OR/MS methods have been deployed to model 3PL supply chain networks under disturbances?
4. What are the limitations of the traditional categories that have guided supply chain resilience research and what future directions should be taken?

In preparing the sample for this study, we only consider the publications after year 2008 to 2018. We use year 2008 as a starting point triggered by the financial crisis. Due to globalization and fragmentation of supply chains, drop in demand may impact a number of entities closing down that can consequently lead to the whole supply chain shutting down. Furthermore, as a result of the credit crunch, overemphasis on cost reduction, and lack of concern to increase productivity and supplier collaboration have increased the vulnerability of today's global supply chains (Mefford, 2009). Finally, since the idea of supply chain resiliency emerged around 2004 (Tang, 2010) driven by the outsourcing trend to low cost countries a s well as the 2001 terrorist attack, the number of publications was dramatically increased after 2011 (Kamalahmadi and Parast, 2016) indicating that the topic has gained a critical momentum; like any maturing research area.

To identify and collect the published research we adopted a two stage approach. Initially, we used Web of Science and Science Direct as a search database and selected a sample of search keywords based on the terminologies used in supply chain risk management using search strings (and substrings of these terms). Subsequently, we performed a content analysis to retain those relevant with the search keywords. More specifically, we extracted and documented information through the scanning of abstracts, conclusions as well as the whole article to identify those that satisfy the concept of supply chain resilience from a 3PL network design and quantitative methods perspective.

The final list of articles were critically reviewed to identify research and methods for a better understanding of effectiveness, disturbances and resilience in supply chain designing process from a 3PL perspective to ensure that performance loss during disruptions are minimal and that opportunities for efficient and effective recovery in fact exist. Also, important points, findings, conclusions, and summaries are included in the final draft to identify research and theoretical issues, and methods in the given domains. Figure 1 portrays the major steps taken in this methodology.

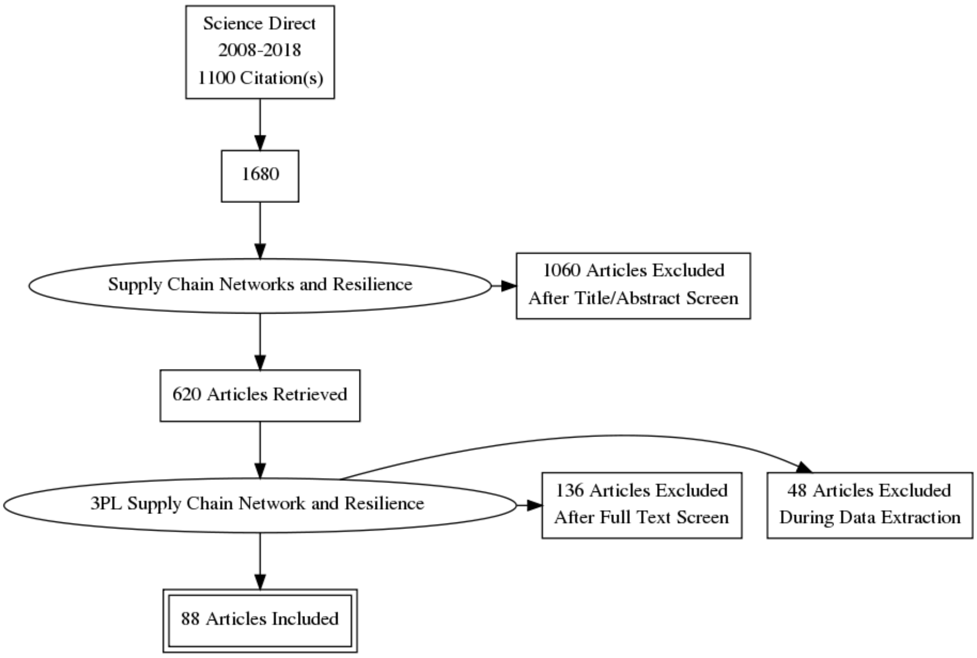

Figure 1. Prisma Flow diagram, (http://www.prisma-statement.org/)

3. Findings

It was found that the concept of resilience from a 3PL perspective has not been explicitly addressed. Most publications are dealing with the definition and principles of resilience, focusing at response to a high frequency, low impact disruptions. Disruption strategies that help a supply chain to grow and move to a new better state have not been investigated. Although the use of OR/MS methods has been acknowledged in the literature, more emphasis has been laid on optimizing the supply chain in terms of cost effectiveness. The (current) numbers read as follows.

- Total number of paper based on the keywords from both databases WS and SD: 2823 (total number of results 7254, but we removed duplicates and also unrelated articles)
- From the 2823 we have filtered five categories: a.Sustainability b. Reverse Logistics, Inventory c.Closed Loop Supply Chain. d. Selection Criteria of 3PL, KPIs, Evaluation of 3PLs and e. Supply Chain Resilience, 3PL Network Design, Perishables, Humanitarian Logistics
- For the last Category: Supply Chain Resilience, 3PL Network Design, Perishables, Humanitarian Logistics total number of papers 620
    - Supply Chain Resilience/3PL/Network Design: 251 - this list includes the papers that we will use for the LR, however it includes qualitative papers, literature reviews and some not related with 3PL- we expect that from the 251 , the number will be reduced as we are looking for 3PL and Resilience.
    - For Perishables , Humanitarian Logistics: total number of papers 137, these papers will help later in the research as they deal with cold chain, perishables , fruits and vegetables while humanitarian logistics related to Africa as well models for disaster relief and etc.
    - The rest of the papers they may have some interest as they contain models of supply chain optimization that may be helpful.

Based on the literature review conducted with focus on 3PL, supply chain network design and resilience we tried to answer the research questions 1 to 3, and thus to identify how resilience has been addressed in the literature and the quantitative methodologies deployed to tackle the issue.

In attempt to synthesize the different dimensions of the research domains the literature has dealt with we propose conceptual framework in Figure 2 that illustrates the relationships between the different elements of the design of a supply chain network from a 3PL point while taking into consideration the principles of resilience as these have been defined in the literature. Having as an objective to design a resilient supply chain network that can function fairly well under deviating condition, the model propose a solution approach to effectively implement in the perishables sector we highlight a research agenda to close the gaps in the literature identified and answer the research question 4 of this study.

The left part of the model represents the supply chain resilience principles, namely (1) supply chain re-engineering, (2) collaboration, (3) agility, and (4) supply chain risk culture (Christopher and Peck, 2004). However, based on the type of the supply chain the importance of the different principles may have a direct relationship with design of the network. For example, redundancy in terms of supply chain re-engineering is more important in a 3PL supply chain network compare to a 4PL due to the fact that profit margins in a 3PL set up are very thin. Therefore, defining the resilient principle will outset the supply chain design in order to combine the different concepts to generate a 3PL supply chain network. Such concepts are represented in the middle section of the model. They constitute the core of the resilient supply chain network design and show the combination of the different step from the design of the network, the impact of any potential events-disturbances and the recovery actions to be taken so that the system can recover to its initial state or a better one after disturbances. In addition, the model will be validated and tested using real data from the perishable logistics sector. Finally, the right side of the model shows the expected outcome for the generation of a resilient 3PL supply chain network without hampering its competitive advantage under normal conditions.

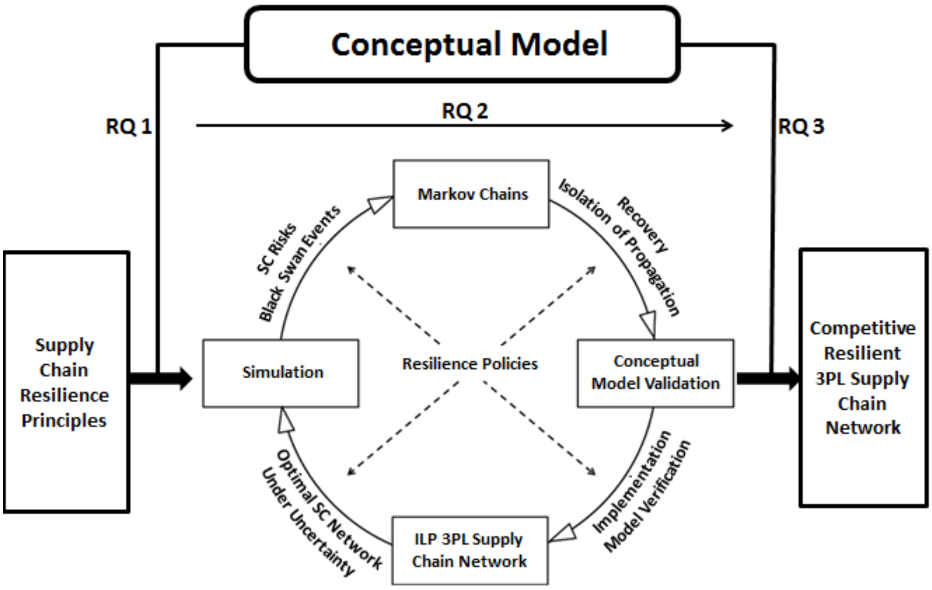

Fig 2. Conceptual model for the design of a resilient 3PL supply chain network. (Source: Author)

4. Contribution

4.1Value

This paper provides a unique review of the literature review on articles addressing supply chain resilience from a 3PL perspective. So far literature reviews (address the concept of supply chain resilience from a holistic point of view disregarding the risks and opportunities of firm's decision to delegate logistics services to 3PLs.

We have identified the need for more research on 3PL supply chain resilience from a quantitative point of view. We propose a conceptual framework to guide the development of resilient 3PL supply chain networks. More specifically, the PhD project aims to:

- Optimize 3PL network design and evaluate its resilience under disturbances;
- Isolate propagation of disturbances throughout the supply chain network;
- Identify sources of competitive advantage or at least design a resilient 3PL supply chain that does not reduce competitive advantage under normal circumstances.

4.2Research implications

Based on the suggested framework and the comparison of the extensive literature review we have identified 3 key areas for future research: 3PL Supply Network Design, consideration of low probability high impact events and resilience as competitive advantage. Thus, a research agenda is needed for to improve resilience for 3PL supply chain network design and the utilization of quantitative methods to support the ability of these networks to recover and grow in the event of deviating conditions.

The following future research agenda topics will allow the study of the resilience in supply chain designing process from a 3PL perspective to ensure that performance loss during disruptions are minimal and that opportunities for efficient and effective recovery in fact exist.

i. How can we develop methods to improve the resilience of a supply chain network?
   a. What are the key metrics of supply chain networks performance?
   b. How can resilience be measured and incorporated in the supply chain design phase?
   c. What is the optimal respond to rare external disturbances that improves the resilience of a supply chain network?
   d. Can we reduce the costs and response time of recovery?
   e. Can we identify the benefits of joint cooperation of companies and 3PLs in terms of disruptions handling?

ii. How can we mitigate disruption propagation in a supply chain network?
   a. Can we model the costs and effects of counter measures on disruption propagation?

iii. How can we develop methods for joint optimization techniques of a supply chain network and supply chain resilience?
   a. Can we design a resilient supply chain network that does not reduce competitive advantage under normal circumstances for a 3PL?

4.3Practical implications

We have based our study on extant literature review of supply chain resilience either if a firm is designing its own solution or outsourcing this to a 3PL. Given than many papers are concern issues related to the supply chain developed by the firm itself there is limited set of papers to provide quantitative models that address the 3PL supply chain resilience. Therefore, considering that more and more companies are outsourcing such supply chain activities, a resilient 3PL supply chain network can aid companies not only perform damage control but improve their competitiveness. As a result, a framework helps in the development of common language and assist 3PLs to select the right optimization models in a certain business context, validate the models before use, reconsider optimization criteria (resilience and competitive advantage instead of a mere cost focus and 'damage control') and eventually create value for all stakeholders.

4.4Conclusions

As soon as in today's global economy, risk is unavoidable the aim of the model is to provide opportunity for a 3PL to adapt in difficult circumstances and furnish a true source of competitive advantage. Managing supply chain risk means recognizing that things won't always go according to plan, and having the right infrastructure in place to succeed even through the unexpected.

On that basis, qualities of a supply chain system can be evaluated in terms of resilience. More explicitly, the level of visibility and type of data needed to handle disruptions across the network can be addressed and identified. Given the fact that disruptions cannot be predicted the objective is to be prepared and able to respond in an informed and planned manner so that we can concurrently restore the residual disturbed supply chain network efficient and effective. Natural disasters and other large-scale disruptions leave no time to re-plan. Through the conceptual model we will foster the ability of a 3PL supply chain to shift direction instantaneously. In other words, to determine several alternative modifications to the current structure based on decision makers' judgment and then performing optimization to determine the best resulting supply chain structure.

The objective of the paper is to produce new insights on 3PL supply chain networks resilience and the quantitative models developed by researchers to tackle the problem. As a start a systematic literature review will help the research to identify and accurately define the problem space of 3PL network design and its incorporated risks. On that basis, we will try to model such network using metrics from reality so that we can simulate the performance of such model in real scenarios. Thusly, an evaluation of the resilience of supply chain can be provided, assessing the response and reaction during disruptions. Through this process the research agenda topics will be addressed, topic 1 will be answered. In order to answer topic 2 we propose a Markov decision process approach to understand the propagation of disruptions so that we can isolate its impact in the residual network. Finally, to answer topic 3, concurrent optimization techniques will be explored in order to concurrently optimize a 3PL supply chain network and the resilience of such network under disturbances.

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REVISITING THE SYSTEMS ENGINEERING APPROACH TO THE DESIGN OF LOGISTICS SYSTEMS.

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Purpose
Design science research (DSR) is articulated as practice-oriented research whereby specific designs, of business systems, yield generic knowledge. DSR has its origins in the professional disciplines, e.g. engineering/medicine, that seek to solve problems with solutions that can have generic applicability.
While it is claimed that the substantive output from DSR is the generic design we argue that the design science 'research design' (DSRD) requires attention. We argue for a generic DSRD, to guide researchers in choosing the right methods to solve specific contextual problems.

Design/methodology/approach
We build on relevant research notably engineering design and systems engineering, the latter having explicitly influenced logistics research. Such research advocate systematic approaches to problem solving, with reference to the need to address not only technological and process factors but also the social aspects. We determine the limitations of the existing methods and, via a synthesis of the existing literature, propose a new DSRD.

Findings
We find a number of similarities between the existing methods proposed with a classic four-stage systems engineering approach (Analysis, Design, Implementation and Operation) offering an underpinning construct for a DSRD. The DSRD needs development in order to account for the human aspects. While there is a tendency to approach problem solving from a quantitative modelling perspective with an aspiration to establish optimum designs, the development of soft systems methodology has enabled the social science aspects to be given due consideration. Also, the driver for change, i.e. the problem, needs to be explicitly attributed. The generic DSRD accounts for varying degrees of uncertainty hence the translation of complex problems into simple designs.

Value
We propose a generic DSRD to support ongoing endeavours to define the modus operandi of DSR. The generic DSRD is adaptable depending on whether the defined problem is simple, complicated or complex, hence establishing the requirements for quantitative and/or qualitative research methods and whether the final design is defined by exact rules and/or guiding learning-action cycles.

Research limitations/implications
The generic DSRD needs field testing and refining based on reflections from lessons learned from such evaluation.

Practical Contribution
The generic DSRD by manufacturers, retailers and logistics service providers as a change management tool. The generic DSRD provides guidance as to the methods and tools to be

used for interventions in processes and systems associated with new product introduction, development and delivery

Introduction

The recent articulation of the design science methodology has highlighted the deep-rooted nature of engineering approaches to solving practical problems while allowing for generalisation (Aken et al., 2016). Design science research (DSR) has its roots in professional fields, such as medicine or engineering, and is aimed at developing solutions (Simon, 1988). In particular, Simon (1988) suggests that the 'science of design' is rooted in systems engineering. Undoubtedly, there is considerable scope for DSR approach in logistics and supply chain management.

Aken et al. (2016) argue that, while there is value is building on disciplines such as systems engineering, the notion of translating the approach to designing artefacts is too much based on a positivistic approach and there is a lack of consideration of the social science aspects. Yet much of the design engineering movement does suggest the need to include the human element in the synthesis of both artefacts and / or organisational structures (e.g. Dixon, 1966, Jenkins, 1969, Simon, 1988, Parnaby, 1979, Towill, 1992). Most notably, Checkland (1999), who built on Jenkin's (1969) systems engineering approach to develop the soft systems methodology (SSM), advocates a social science perspective of system design.

While transferring engineering methods into a social science context is still seen as a challenge for operations management research (Aken et al., 2016), we argue that there are already well-established approaches that take due account of technology (artefacts), processes (organisational structures) and attitudes (human aspects). But much of what has appeared in the past has been forgotten. The aim of this paper is therefore *to propose how best to align the solution design to the problem domain, taking into account associated research tools and techniques to underpin the outcomes of DSR.*

Building on a long history of systems approaches to problem solving and research design we develop a generic DSRD to guide researchers on the existing engineering and social science methods and techniques available to them in order to address problems with different degrees of uncertainty (Kurtz and Snowden, 2003).

Engineering approaches to problem solving

Systems engineering is "the science of designing complex systems in their totality to ensure that the component sub-systems making up the system are designed, fitted together checked and operated in the most efficient way" (Jenkins, 1969). Jenkins (1969) states that "the first property of a system is that it is a complex grouping of human beings [including management and technical teams] and machines" and the system should to be "designed in such a way that each component and human being is ready to play its designed role efficiently in making the [system] achieve its predetermined [multiple] objectives". Jenkins (1969) advocates a four-stage design process that starts with "Systems Analysis [using flow-block diagrams]… involving [r]ecognition and formulation of the problem", with the second stage being solution design, solution implementation with the final stage being the operation of the system (Jenkins, 1969).

Parnaby (1979), following a similar schema to that of Jenkins (1969), emphasises that "[m]anufacturing systems involve many people and exist to serve people", that "interact in complex ways… with our social system and physical environment" and involved in "increasingly complex interactions and constraints of a technical and sociological nature" although each individual manufacturing system has "differing interactions with the social and business environment". As can be seen, the human aspect is crucial. Because "the output products of one manufacturing system may be the inputs to the other" (Parnaby, 1992), Towill (1992) extends a systems engineering based to provide solutions to supply chain dynamics problems.

"Design… is the core of all professional training: it is the principal mark that distinguishes the professions from the sciences. Schools of engineering, as well as schools of architecture, business, education, law, and medicine, are centrally concerned with the process of design" (Simon, 1988). Both Dixon (1966, p.9) and Simon (1988) argue that the concept of design is so important that is should be seen as a scientific discipline in its own right. Hence, the more modern focus on 'design thinking' (Brown 2008).

In proposing DSR, with its roots in engineering, for general problem solving in operations management, Aken et al. (2016) suggest that an emerging research gap exists in relation to integrating social science elements. But a fundamental development of systems engineering, as proposed by Jenkins (1969), is SSM (Checkland, 1999). Explicitly addressing so called 'wicked problems', where the problem is not well defined, in contrast to the design of artefacts, SSM rejects the concepts of goal seeking and optimisation, instead proposing that when addressing social science problems there is a need to develop action based learning-cycles in an attempt to maintain a system's desired behaviours.

What we can deduce from the brief review above is that DSR needs a fundamental synthesis of existing methods to guide those embarking on DSR. We therefore highlight the distinguishing features of different approaches and how they may be exploited for the right context.

A generic DSRD to match problem context and design solution

Building on the phenomenological framework developed by Kurtz and Snowden (2003), Table 1 that shows the varying domains and the appropriate systems methods and tools we believe are applicable. Table 1 provides a guide for those design researchers to determine the relevance of various systems approaches to their particular problem domain. More importantly, there is an expectation that there will be multidisciplinary system design team who have to agree at the outset, and during the lifetime of a design project revisit, which domain the problem resides in and which is the desired solution domain.

Each of the seminal papers for DSR, whether from practice or academe, have common elements in the problem-solving process, akin to Jenkins' (1969) four-stages, with slight nuances in terminology or structuring. This includes the implementation and operation of the new design. Checkland's (1999) learning cycle, although with a quite different ethos to engineering design, has similar phases.

The shared tenets of all approaches is that there is a need to recognise and elucidate the problem being tackled. This first stage is critical in determining which Cynefin domain the problem resides in and directs the direction of travel for the DSRD. Because by their very nature logistics and supply chain operations are complex socio-technical systems, consisting of machines, products, processes and people, people, with multiple flows and objects, then the starting point for the system as a whole is that the problem resides in the Complex domain.

Domain	**Explanation & examples**	**Systems principles, tools and techniques**
Simple	It is easy to determine, model and forecast cause and effect relationships and develop standard operating procedures e.g. single minute exchange of dies	Based on 'facts', deterministic tools and techniques are used to analyse and determine the

		problem and to develop solutions.
Complicated	It is still relatively easy to determine, model and predict cause and effect although they are separated by time and space e.g. develop discrete event simulations of factory shop floors.	Here we may see the opportunity to utilise both qualitative and quantitative approaches.
Complex	Cause and effect relationships are observable but only after they occurred. Behaviours and patterns emerge, which are then described through narrative forms e.g. case studies of supplier development initiatives.	We may turn to SSM, including 'rich pictures' visualisation modelling, CATWOE analysis, influence diagrams and causal loop diagrams.
Chaos	This domain is unwelcome, and cause and effect relationships are not apparent in this domain e.g catastrophic events, such as a tsunami impacting a global supply chain.	The goal here is to move out of chaos and relocate into another domain as quickly as possible.

Table 1: The relationship between problem domain and solution design tools / techniques (source: authors based on various references cited in the text)

It may then be possible to decompose the problem into sub-elements, or to focus on sub-systems, which then can be represented, analysed and synthesised in another domain. But the solution developed will ultimately have to be recharacterized for the complex whole.

Take for example the design of production planning and inventory control systems in a supply chain, and the method developed by Naim and Towill (1994) to ensure that such systems do not exacerbate the well-known 'bullwhip' problem. The core of the approach is the application of control engineering analytical and computer simulation modelling to analyse and design. Such techniques are in the Complicated domain. This is appropriate, given the nature of production planning and control systems, which are predominantly automated and consist of algorithmic rules and software code.

But at the outset of the design process, Naim and Towill (1994) recognise the 'wickedness' of articulating the problem, so that at that stage the DSRD is in the Complex domain, so here SSM may be exploited. An output of SSM as visual models, which are in themselves representations of reality that transform the real-world complexity in an artificial Simple domain so help those working in the system to fully understand the problems being faced and to determine possible solutions.

Such visual models include causal loop diagrams, that determine cause and effect, which then be translated into the Complicated domain in the form of control engineering block diagrams and transfer function formulations. The resulting potential multiple solutions may then be represented in Simple domain form, say, as cost-benefit figures, to aid decision makers can make informed choices. The choices made then have to be implemented in the real-world, that is, back in the Complex domain.

Conclusions

We have shown that there already exists a foundational and comprehensive body of knowledge that articulates the application of DSRD from both an engineering and social science perspective. The systems movement, consisting of a portfolio of methods and tools, ranging from systems engineering through to soft systems thinking, allows for a contingent approach to DSR. Hence, our generic DSRD allows for the selection of the most appropriate techniques dependent on which domain of the Cynefin framework the problem resides but with a realisation that the final outcome may be the result of various translations of the original problem definition through multiple domains during the design process life cycle.

Our research identifies various future research challenges. These include the determination of the source of the problem, say whether due to changing product requirements, legislative forces, or advancements in manufacturing processes, and how that impacts the foregoing design process method. There is also the issue of how best to address hierarchy; given the supposition that the whole is greater than the sum of the individual parts how can we best decompose a complex problem into meaningful simple solution that when reintegrated ensuring the whole satisfies desired behaviours.

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LOGISTICS OF TOURISM: A CASE STUDY IN THE SLOVENIAN TOURISM INDUSTRY

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Abstract
PURPOSE OF THIS PAPER
The purpose of this paper is to emphasize the significance of the Melania Trump factor in the branding of Slovenia as a tourist logistics destination. Slovenia saw significant mass media attention at the beginning of 2016 when Donald Trump successfully emerged in the American Presidential Campaign.

DESIGN
The reason that events in the United States affected Slovenia and also a small town of Sevnica located on the banks of the Sava River is the fact that the First Lady of the United States Melania Trump originates from the Slovene town of Sevnica. Slovenia is logistics in the middle of Europe. Thus, Slovenia suddenly appeared in the world's most important media, such as Washington Post, ABC, NBC, CNN, etc, which turned out to be a significant potential for the economic development, especially for the Slovene tourism industry.
VALUE
Ever since 2016, the number of American tourists in Slovenia has been increasing significantly (according to some statistics the increase of American tourists in 2017 was by 11 % in comparison to 2016). In 2017, the number of all tourist arrivals at accommodation in Slovenia was approximately 4.9 million. This article explores the media representation of Slovenia and some of its influences on the community. The research also indicates the relation between the Melania Trump factor and the development of good logistics in tourism in Slovenia. After increased number of tourists started visiting Slovenia, tourism stakeholders launched new tourism products, among them a new brand called First Lady, which includes local products and specialties, such as beauty creams, bottles of the Blue Franconian wine, tea, pralines, the Sevnica apple slices dipped in chocolate, and cured salami sausages.

INTRODUCTION

Logistics enterprises want to supply customers in such a way that the difference between the revenue of the service and the operating costs is the highest possible, however they are often limited by obligatory standards or standards that the competitive companies guarantee.

Today's technological developments, economic globalization and rapidly growing population are increasingly affecting the rising demand for products and services.

Sevnica is a city in the heart of Slovenia, where the first lady of the USA, Melanija Trump, spent her childhood and her youth. One of the most attractive things in Sevnica is the Castle which is proudly elevated, from where the view of the city in the woods has grown the most beautiful surroundings.

The Municipality of Sevnica in Slovenia experienced large mass media attention at the beginning of 2016 when Donald Trump successfully emerged in the American Presidential Campaign. The reason that events in the United States' Presidential Campaign affected a micro Municipality of is the fact that Donald Trump's current wife Melanija Knavs Trump originates from Sevnica. Thus, a small town of less than 5000 inhabitants suddenly appeared in the majority of the world's most important media.

Destination branding, especially branding of micro-destinations, such as the municipality of Sevnica is a highly complex process due to the fact that it involves a lot of stakeholders. For successful branding of the micro-destination and consequently for the successful development of sustainable and green tourism, which is the main objective, according to the development strategy of the municipality of Sevnica, it is significant to consider opinions of all the stakeholders in the community.

Because of the attention devoted to Melania in the town itself many new products emerged. Cafe Julija on the main street in Sevnica offers a delicious "Melania" cake made with an apple and almond filling in a housing of white chocolate. The cake also has edible gold streaks. (https://edition.cnn.com/travel/article/melania-trump-sevnica-slovenia/index.html)

The Kruhek bakery and coffee shop sells the Prva Dama (as "first lady" in Slovenian) -- an apple pie, complete with an embossed "M" and a tiny American flag. Inside Sevnica Castle, over the 13th century old town center, visitors can buy various products under the "First Lady" brand which emerged in 2016. These include beauty creams as well as bottles of red wine, tea, pralines with raspberry filling and two local specialties -- cured salami sausage and apple slices dipped in chocolate. (https://edition.cnn.com/travel/article/melania-trump-sevnica-slovenia/index.html)

The number of tourists in Slovenia has been increasing significantly (according to some statistics the increase of tourists in 2018 was by 8 % in comparison to 2017). In 2018, the number of all tourist arrivals at accommodation in Slovenia was approximately 5.93 million. This increase affects also the attractions which are under the Unesco Heritage protection in Slovenia.

METHODOLOGY

The research is founded on a literature review, combined with field work, participant observation during the tours around the Škocjan Caves and the Idrija Mercury Mine, and the technique of unstructured interviews with tourism experts and managers who protect and explore the selected heritage (the Škocjan cave, the Krokar virgin forest, the Idrija Mercury Mine), and tourist providers who interpret heritage in various ways and incorporate it into modern (boutique and exclusive) tourist offers. Information will also be obtained through the content analysis of websites. In doing so, we will answer the following research question: In which ways is the UNESCO heritage in Slovenia included in the modern tourist offer? Further on, we will highlight examples of good practices for each UNESCO heritage case. On this basis, we will determine what are the possibilities, opportunities and innovative approaches for integrating UNESCO heritage into the modern boutique tourist offer of Slovenia, and how the Melania factor can be used in the promotion.

ATTRACTIONS OF CULTURAL HERITAGE

Cultural heritage is a significant co-creator of the tourist offer, especially if it carries the prestigious title of a UNESCO World Heritage Site. Unesco's heritage strengthens national identity and is universally recognizable. Of course it needs to be emphasized that the concept of heritage and cultural heritage has changed and evolved through time (Vecco, 2010). Nowadays, heritage is no longer defined on the basis of its material aspect. This development has enabled the recognition of intangible cultural heritage, which was ignored for a long time, as heritage to be protected and safeguarded (Vecco, 2010). Also, Bogataj (1992, 11), defines cultural heritage as something that has been created outside of the natural action of nature or from it, whereby the heritage is not only the monuments, but all those cultural elements that have been preserved in different forms in the past, or at least they are known as forms of lifestyle of the past. A significant part of the natural heritage is, in its basic essence, cultural heritage, so, not only the conscious and deliberately designed natural environment, but also everything created by the men in this environment or from it. Cultural heritage involves various relationships between men and their cultural environment, and answers questions about who we are, where we come from and where we belong (Jezernik, 2010, 196). Cultural heritage is significant for the local and regional environments, especially if it carries the prestigious title of Unesco World Heritage.

UNESCO HERITAGE SITES IN SLOVENIA

Slovenia is ranked on the UNESCO World Heritage List with the following Heritage Sites: The mercury heritage (mercury mine in Idrija), prehistoric catches at the Ljubljana Marshes, and natural heritage - the Škocjan Caves, the ancient and primaeval beech forests in the Krokar jungle, and the Snežnik Ždrolce reserve. On the UNESCO representative list of the intangible cultural heritage of humankind, there are tours of the Kurent traditional masks, the drywall construction, lace knitting and Processio Locopolitana (the Škofja Loka Passion Play). The particularity of Slovenia is the fact that only the Škocjan Caves are among the main tourist attractions of the destination as an example of a UNESCO (natural) Heritage Site. All other UNESCO Heritage Sites in Slovenia are less known, but they represent – according to the directions of the Strategy of the sustainable growth of Slovenian tourism 2017-2021 (Strategija, 2017) the foundation for the development of boutique and exclusive tourist offers, and Boutique Tourism in contrast to mass tourism, which is challenging at many destinations which brand themselves as UNESCO Heritage Sites, since they are very often facing overtourism.

The inclusion of heritage into a modern tourist offer requires reflection and a professional approach. What is good for protecting and preserving the heritage is not necessarily good for tourism, and what is good for tourism is rarely appropriate for heritage protection. Therefore, the integration of heritage in the tourism offer, the creation of heritage-based models, is a matter of strategic design and professional decisions.

In the article, will be analysed how, or in what way, the UNESCO heritage in Slovenia is included in the modern tourist offer, especially now that Slovenia has been attractive for many tourists who heard for the destination only because of Melania Trump. The subject of the research is topical, since heritage is an important co-creator of our future. The discovery, exploration, scientific research and tourism experience of heritage, along with its preservation, help to strengthen the identity of the nation, the sense of belonging and dialogues between cultures. According to Lenzerini (2011, 103) »appropriate safeguarding of the international cultural heritage of the diverse peoples making up the world – is essential for promoting harmony in intercultural relations, through fostering better appreciation and understanding of the differences between human communities«. Due to all these factors, 2018 was proclaimed European Year of Cultural Heritage.

EXPERIENCE TOURISM

Tourism is an activity that is changing and adapting to new needs and trends constantly. The modern tourist is no longer satisfied with the sightseeing of the places and sights that they are visiting, but wants to experience a lot of new, different, interesting things on their travels. The modern tourist wants experience, contacts with the local population, their way of life, culture, habits and customs, local cuisine etc. They also search for various activities and want to become part of the local events. Today's tourist is no longer satisfied only with observing natural and cultural heritage and attractions, but simply wants to participate actively in the daily and festive way of life of the locals. Experiences are the main motive for people to travel. Because of different experiences, the trips are unique and invaluable (https://www.thetravelword.com/, 3.5.2018).

Experiences come in many colors and shapes. Experience is a meeting with a group of children in the African countryside, a sunrise over the mountain, a descent into a cave, a visit to a local wine cellar with tasting wine and culinary specialties, a holiday at a tourist farm where guests take care of pets, fishing with the local people, dancing with locals, weaving on looms, watching bears etc. The experience tourist is eager for new adventures, is spontaneous and ready for active leisure time. We distinguish two forms of experiential tourism: A soft and a hard shape (Swarbrooke, 2003, 33). We talk about a soft form when it is less risky and tourists do not need previous experience. Soft forms also require less psychological effort than hard forms. The wider concept of experiential tourism represents Alternative Tourism, which is the opposite of Mass Tourism. It is a step away from Mass Tourism such as sea-sun-beach. Later, Alternative Tourism was also associated with the concept of Ecological (Mihalič, 1999, 319) and Boutique Tourism, the development of which is based on the natural and cultural heritage of Slovenia and all of its experiences.

CONCLUSION

All trips include experience of the unusual, beautiful, mysterious and inspiring. What is essential in tourism is the subjective positive impression that stays after the tourist`s visit (Potočnik Topler et al., 2017). That is why this positive impression needs to be incorporated into tourism logistics planning to enable a good and positive experience for tourists. Tour guides play a significant role in this part of the creation of the tourist experience (Potočnik Topler et al, 2017).

On the world tourism map, Slovenia wants to position itself as a "green, active and healthy" boutique destination offering world-class tourist five star experiences. This is also especially relevant in connection with the natural and cultural heritage.Thus, this article deals with the creation of tourism experiences based on natural and cultural heritage, and the ways of integrating these tourism products into the modern tourist offer, which can use modern tools of promotion, digital marketing and also references to the American First Lady. The content analysis of web pages and the analysis of conducted unstructured interviews with the representatives of different stakeholders at tourism attractions sites, (tourist guides in the Škocjan Caves and the Mercury Mine in Idrija, a local tourist guide in the Karst region, the head of the Kočevje Tourism and Culture Center, a member of the Association of the Kurents, and a Professor from the College of Tourism and Hospitality in Bled), analysis of participant observations and participation in guided field tours, has shown that all tourist providers of Unesco's cultural heritage use various contemporary interpretive techniques, and also references to Melania when the questions are asked by tourists or when the opportunity arises.

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EFFECT OF INDUSTRY DIMENSION ON MANAGING THE GLOBAL SUPPLY CHAIN RISKS: A PROFILE DEVIATION APPROACH

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Abstract
Purpose of this paper: To provide an in-depth analysis of the effect of the industry dimension on global supply chain risks management. Although there have been many articles discussing global supply chain risks and their mitigation strategies, there has not been much insight into how different industries tackle different global supply chain risks while internationalizing abroad. We believe that each industry has a particular context; therefore, global supply chain risks and its mitigation strategies would differ as per industry context.

Design/methodology/approach: We have used profile deviation and ideal profile methodology to identify top performers in each industry segments and evaluated their best practices to deal with global supply chain risks. We have utilized online survey methodology to get a deep insight into how Indian executives across various industries manage 11 different global supply chains risks during their internationalization process.

Findings: This study extends existing knowledge on global supply chain risk management practices. The literature provides contradictory results on why and how specific global supply chain risks management practices works better in one industry context than others. provide a clearer understanding of why particular risk mitigation practice work well in some industries but not for others. Consequently, we intended to extend the existent knowledge of global supply chain risk management practices.

Value: Our findings aim to provide new insight for practitioners and researchers alike. The results may serve as a useful tool for prospective Indian executives planning to internationalize. We believe that based on our results, executives can plan and execute their international undertaking well by mitigating various global supply chain risks across industries. Similarly, our findings contribute to the theory development of global supply chain risk management practices.

Research limitations/implications: The present study focuses on Indian executives; therefore, the findings may not be generalized in another country/institutional context.

INTRODUCTION

The outward FDI by Indian firms amounts to US$ 11.33 billion in 2017-18 ranking India at the world's 21st largest outward investor (Iqbal et al., 2018). Several international business scholars have studied the internationalization of Indian firms and realized that the Indians firms, unlike the firms from the developed countries, do not follow the standard internationalization path as explained by Uppsala and OLI model (Ramamurti & Singh, 2009). Owing to this unique way of internationalization and their rapid expansion, firms from India and those of other emerging economies are of particular interest for researchers. Several scholars explained this unique way of internationalization in terms of active networking behavior approach to compensate for deficiencies in technology, resources and know-how (Agndal & Chetty, 2007; Srivastava et al., 2018). One of the most critical factors in the success of any firm in the international market is the approach and efficiency in dealing with various global supply chain risks. This is evident by the number of recent world examples where companies struggled to handle global supply chain risks in the foreign market. For example, the earthquake and tsunami in Tohoku, Japan in 2013, extensive wildfires in California in 2018, the Toyota vehicle recall from 2009-2011, all depicted the importance of good governance in global supply chain risk management. Moreover, the dispute between VW and its supplier from Bosnia (Prevent Group) triggered issues across German factories and created significant labour issues for all parties involved (Ivanov, 2019). These examples further reinforce the need to learn from and act on global supply chain risks efficiently and effectively.

Research on global supply chain risk management has been growing, as more firms from different countries expand their base into international markets (Manuj and Mentzer, 2008; Straube and Pfohl, 2008) owing to cost pressure and internationalization of sales markets. The research on global supply chain risks showed that the firms should study and understand the foreign micro and macro-economic environment to handle supply chain risks effectively (Kleindorfer and Saad, 2005). Although this provided useful insights, the findings do not offer a specific approach to handle global supply chain risks in terms of industry requirements. There have been several types of research on various industry segments individually, as well as in conjugation to explore the various global supply chain risks and multiple measures to handle them (Rajesh and Ravi, 2015; Tse et al., 2016). However, the extant literature does not provide guidance on important industry dimensions to deal with supply chains. In particular, it is not clear why some risk mitigation strategies work for one industry segment but not for others. This is evident from the literature that examines different measures to deal with different types of supply chain risks across various industry segments. However, we could not find any empirical evidence confirming that the supply chain risk mitigation strategies should be fine-tuned as per industry requirements. This is particularly true considering Porter's industrial organization view (Porter, 1981), which states that industry dynamics play a vital role in the profitability of a business. Consequently, we aim to explore the effect of industry dimensions on dealing with various global supply chain risks.

We hypothesized that each industry impacts global supply chain risks differently; therefore, the risk mitigation strategies should be fine-tuned accordingly to mitigate adverse effects of global supply chain risks and attain high performance. Stated differently, there should be a fit between industrial dimensions and the supply chain risk mitigation approach adopted, to achieve the highest performance in the international market. We surveyed Indian supply chain professionals to explore their risk mitigation strategies across various industry segments. We then selected high performing firms in each industry segment to determine the ideal profile (consisting of an ideal way of dealing with different supply chain risks).

THEORETICAL BACKGROUND

Global supply chain risk management – Industry dynamics

As per Porter's industrial organization theory (Porter, 1981), industry dynamics are essential for the success of the firm. However, Barney's resource-based view (Barney, 1991) says that the firm's internal resources are the primary source of performance in the market. For example, the aviation industry is (in part) not profitable, but within this segment, Southwest airlines is highly profitable. However, in reality, they both are essential, and they are complementary in fact (Gellweiler, 2018). We base our paper on these two approaches and argue that industry dynamics trigger particular conditions for the firms in that specific industry and provoke firms to develop individual strategies to tackle those specific industry conditions. Therefore, we aim to prove that these two views are complementary using an empirical approach.

The existent research focused on a variety of general supply chain disruptions such as product safety and security, financial health, breakdown (Tang, 2006; Craighead et al., 2007), procurement failure and forecasting. Many authors proposed various means to handle these supply chain disruptions. For example, Harland et al. (2003) identified 11 risk types and proposed related risk mitigation strategies accordingly. Blackhurst et al., (2005) proposed eighteen measures to handle risk management. This was further refined by Manuj and Mentzer (2008), who created a framework to deal with global supply chain risk management based on a five-step approach. Optimal disruption management strategies (Schmitt, 2011) and managers approaches to global supply chain risk management (Christopher et al., 2011; Vedel and Elegaard, 2013), were some of the additional strategies proposed by researchers to mitigate the effect of supply chain risks. However, it has been shown that these risk mitigation strategies would not be highly effective unless there is suitable identification of the key risk driver. The situation becomes even more complicated when dealing with global supply chain risk management, due to (among other factors) increased volatility, just in time, information asymmetries and multiple interfaces. Although several authors proposed a wide range of risk drivers (Rogers et al., 2015; Manoj and Mentzer, 2008), most approaches focused primarily on the firm's internal and external environment, based on a generic supply chain and without considering the peculiar industry dynamics affecting supply chain.

A few researchers approached cross-industry dynamics (Zsidisin, 2003; Harland et al., 2003). Supply chain risk management in the automotive and electronic industries was the focus of a study by Blos et al. (2009). They found that efficient communication, business continuity planning training and deployment of a Chief Risk Officer are effective strategies to mitigate risk. Similarly, Sodhi and Lee (2007) divided the supply chain risks in the electronics industry into the supply side, demand side and contextual risks and proposed risk mitigation strategies. Rajesh and Ravi (2015) investigated the electronics supply chain and identified three enablers for supply chain risks management; dynamic assortment planning, accurate demand forecasting, and a flexible supplier base. Tse et al. (2016) explored the SCRM in the beverage industry and found that the demand and quality uncertainties were paramount for success in the beverage industry and therefore more focus should be on forecasting accuracy and better risk appraisal. In the construction industry, some of the main issues were volatility and business process issues due to the long durability of the construction products (Segerstedt and Olofsson, 2010). In contrast, in the dairy industry, the most critical factors were market and process risks. The authors suggested various risk mitigation strategies such as fleet management, communication infrastructure, multiple suppliers, etc. Chowdhury, and Quaddus (2015) studied the garment industry and described three main supply chain risks here; high dependence on important materials, disruptions in utility supply and increased completion times. It is very clear from the findings that each industry faces a different nature and level of risk, meaning that the appropriate mitigation strategies also differ. Hence, there is a need to design supply chain risk management strategically.

Wagner and Bode (2006) highlighted that accurate identification of risk drivers involves a degree of reliance on global sources, as well as identification of customers, suppliers and sourcing streams. Juttner et al. (2003) indicated that the planning strategies should be configured based on industry specificity. Similarly, Rao and Goldsby (2009) suggested that the risk classification should be based on environmental, industry and organizational contexts. Tang and Musa (2011) further supported this by suggesting the need for more robust and specific methodologies to analyze supply chain risks to explore industry-specific features and practices. Consequently, Ghadge et al., 2013 provided seven distinctive research factors needed to provide industry-specific proactive and reactive supply chain risk management processes. It is evident that there is a need to evaluate supply chain risks industry-wise to provide a more holistic approach to manage them. It is widely accepted that the appropriate identification of risk drivers is of utmost importance to carve out their mitigation strategies. Hence, it is advisable to study top performing firms in each industry and evaluate their risk mitigation strategies. We propose that the risk mitigation profile of these firms would constitute an ideal profile, which should be adopted by all the firms in that specific industry to increase their chances of performing well. Therefore, we propose two hypotheses:

Hypothesis 1*– There exists an ideal profile for each type of global supply chain risk and for each specific industry*

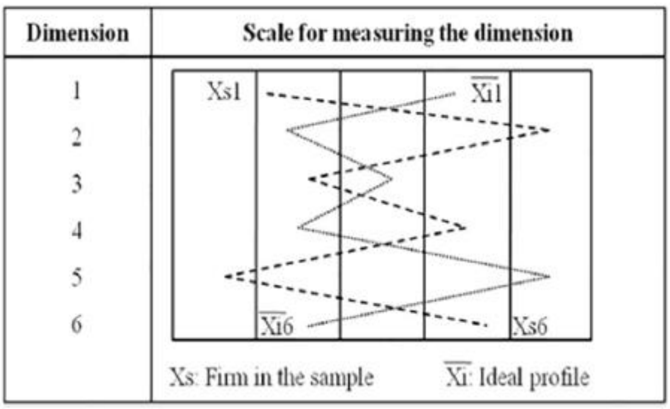
Hypothesis 2*– There exists a negative correlation between profile deviation and performance.*

EMPIRICAL ANALYSIS

Research approach

To determine ideal risk mitigation strategies across various industries, we have developed measures for performance and risk mitigation based on our findings from the literature. To define multiple supply chain risks, we have used the risk definition from Rogers et al., (2016). We have also used a profile deviation methodology (Moser et al., 2017; Srivastava et al., 2018) to determine the ideal profile for various key global supply chain risks. We are arguing that there is an ideal way to mitigate global supply chain risks industry-wise, and the ideal profile consists of the right proportion of risk mitigation strategies. Firms close to the 'ideal' profile perform better and firms who deviate more (profile deviation) from the ideal profiles, perform poorly; therefore, we are looking for a negative and significant beta between the values obtained for profile deviation and the performance score. We have administered an online survey, using Qualtrics, consisting of questions on the application of various supply chain risk mitigation strategies for a range of supply chain risks. Furthermore, we asked supply chain executives about their perceived performance in the international market along with general information about their company, such as the size and revenue of their company (see Appendix for further information).

The online questionnaire was sent to Indian supply chain executives across various industries. We received 244 responses out of which 198 were usable (fully completed). The ideal profile approach requires three steps. First, all of the cases were sorted, based on their performance score. In this step, we determine the highest performing firms in each of the industries. We then took the average of all the risk mitigation strategies across all the supply chain risks of top 5 firms. This average score would constitute the ideal profile. Second, we calculated and summed the profile deviation score (Euclidean distance) between the ideal profile score and each of the remaining cases in the sample, as shown in Figure 1. In the final step, we performed a regression analysis between performance score of each of the firm and the total profile deviation score.



$$\text{The Euclidean Distance or Misfit} = \sqrt{\sum_{j=1}^{7}(X_{ij} - \overline{X}_{ij})^2}$$

Figure 1: Calculation of Euclidean distance

DISCUSSION OF RESULTS AND NEXT STEPS

The ideal profiles for three industries; automotive, audit/financing/consulting and for IT and software shows marked differences in terms of emphasis on various risk mitigation strategies for different types of supply chain risks. The regression results show a significant beta between performance and profile deviation. We could find significant results only for four supply chain risks for the automotive industry. However, for audit, financing, and consulting as well as for IT and software industry, we obtained significant results for all 11 supply chain risks investigated. The results show the risk mitigation strategies where the difference between the ideal profile and the remaining firms is the highest. For example, for the automotive industry, the most successful firms emphasize more on dual sourcing, CPFR, ECR, VMI, back up IT system and hedging for mitigating warehouse risk. However, the less successful firms showed less focus on these mitigating risk strategies hence performed poorly. This provides a useful finding for the firms operating in the automotive sector to focus on dual sourcing, CPFR, ECR, VMI, back up IT system and hedging for mitigating warehouse risk. More specifically, in some risk mitigation strategies, other firms deviate more than other dimensions, which shows that firms that are not performing well need to focus on those specific dimensions and bridge the gap of profile deviation. Mostly, the figure for the ideal profile is higher as compared to other firms. However, for operational risk (audit, financing and consulting), for hedging, it is opposite (i.e. a higher value for other firms and lower value for an ideal profile). This indicates that it is not always necessary to place more emphasis on everything but rather a right amount. This confirms our hypothesis 1 and 2. Our results provide useful insights for managers seeking to expand their business in the international markets by providing industry-specific supply chain risk management strategies. Follow on case studies will provide the opportunity for more in depth analysis in selected firms.

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APPENDIX

Constructs (number of items)	**Items**
Global supply chain risks	*Please indicate the extent of the effect of following supply chain risks on your global supply chain and impact on environments on your business activities (1=extremely low, 7= extremely high)* Operational risks *(such as business practices, forgery, bribery, antitrust, security)* Infrastructure risks *(such as water and electronic supply, reach of remote areas, technology, port delay, custom clearage etc.)* Legal risks *(such as legal proceedings, delayed legal settlements, vague contracts enforcement of laws etc.)* Culture risks *(such as corporate social responsibility, operating business in different religious beliefs, local culture etc.)* Economic risks *(such as exchange rate hike in price of raw material, commodity prices, fee and regulatory charges)* Supplier risks *(such as supplier location, single sourcing or multiple sourcing, lead times, quality and price of raw material, supplier incentives)* Forecasting risks *(such as demand uncertainty, demand-forecast alignment, long range forecasts, loss due to wrong forecast, inventory carrying cost of cost of unfilled demand)* Transportation risks *(such as transportation failure, condition of roads, taxes and fleet utilization)* Labour risks *(such as labour practices, strikes, working conditions and wages)* Natural disaster risks *(such as floods, earthquakes and droughts)* Warehouse risks *(such as storage practices, security/fire/location etc.)*
Risk management strategies	*Please indicate how do you currently reduce operational/infrastructure/legal/cultural/economic/supplier/forecasting/transportation/labour/natural disaster/warehouse risks (1=least and 7=most important)* Information sharing/communication Dual sourcing/multiple sourcing/flexible supplier base Postponement strategies (minimizes risk by delaying further investment into a product or service until the last possible moment Speculation strategy (saving created through economies of scale, by creating and delivering the finished goods in bulk) Avoidance strategies (reducing the frequency and probability of a risk event) Network effect/relationship building/inter organizational learning Segment the supply chain/regionalize the supply chain Efficient human resource management

	Implementation of CPFR, ECR, VMI concepts
	Earlier supplier involvement/joint development
	Risk sharing contracts, Economic supply incentives
	Back up IT systems
	Safety/strategic stocks
	Customer collaboration
	Hedging
Performance	*How satisfied are you with the performance of your most recent internationalization project through global supply chain, as measured according to the following performance dimensions (measure relate specifically of your company in the country of your recent internationalization effort)? (1=very dissatisfied, 7=very satisfied)*
	Sales growth
	Sales level (absolute amount)
	Profitability
	Market share
	Marketing effectiveness
	Distribution efficiency
	Reputation development
	Market access

LIFECYCLE-CENTERED STRATEGY EVOLUTION OF COMPANIES ALONG THE VALUE CHAIN; COMPLEXITY AND ADAPTIVE BEHAVIOR

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Abstract

The lifecycle explains and predicts much about market and firm behavior and does it symmetrically in time. It will forecast the future and explain the past. Most of the firm's internal functions can and have been mapped along with the evolution of the market from effectiveness to efficiency zones and the rise of platforms such as standard settings and value chains. In addition, the explanations correlate with the developing strategies of the firms. Nevertheless, in the age of time-based competition (especially of high-tech products and services) we find a market nonlinearity, due to increasing network complexity, which creates an edge of chaos zone. To overcome this problem, new emerging platforms appear () which enhance market survival and defend against further intrusions into the market by competitor value chains. These platforms of standard setting along the value chain join forces and reinforce the firm's ability to adapt to the transition from effectiveness to efficiency zones. Furthermore, the firm's own structure continues to evolve to meet these new efficiency demands. The article will provide the explanatory framework from a complex systems perspective of customer segmentation over the lifecycle as managing the "effectiveness" vs. "efficiency" zones. The paper further examines the learning process under complex conditions based on the analogy of two "climate zones". The article is based on desk research and examines the above questions on a strategic level

Keywords: product lifecycle, strategy, structural evolution, value chain, learning process under complex constraints

1. Introduction

Time based competition has especially hit the value chains of the hi-tech industry. Life cycles and turnover times are shrinking, market is unpredictable. The lifecycle itself seems to drift over the "deep structure" with its own dynamics as expressed by the various interactions between the firm and its external alliances prevailing at each point of the market. These external types of alliances range from extremely flexible and malleable ecosystems in early markets that resist shock loadings quite well, to life rafts of safety in platforms, which provide defense against disruptive innovation and help pull in the pragmatist customer base to clusters. Consequently, they start to iron out structural nonlinearities found in ecosystems and get the firms ready for the late stage productivity region that culminates in the linear and symmetric value chain that washes out the last vestiges of nonlinearity and complexity.

Too many changes over a given period can exhaust firm- or value chain resources. In an evolutionary phase (that borders on revolution), the fastest firms survive and not the biggest ones. The future may be Tesla, not GM (a strategic dilemma of further innovation of the clutch…no need for gearshifts for electric cars). And this is key, the interplay

between evolution and revolution. Most firms can cope with evolution, but revolution can destroy a firm in a hurry, it depends on the relative clock speeds of the firm and the environment [5]. So, complexity arises from structural, or network effects that are parallel and create layers of complexity from the firm, to the alliance to stakeholder levels. Moreover, as this network related connectivity is nonlinear, we can expect zones of edge of chaos to form that allow for adaptive learning modes and give rise to pattern emergence. Nevertheless, the edge of chaos can further disintegrate into randomness, where all learning is redundant and impossible.
The authors will look at the efficacy of one particular strategy-development tool, the (product) life cycle model.

2. Market segmentation of hi-tech products over product life cycles

At the deepest level, the customer profiles define the fundamental market behavior, which is especially true for hi-tech markets. According to Moore [1], the hi-tech market customers can be segmented according to the lifecycle of a product. We can group them to three "markets", based on their attitude towards the major phases of the product/service lifecycle:

- The early market is populated by technology *enthusiasts* and *visionaries*.
- The mid-market is shouldered by the *pragmatists* and *conservatives* and
- The late market is closed out by the *technology skeptics*.

This "market deep structure" can dictate some intriguing surface phenomenon along the lifecycle (as shown in Figure 1).

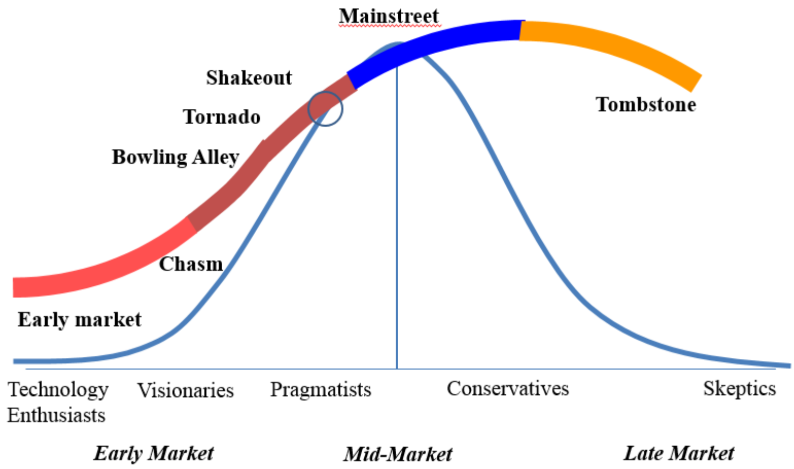

Figure 1: The three major customer segments of the high-tech market
Source: own elaboration based on (1)

The *first segment* (early market) is comparatively small but unleashes some interesting dynamics that define the conduct and timing of the mid-market. Technology enthusiasts deal with the early market entrepreneurs who usually stumble from failure to success in a rather unpredictable fashion. The enthusiasts are more than a match for the hi-tech entrepreneurs and often buy into incomplete products and twist these to their needs. Although their numbers are small, they do generate decent margins and forgive mistakes. The visionaries, on the other hand, don't like mistakes and will respond if the product/service promises significant improvements to the performance of their product line-up. They are adventurers with a purpose, to gain a competitive advantage at a reasonable risk. At this point, the market customer population is getting to be significant and by the time, lifecycle traverses this group the sales start to skyrocket into tornado mode that is a brief spell when the market growth goes exponential.

In the *second segment*, the pragmatists like products that are complete, functional, fit seamlessly into existing operations, are reliable and have a high performance/price ratio.

The conservatives are all that pragmatists are but with a much lower tolerance for risks and will wait for market results before embarking.

Finally, as the *third segment*, the skeptics are laggards who distain technology and wish the market was never disturbed by innovation. However, such skeptics exist even in the most mundane of markets, such as the automobile one, where skeptics are still looking for stick shift models in the age of electric and autonomous cars [1].

Along the way, the deep structure creates phases for the lifecycle that can be divided into transient and steady states, one succeeding the other. (Figure 2).

Steady states are relatively well ordered and predictable in behavior whereas transients contain progressively bigger sinkholes where firms disappear, and turbulent dynamics make prediction difficult if not impossible.

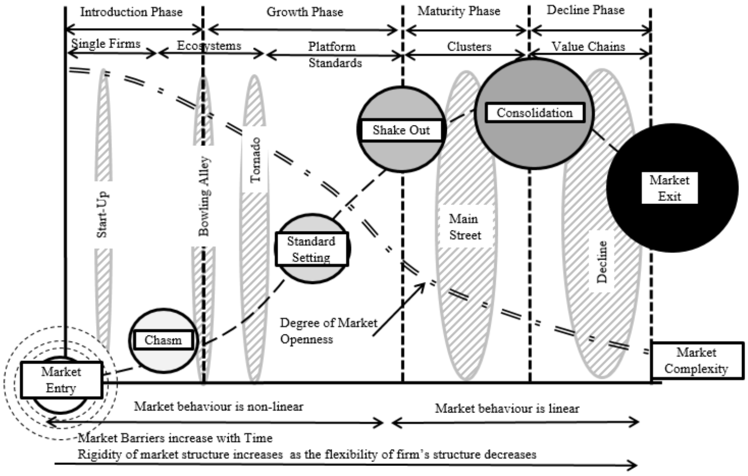

Figure 2: Summary of the steady, transient state succession and the sinkholes that accompany the transients

These sinkholes are part of the surface geology shaped by the core structure and get bigger, deeper and more menacing as the lifecycle progresses until at the end the final sinkhole swallows all firms left in the market. We have then a progression of features that arise from the very bottom, the deep structure or the core, generated by the customer profile base, which creates a succession of an alternating transient and steady states. All transients have sinkholes except the first one, the market entry, a white hole that spews firms into the market.

Early firms are adept at market repositioning and late firms capable of defending their chosen market positions. In fact, they have no choice given the enormous investments in tangible and intangible assets. This leads us the third level of market organization engendered by the competitive forces in two specific zones of the market.

3. Managing lifecycles in the climate zones, along the value chain

Early markets harbor forces of effectiveness expressed in the firms' ability to reposition in the market either by own volition or under pressure, and the loose structure of the ecosystem helps this process. The firms barely tied to their ecosystem neighbors and cutting ties is relatively easy, so relocation is the ecosystem is swift and carries low costs.

The ecosystem itself is flexible and deforms under shock loads without impairing key connectivities. This type of structure allows for adaptive behavior, in the sense that under pressure the firm has time to internalize the message and relocate thereby reducing the impact of the force, which can be force majeure, competitive pressure or internal investor/strategic pressure, to find a better niche. However, this is just the beginning, as soon as the platform arises, effectiveness cedes its formative role to efficiency or productivity and the rest of the market voyage is perfecting productivity.

Figure 3 shows the partition of the market into the two zones.

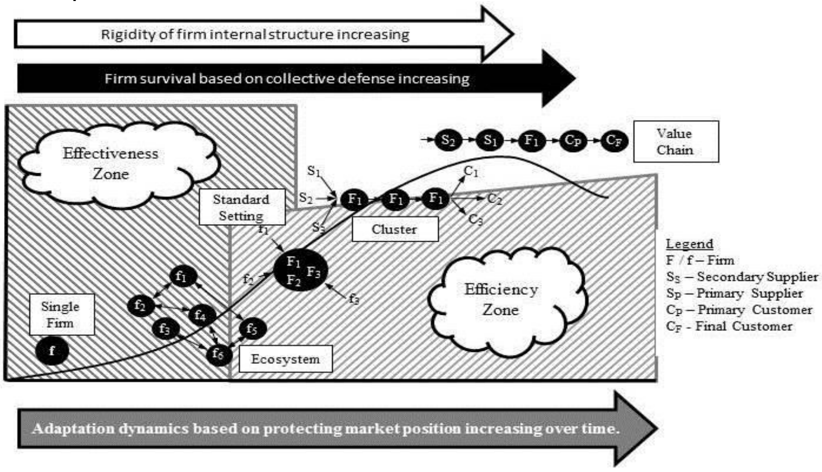

Figure 3: Adaptation dynamics based on protecting market position increasing over time.

The two market zones further shape the strategic options of the firms. In the effectiveness zone, many market positions are available but as the market progresses, the choices get limited, the strategies are funneled towards the ultimate and unique choice cost leadership, which is no choice at all but given by the market to the firms. Therefore, we have two climate zones that deliver very different messages to companies.

The *effectiveness zone* demands quick yet fluid adaptive moves whereas the *efficiency zone* is more patient but requires a more deliberate and permanent response. This climate change in the market has long-term implications, what made the firm successful in the effectiveness zone; an entrepreneurial timely and innovative response must cede its place to well considered and planned managerial type reaction at efficiency stage. That is why entrepreneurs are often replaced by professional managers just as the tornado strikes.

The weather of the market, in turn, is formed within the climate zones. In effectiveness zones, the weather turbulence is caused by the influx of firms attracted by high margins, high growth potential and innovation-based competition, whereas efficiency zone conditions unleash forces that push firms towards a collective defense of chosen positions and further reinforce the adaptive choice of the value chain. By this time, the market boundaries firm up, a new influx of firms is reduced to negligible numbers, and competition becomes a zero - sum game. The small entrepreneurial skiffs are replaced eventually by big supertankers, the value chains that create quite a bit of turbulence of their own. Therefore, a significant move by one chain may force a reaction from all the chains in the market. Independence of firm moves is history by now, and at this point, every move must be measured against expected countermoves and the firm that makes the move better have reliable benchmarking capabilities.IT become a chess game moves and countermoves, all deliberate and risk assessed. When markets are reduced to oligopolies, a significant learning mode fosters collaboration among firms at the expense of competition. It may be less expensive to maintain the status quo than to strike for market leadership and unleash zero-sum based desperate counter moves. Learning moves from focusing what's best for me in early markets to what's least harmful to me in late markets, and efficiency quest combined with the closure of market boundaries engenders such zero-sum calculations; I need more market share for implementing productivity but so does every other competitor. If I cannot steal can I buy? And the answer is yes, so M&A activities ensue. Now it is obvious, the art of navigating the market ocean shifts slowly from sudden pressures of competing firms to slowly developing pressure among value chains. Added to this collective pressure is the influence of the developing stakeholder universe.

4. The learning process of companies under the two climate zones

Organizational learning is concerned with improving the behavior and capability of individuals so that the organization can more effectively operate within its environment. That is why organizations need to find better ways to learn [6-7], develop skills [8] and learning by doing [9]. The learning process is a crucial part of the evolution of enterprises. It is the result of a series of reactions to critical events in which the firms learn to process the information, adjust strategy and take decisions. The last decades were characterized by the growing emphasis on new organization forms, promoting functional flexibility as responses to the challenge of the learning economy [10-11]. Moreover, much of this is a response to emerging complexities in the market under highly structured and static conditions where no learning is required but fluid conditions, as created by complex behavior, need to be tracked and understood. Furthermore not just understood but properly responded to, which means, among other things, that the firm's speed of response (the clock speed) must be close to the market speed. If they are markedly different, both learning and response can be impaired. The succession of firm structural types throughout the lifecycle is well known but perhaps not that well understood.

There is a need of different types of learning. An adaptive learning process is smart and can correct mistakes in the short run and not be doomed to extinction due to incorrect structure selection. It is pressured to arrive at the right choice by the market forces. Here we should come back to the "climate zones", which dictate certain patterns as the correct choice.

The *effectiveness zone* puts pressure on the horizontal dimension of the structure, and the *efficiency zone* exerts pressure on the vertical dimension. In the first zone, firms must remain nimble and proactive to survive under shock loads and hence must keep their total structure minimal horizontally and especially vertically, as deep structure tends to anchor the firm. In addition, the firm's relationships with its ecosystems should be flexible; the node connections to the ecosystem should be interruptible.

The contrasting roles of vertical and horizontal dimensions of the structure are shown in Figure 4.

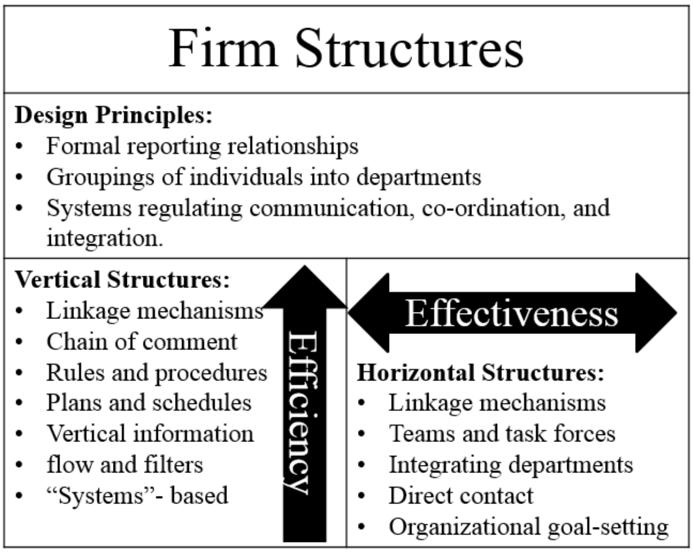

Figure 4: Understanding horizontal and vertical company structures

The *vertical structure* reinforces firm commitment to productivity through simplifying deeper level geometry by repeating the same symmetrical pattern, thereby keeping internal structural complexity minimal. This guarantees easier control and top-down direction. It also provides the shortest path for internal communications and allows the segregation of information. Furthermore, working with the vertical structure can help in developing formal long-range plans, where the sense of purpose and mode of operation of each level and functional unit is defined to the projected planning horizon. Finally, this dimension helps establishing codes of conduct for functions, based on rules and procedures, which can be defined because by now, the environment is stable and market clock speed is markedly slower. This can also be viewed as a passive control in the firm.

The firm is in a tentative learning mode when *horizontal structures* dominate in early markets. It does not know what is likely to happen in the environment but anticipates various scenarios and either confronts these or moves to a less threatening corner of the market. The firms' effectiveness zones are like *blue oceans* where threats are minimal and avoid hard competition. In the effectiveness zone*:* when a local neighborhood of the early market gets too crowded [a red ocean situation], firms move on.

So, we have in early climate zone an adaptive behavior that goes with minimal horizontal structures that can relocate a firm quickly. In the second climate zone, we have progressively heavier structures emerge that produce superior results for productivity. This coincides with the strategic funnel closing in on the only strategy left, and given by the market to the firm, cost leadership. That is why the firm grows at breakneck speed in the tornado, and that is why the frenzied M&A activity was undertaken, to build market share that will buttress productivity strategies in late market. Finally, that is why the value chain thinking emerges to create this best fit with the productivity strategy. Value chins reduce total costs by harmonizing JIT and quality control based supply chain and distribution channels management a

5. Conclusions

Markets have different levels of structure that lead to markedly different coping strategies by firms and hence lead to the emergence, under complexity rules of new structures. These "new structures" emerge in the form of alliances that help companies to navigate the market turbulence at each phase of the market lifecycle. They are the rafts firms cling to in weathering market storms

The dynamic tipping point of how collaborations morphs into collusion, which in turn can degenerate into corruption, is not yet known, but the authors have a potential framework to examine this corrosive market behavior and it will be the subject of a further article.

The authors can state and validate that in this present, dynamic environment, there is room for applicability of the life-cycle model. Based on that, companies can improve their strategies, which should be applied at different stages of a product's (shrinking) life.

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SUPPLY CHAIN EMERGENCE: A RECONCEPTUALISATION AND EVIDENCE FROM PRACTICE

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ABSTRACT

Complex systems research argue that supply chains can demonstrate dynamic, nonlinear, emergent and self-organising behaviours (Choi et al., 2001; Surana et al., 2005). Although supply chain complexity commits to the existence of self-organisation and emergences, it fails to conceptualise emergence from a supply chain perspective. Existing supply chain research also falls short of providing empirical evidence of self-organisation and emergence in a real-world scenario. This study aims to explore a holistic conceptualisation of self-organisation and emergence, that looks beyond its current unitary view of the structure. This paper qualitatively investigates 167 cases of supply chain disruption from 21 firms to draw interesting inferences.

INTRODUCTION

Complexity is considered to be the science of nonlinear, dynamical, evolutionary and emergent system behaviours (Bak, 1996; Dooley, 1997; Gell-Mann, 2002). The complexity view proposes that the future of a system is not predetermined, instead the system emerges or self-organises itself out of the interactions among system entities (Dooley, 1996; Gell-Mann, 1994; Holland, 2006; Levin, 1998). 'Emergence' is a fundamental characteristic of a complex system (Allen and Varga, 2006). Emergence in complexity science represents a group of system phenomenon such as the growth of new, unexpected system structures, behaviours, patterns, processes or system properties (Dooley, 2002).

Supply chains are also complex systems (Choi et al., 2001; Surana et al., 2005) and they too demonstrate nonlinear, self-organising and emergent behaviours (Choi et al., 2001; Surana et al., 2005). These behaviours are suggested to be a consequence of an aggregation of multiple diverse system agent interactions driven by individual behaviours, decisions, choices, mental models and beliefs. Although, supply chain complexity commits to the existence of emergences, but unlike the complexity research in other organisational science domains like leadership (Lichtenstein and Plowman, 2009), entrepreneurship (McKelvey, 2004) or new product development (Mccarthy et al., 2006), supply chain complexity research fails to clearly conceptualise emergence from a network perspective. The current conceptualisation of supply chain emergence takes a restrictive view of the phenomenon and fails to recognise it beyond structural evolution or rearrangement. Existing supply chain research also falls short of providing empirical evidence of emergence in a real-world scenario. Thus, this study aims to explore a holistic conceptualisation of emergence, that looks beyond its current unitary view of the structure. This will be done using the following research question; *What constitutes of supply chain emergence?*

LITERATURE REVIEW

Emergence

Goldstein presented a glossary of terms in (Zimmerman et al., 1998:p. 270); where he conceptualised emergence to be; *"a process ... , whereby new emergent structures, patterns, and properties arise without being externally imposed on the system"* Goldstein, in (Zimmerman et al., 1998:p. 270). In the recent times, the field of complexity science has contributed the most to the phenomenon of emergence with many valuable contributions looking at emergence in natural, manmade, social and organisational systems (Bak, 1996; Kauffman, 1993; McKelvey, 2002; Prigogine and Stengers, 1984).

In view of Goldstein, a prominent characteristic of emergence which differentiates emergence from other phenomenon is that it emerges out of bottom-up causation, refer to Goldstein (2013), and is characterised by the presence of the following properties; (i) Radical novelty indicating irreducibility , unpredictability and non-deducibility of the observed change, (ii) Coherence or collective wholeness indicating an integration or aggregation of higher level system patterns at a macro level and (iii) Dynamism in emergent systems that is demonstrated by bifurcating system behaviours and the rise of new attractors or forces that bring in dynamical characteristic.

Emergence is not a new abstraction to organisational researchers (Allen and Varga, 2006; Chiles et al., 2004; Lichtenstein, 2000; McKelvey, 2002). Organisational scholars have listed some system conditions associated with the phenomenon of organisational emergence. These are; (1) Dis-equilibrium state of the system; (2) Amplification of small actions into system level fluctuations; (3) Recombination/Self- organisation such that after reaching a critical limit the system either explode into different structure or it collapses and reorganises itself; and (4) Stabilising or dampening feedback that brings a system to a new equilibrium state after self-organisation or recombination (Lichtenstein and Plowman, 2009).

Being complex systems, supply chains are also poised to demonstrate emergence. Like any other natural or manmade system, supply chains are also expected to possess emergence characteristics as proposed by Goldstein (2013), and organisational conditions as listed by Lichtenstein and Plowman (2009). Based on the assertion made by Goldstein (2013) about the features possessed by emergent phenomenon, that are distinct from any other form of transformation, we propose the following system and organisational level changes to represent emergence in supply chains.

i. *A bottom-up change in the structure of the supply network*: When there is a sudden alteration in a network, often followed by a destabilising condition, such as natural or manmade disruptions, then the supply chain network evolves organically rather than strategically. Such explosion, collapse or rearrangement of supply network connections should be viewed as emergence. It is bottom up, unpredictable, dynamic and has a radical degree of novelty and is often a result of a corroborative aggregation of micro-level events at a system level.

ii. *Change in any established process:* If operational routines in the supply chain are altered in an emergent manner then this transformation could be viewed as emergence. In a supply chain scenario, if a destabilising organisational condition prompts a bottom-up change in routines and processes, then it is a definite case of supply chain emergence.

iii. *Change in organisational priorities or goals:* If destabilising system conditions, such as supply chain disruptions or changes in competitive scenario of the network, resulting in organisations changing their goals or priorities, then this could also qualify as supply chain emergence. This transformation of organisational priorities should happen radically, in a novel way and are prompted by bottom-up causation.

RESEARCH METHODOLOGY

This study adopts a qualitative research design (Glaser and Strauss, 1967) with the retrodictive mode of inference (Bhaskar, 1975; Hanson, 1958; Peirce, 1955). Contrary to the hypothesis-deductive research approach, retroductive research design engages with an initial theory, in a creative and iterative manner called "Theory matching" (Dubois and Gadde, 2002), to test the efficacy of observations and in turn validates or further specifies theories (Poole et al., 2000; Shah et al., 2008). To put, a retroductive argument suggests a theory that if true, will render explanatory relevance to any observation or empirical data connected to a phenomenon. In this case, we have proposed the possibility to observe supply chain emergence, and retroductive logic can be used to establish its presence in supply chains undergoing disruption, i.e. destabilising system conditions.

A total of 21 middle managers and senior managers were interviewed in about 167 cases of supply chain disruption. The selected participants represented 15 different industries, varying degree of responsibility, and 6 to 27 years of work experience. Data was collected using a systematic data collection method similar to Repertory grid (Jankowicz, 2005). After transcribing, the interviews were analysed using qualitative coding approach offered by (Strauss and Corbin, 1990). Coding followed a reproductive, theory matching process.

FINDINGS AND CONCLUSION

Retroductive data analysis of supply chain disruption cases found multiple evidences of system conditions supporting emergence. These were; (i) loss of trust and patience, (ii) evidence of conflict escalation, and (iii) acceptance or realisation of previously ignored issues. Table 1 presents a summary of qualitative coding indicating the presence of emergence promoting supply chain conditions. These conditions were prevalent during, before and also after the occurrence of disruption.

First order findings	Second order findings	Aggregated dimension
Multiple communication ranging from emails to teleconferences being pursued at various levels in the organisational hierarchy over a significant duration of time. After being furnished inaccurate and misleading information for an extended period, the buying firm is forced to visit the supplier firm to find out what exactly was wrong. Non-relenting and inconsiderate behaviour of monopoly suppliers to accept a fair price for their products and services.	Loss of trust and patience	Act against the people or organisation responsible for it
Once lower management failed to negotiate an amicable solution higher management forced to intervene. Required arbitration or proof for resolving the conflict. Escalating frustration or anger.	Conflict escalation	
Late recognition of growing discontent and grievance among union and workers.	Acceptance or realisation of a previously ignored issues	Introspect and take a corrective action

Table 1: Summary of qualitative coding

Although not all disruptions led to system emergence as seen in figure 2; yet there were some cases where the supply chains underwent bottom-up transformation leading to unpredictable, radical and novel changes that demonstrated dynamism.

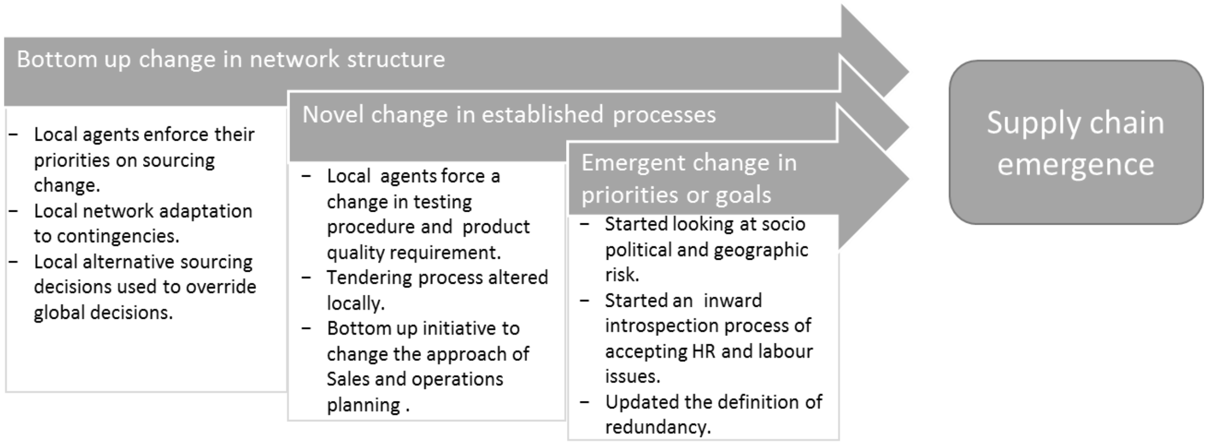

Figure 1: Dynamics of supply chain emergence

Unpredictable and novel changes were observed in multiple cases indicating emergence. In some cases, a quick restructuring of the network was undertaken to avoid a specific disruption. While on multiple occasions, the local agents were annoyed and frustrated by continuing false commitments and inconsiderate and non-cooperating supplier behaviour. This led to a bottom-up change in sourcing.

A few occasions, the quality function was forced to relax their quality parameters and permissible ranges for procured products used in manufacturing. This was a change in the set process. Many firms accepted that events of disruptions forced them to look inwards into their supply chain strategies, priorities and goals. This introspection led to the firms self-organising to adapt better with the changed circumstances and accrued learnings. Adoption of these new set of priorities and goals can be argued to be system level emergence. It can be summarised that emergence in supply chains should be viewed beyond structural changes. Change in process or priorities of organisation is also a radical and novel change, and if it happens dynamically and unpredictably, it also represents emergence.

Self-organisation and emergence refer to change, and supply chains facing disruptions were found to have changed and emerged in four different ways; (i) structural change, (ii) change in established processes or procedures; (iii) change in agent behaviour and (iv) change in organisational goals and priorities. These changes were found to have emerged by multiple, micro level, agent interactions and thus suggestive of them being complexity driven instances of self-organisation and emergence. The findings also revealed that these patterns were not enforced top-down; instead, they evolved bottom-up; reinforcing the complexity view.

The research provides empirical evidence to argue that it is necessary to re-conceptualise self-organisation and emergence in the supply chain beyond structural changes. By recognising the emergence of complex self-organised order through multiple agent interactions, firm can achieve a higher level of innovativeness and resilience to turbulent and chaotic complex scenarios. Organisations have already accepted supply chains to be complex but recognising emergence and self-organisation to have dimensions beyond structural changes, such a change in processes and behaviour of the agents, could provide them with a new mechanism of embracing change.

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Session 8: Sustainability in Logistics and Supply Chains

FOOD WASTE IDENTIFICATION AND MITIGATION IN MULTI-TIER FOOD SUPPLY CHAINS IN VIETNAM

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ABSTRACT

Purpose: About a third of the food produced globally (or 1.3 billion tonnes) is wasted along the supply chain, causing a burden for economy, environment, and food security. In developing countries like Vietnam, the upstream stages like growing and harvesting have much higher proportion of food wastes (FW) compared to downstream stages like retailers and consumers (Gustavsson *et al.*, 2011). However, there is limited exploratory researche towards waste identification and treatment for the perishable food in developing countries. The paper aims to identify the main causes of FW and locate the occurrence of FW from post-gate farm to the processing plant and retailers in a perishable supply chain in Vietnam. The supply network of three types of vegetables, tomato, cabbage and sweet peppers were investigated.

Design/ Methodology/Approach: Six semi-structured interviews were carried out on multi-tier vegetable supply network in Vietnam including farmers (3), fruit and vegetable processor (1), and supermarkets (2). It is to identify different types of wastes and position occurrences of FW at each stage of the food supply chain with three stakeholders namely farmers, processing plants and retailers. Also, destinations of food waste were investigated.

Research scope: The research's scope focuses on primary production, harvesting, transportation, and processing from the farm via processing company to supermarkets in Ho Chi Minh city. The scope of the research could be extended to multiple case studies for perishable supply chain in Vietnam and Thailand. This approach allows cross-case study analysis and contributes to deepen the understanding of food wastes along perishable supply chain in the developing countries.

A theoretical contribution: This research is exploratory in nature, which contributes to widen the understanding of wastes in perishable food supply chains. The paper provides new insights into how waste can be identified, quantified and mitigated.

Practical contribution: Food waste identification method developed in this research can assist supply chain stakeholders in analysing their processes, and thus providing a basis for identifying hotspots of wastes and mitigation actions.

1. Introduction

Thousands of tons of perishable foods are transported and traded into Ho Chi Minh City on the daily basis, which is estimated to generate at least 240 tons of food wastes, costing the government more than £2000 per day to handle the wastes (Thanh, 2018). The amount of foods flooding into Ho Chi Minh City is in an upward trend, which poses more pressure on municipals to find solutions for waste treatment. A high proportion of food waste does not only impact negatively on the well-being of the neighbourhood and environment, particularly water source, but also reflects inefficiency in the operation of the supply chain. The situation eventually leads to higher prices of perishable foods that are borne by consumers. However, food waste management for perishable products with relatively short shelf life such as fruits, vegetables or diary is a challenging task.

There are limited exploratory researches on the root causes and destinations of wastes in this perishable supply chain in developing countries. Therefore, this paper aims to fill in the gap by identifying the causes and destinations of Food Loss and Waste (FLW) in different stages of a multi-echelon supply chain for perishable foods in Vietnam. To achieve the main goal, the paper initially mapped out one vegetable supply chain of a processing company in Vietnam with the main focus on three commodities (tomato, sweet peppers and cabbage). From the visibility in the supply chain, root cause analysis is carried out via interviews, site visits and internal documents of different actors in the supply chain.

2. Literature review

Food waste management topic has drawn an increasing attention in the literature. The identification of causes and occurrence points of FLW along the food supply chain (FSC) are highlighted as the first and critical step contributing to understand the origins of wastes for further prevention and mitigation stages in FLW management process (Chabada *et al.*, 2014; Fanelli, 2019; Magalhães, Ferreira and Silva, 2019). Several methods have been proposed in the literature to identify the root causes of food wastes. For instance, seven waste categories under lean theory (Chabada *et al.,* 2012); a causal map tool like current reality tree maps (CRT) (Mena, Adenso-Diaz and Yurt, 2011), fishbone diagram (Chabada *et al.,* 2014), or causal map at household level (Fanelli, 2019) in-depth expert interviews in German processing industry (Raak *et al.*, 2017) or in consumption stage (Aschemann-Witzel *et al.*, 2015); multiple case studies in fresh food supply networks in the UK (Mena *et al.*, 2014) or in German food industry (Göbel *et al.*, 2015). Some other methods include conceptual framework from literature review and consultation with stakeholders (Priefer, Jörissen and Bräutigam, 2016; Canali *et al.*, 2017); value stream mapping (De Steur *et al.*, 2016); or total interpretive structural modelling (TISM) in Indian perishable food supply chain (Balaji and Arshinder, 2016).

It is noted that these studies are mainly exploratory using qualitative method via case studies and semi-structure interviews to analyse and identify the causes of FLW. It is explained by a limited understanding on the causal relationship behind wastes in the food supply chain. Additionally, while the list of waste causes is generally exhausted (such as a list of 286 causes in the paper of Canali *et al.,* (2017)), many paper aimed to propose the way to categorise and model the causes of wastes rather than list all possible types of wastes.

Although all papers did not address the wastes from plantation stage, the scope of research in most papers is very narrow. While some studies only focus on a single stage such as processing stage (Raak *et al.,* 2017) or consumption stage (e.g. Aschemann-Witzel *et al.*, 2015; Fanelli, 2019), others address supplier-and-retailer interface (e.g. Mena *et al.,* 2011) or the whole supply chain (e.g. Chabada *et al.,* 2014). ***Table 1*** summarised main root-causes identified from various publications in the literature. These causes are presented in different stages of the supply chain from harvesting, processing, packaging, logistics, wholesale/retailers to catering or hospitality industry and consumption stage at household level.

Table 25: List of causes along the food supply chain

Stages	Factors
Harvesting step	Product quality from poor harvesting techniques Inappropriate temperature control Out-grading due to retail specification (size, colour, mix) Sorting loss Spoilage (sprout, etc)
Processing	Temperature control (cold chain management) Sale variability due to weather-related factor Inaccurate forecasting Temperature changes (too hot in the summer) Overstock – lack of inventory management Weight loss during storage
Packages	Poor/ improper packaging, package deformation Improper handling, stacking and improper sizes of packages.
Logistics, transport and storage	Distance Delays in shipping Shortage of refrigerated carriers Loss/damage /contamination during loading Microbial deterioration
Retail/ wholesale	Quality control Poor handling in stores

	Take back policy Promotion Label misunderstanding– best before Poor forecasting, ineffective demand management, lack of shelf life management Seasonality factor Cold chain management (temperature control) Lack of communication/coordination among players Lack of traceability system and procedure
Hospitality and catering	Oversized dish Inadequate package size for ready-to-eat meal Poor storage management Buffet restaurant Difficult to forecast demand
Consumption stage	Social influence Macro-environmental factors Socio-demographics, psycho-graphics Confusion about labels (best before or use buy) Lack of food preparation skill Poor meal planning skill Oversized meals Do not utilise left-overs

Source: Combined from various sources
(Mena *et al.,* 2011; Mena *et al.,* 2014; Chabada *et al.,* 2011; Chabada *et al.,* 2014; Aschemann-Witzel *et al.,* 2015; Leal and Kovaleva, 2015; Priefer *et al.,* 2016; Raak *et al.,* 2017; Fanelli, 2019)

3. Methodology

The aim of this paper is to analyse the qualitative data collected from interviews and site visits in different companies along a vegetable supply chain case to identify the main causes and destinations of food wastes. The case study was built mainly based on six semi-structured interviews, two site visits and supplemented with secondary sources from companies' internal reports. The network of three vegetable products were mapped and analysed from harvesting stage at the farm to supermarkets. Company supplies over 40 different types of vegetables to the market, but only three types of vegetables were selected in the case study thanks to its high demand volume and price (50% of total output for cabbage and tomato) and special waste characteristics (for sweet peppers).

Six interviews were conducted over three months starting from February until May 2019. Snowball technique were used for the recruitment of interviewees, starting with an initial company, *a processing company*, who provided the contact information of other companies in its supply chain, including its suppliers (farmers) and its customers (retailers) along the perishable supply chain. Since data on wastes are treated as highly sensitive, confidentiality and anonymity are required for all participating companies. The names of the companies are therefore kept anonymous.

The interview questionnaires covered four main themes:

- Contact details: background and introduction of the companies and products.
- Causes of FLWs: main causes and occurrence points of waste generation along the network.
- Quantitative data on wastes: data on waste volumes and percentages
- Destination of waste: discussion of which way waste is managed and how to improve the management process.

Each interview has an average duration of one hour and generally conducted by two researchers in face-to-face approach. Occasionally, phone call was carried out due to geographical distance or the need of supplement information. The interviews were recorded, transcribed and translated from Vietnamese to English language. The interview transcriptions were then sent to the interviewee for validation of the accuracy of the data and additional comments.

Observations from two site visits and internal reports were used as secondary methods of data collection. The first site visit to the processing plant was taken in April by two researchers and the second visit was in the greenhouse farm in May by one researcher. Observations during site visit provided critical information that supplemented the content of interviews and enriched researchers' understanding regarding the whole process and hotspots for wastes along vegetable supply chain.

Main Findings

This section starts with a description of the supply chain networks for three vegetable products in a single case study (figure 1 to 3). A vegetable processing company, so-called Company A, has a network of 200 small-scale farmers in a total area of over 200 hectares to supply vegetables for three supermarket chains in Ho Chi Minh City. For tomato, cabbage and sweet peppers alone, Company A has only 150 farmers in an area of more than 150 hectares which simultaneously supplying all three types of vegetables. These farmers receive financial and technical supports from Company A so the relationship between farmers and Company A is very strong in a collaborative manner. Not only acquiring vegetables from farm, Company A also has its own plantation in an area of 50 hectares. The farms and Company A are located more than 300 kilometres away from Ho Chi Minh City, which takes eight hours to transport final products to the market.

Farmers are all located within a radius of 20km from the factory. After being harvested in the farms, vegetables are transported by motorbikes from farms to the collection points where they are then being collected by Company A's trucks to its factory. Temperature at this stage is ambient, approximately 18 to 22°C in the raining season and 25-30°C in the hot season. In the processing plant, vegetables go through several stages, from washing, grading, packaging to storage before being sent to supermarkets in Ho Chi Minh City. Lead times for harvesting, washing/grading, packaging, and storage are 3-5 days, four hours, six hours, and two hours, respectively. A maximum time to store vegetables in the plant's warehouse is 12 hours. Average lead time to process and ship vegetables inside the factory is less than 12 hours. **Figure 1 to figure 3** presented data on supply chain, temperature management, waste quantifications and destinations for wastes of tomato, sweet peppers and cabbages.

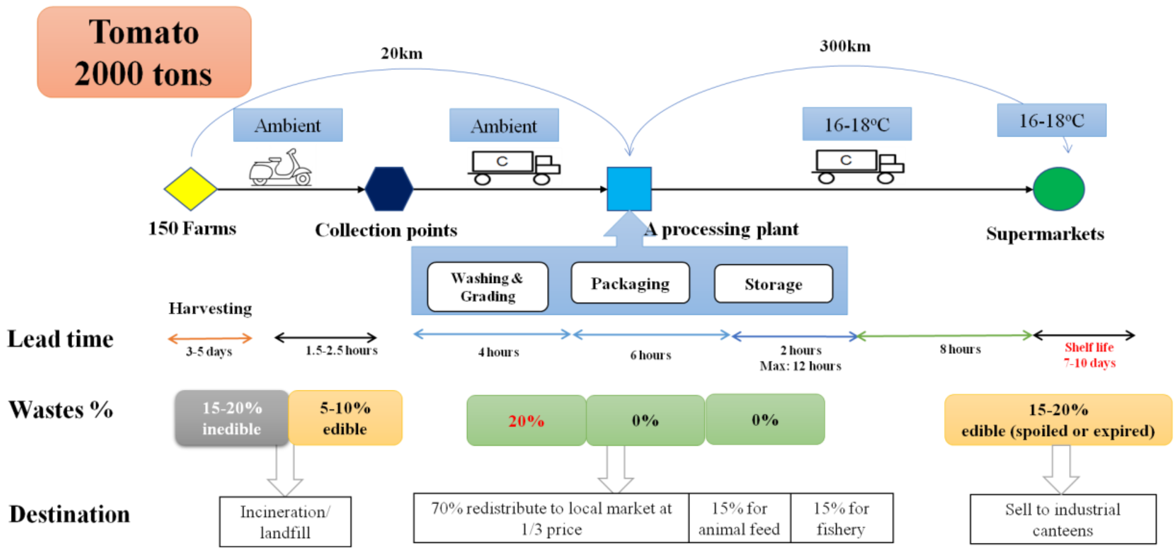

Figure 50: Tomato supply chain and food waste identification

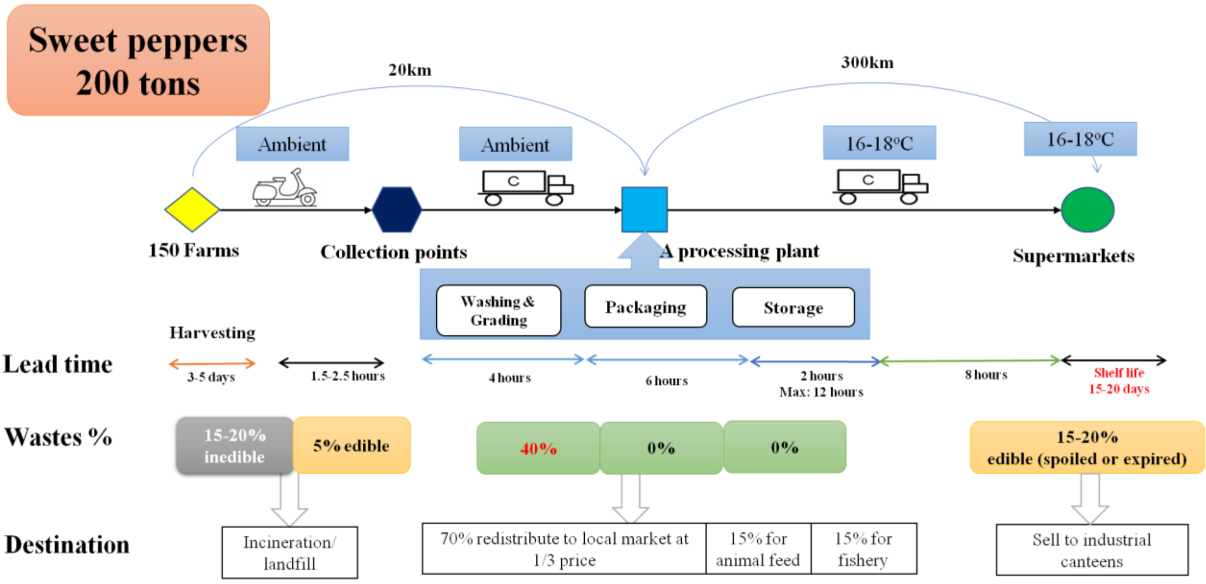

Figure 51: Sweet pepper supply chain and waste identification

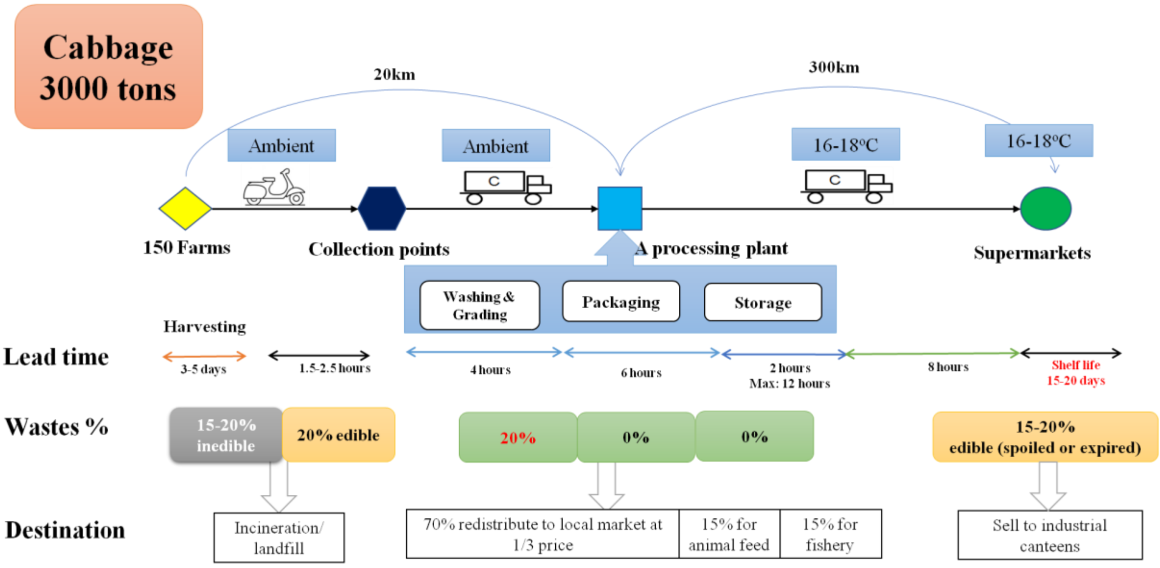

Figure 52: Sweet pepper supply chain and waste identification

Key stages in the perishable supply chain of the case study:

(i) ***Harvesting stage:*** all three types are harvested by hands, packed in big bags and transported to the collection points of the Company A by motorbikes. From here, Company A's internal trucks collect vegetables and move them to the processing plant for further processes.

(ii) ***Washing and grading****:* Vegetables are washed thoroughly before the grading process. For tomato and sweet peppers, company has the sorting and colouring machine to sort and grade in accordance with supermarket's specification. Cabbage is graded manually to select the weight of greater than 1.5 kilograms.

(iii) ***Packaging:*** tomatoes are packed in a plastic pack of four; sweet peppers are packed in a carton box of five to six kilograms per carton; plastic cling film is used to wrap cabbage.

(iv) ***Storage:*** after grading and packaging, vegetables are stored in a warehouse for an average of two hours before dispatch. Thanks to really short storage lead-time, as well as efficient cold chain management system, the wastes in storage stage is reviewed as "zero" percent. Temperature for vegetables is kept at 16-18 degrees inside the warehouse and during transportation.

(v) ***Transport:*** Company A has its own transportation fleet to transport products to supermarkets twice per day with an average shipment time of eight hours over more than 300km from Dalat to Ho Chi Minh City. The fleet consists of ten refrigerated container trucks (10 tons each truck).The fleet is sufficient enough to meet demands of customers so there is no need to hire external trucks and the risks for transportation is minimised.

(vi) ***Retailing at supermarkets:*** Company A and supermarkets sign advanced contracts specifying quantity and price for a period of 3 months. For every shipment, a quantity discount of 15-20% is applied to offset deteriorated or spoiled vegetables during transportation and handling in step (v), and also for the amount of unsold and expired products in the shelf presence.
If company A stops supply, twelve-month notification to the supermarket is required.

4.1 Main causes for food wastes along the food supply chain

After six in-depth interviews with five stakeholders along the perishable supply chain in Vietnam, the causes of food wastes were identified, quantified and summarised in **Table 2**. Food waste treatments for both edible and inedible fractions of vegetables were also investigated in **Table 3**.

Table 26: Characteristics of products and quantification of food wastes along the supply chain

	Tomato	**Sweet peppers**	**Cabbage**
Annual output	2000 tons	200 tons	3000 tons
Market price per kg	VND 27.000-30.000	VND 32.000-35.000	12.000-15.000
Plantation characteristics	5 months in open field 8 months in greenhouse. Main season: Jan and February – dry season	Planted only in greenhouse within 5 months	80-90 days in open field
Pre-processing temperature	Ambient	Ambient	Ambient
Post-processing temperature	16-18ºC	16-18ºC	16-18ºC
Shelf life	7-10 days	15-20 days	15-20 days
Percentage of inedible wastes	20% if open field plantation 10% if greenhouse plantation	15%	15% in dry season 20% in raining season
Percentage of edible wastes	45-50%	60-65%	55-60%
(i) Harvesting& transports	5-10%	5%	20%
(ii) Washing & grading	20%	40%	20%
(iii) Packaging	Nil	Nil	Nil
(iv) Storage	Nil	Nil	Nil
(v) Transport and retailing discount	15-20%	15-20%	15-20%

Followings are the key causes for food wastes along perishable supply chain for three types of vegetables. Wastes arising across the network are quantified and dominant causes are identified. The scope of research is expected to expand in the figure in term of number of case studies, commodities, and interviews.

4.1.1. Causes in the growing and harvesting stage

Even though the data in the table 2 does not capture the percentage of loss and waste in the growing stage due to the data inconsistency and complexity of growing stage, the interviews with farmers disclosed that the primary causes of waste in growing stage arise from **weather conditions, diseases and pest infections**. Farmers claimed that these factors are closely related, e.g. in the raining season (from May to November) with high humidity level, disease spreads out for all types of vegetable, whereas in the dry season (December to April), pest infection poses a serious threat. All farmers expressed more concerns on the disease than pests given pests can be treated whereas disease is much harder to cope with.

Main causes in the harvesting and transportation stage from farms to the factory:

(i) **Market price is lower than the cost of harvesting due to oversupply and seasonal factors:** Particularly in good season, post-Lunar year, supply is abundant thanks to good weather, but demand is low. The selling price, in many cases, is not enough to cover for the harvesting cost. Farmers, therefore, do not harvest them and let other parties, like animal farmers, to come and collect them to produce free animal foods.

(ii) **Improper handling and stacking techniques from the farm to the factory:** this is due to the traditional practice of packaging and carrying vegetables from farm to the collection points. After harvesting from the farms, farmers put vegetables into bags and stack on the top of each other to be transported by motorbikes to the collection points. This practice caused high rate of damage, and has been emphasised by the interviewees as the main cause for high loss of sweet peppers in the later stage of the supply chain (40% in the washing and grading stage).

4.1.2. Main causes in grading

Grading is a hotspot for waste occurrence, especially with sweet peppers. Vegetables are selected according to the specifications set by supermarkets regarding weight, size, colour, and shape.

- **Tomato:** graded by colour and size as well as the softness.
- **Sweet peppers:** graded by colour, sizes and shape. “Ugly” or small peppers are not selected according to supermarkets’ specification.
- **Cabbage:** picked by hands according to the weight (greater than 1.5 kilograms). Also, “ugly” cabbages with bad, spoiled and old sleeves are not selected.

4.1.3. ***Zero waste is claimed in the packages and storage stage***

- Interviewees from company A and retailers expressed no concerns over package wastes and suitability of the packages.
- Due to a relatively short storage time in the factory (around two hours for all types of vegetables), the rate of loss or wastes in this step is considered as nil.

4.1.4. Main causes during outbound transportation and retailing at supermarkets

- Storage and transportation with low risk of spoilage, which comes from the company A’s own transportation fleet and twice-per-day transport policy.
- However, both retailers and processing company expressed a concern on **handling risk** in loading and unloading stages. It is also difficult to quantify the percentage of wastes associated with handling risks so both Company A and supermarkets agreed with a discount **of 15-20%** on the total purchased volume. This discount is applied to offset the amount of deteriorated vegetables in handling stage and upon display on the shelves of the supermarket (spoilage or expired vegetables in the shelf).

4.2. Current destination of food wastes

For inedible parts

On average, inedible parts accounted for 20% of total weights of the final products (table 2). However, the percentage varies significantly depending on the plantation conditions (greenhouse versus open field, and weather conditions (summer versus winter)). If vegetables are planted in the open field, farmers will gather the remaining parts (inedible fractions) of the plants and burn (incinerate) them in the field. The ashes from burning are then returned back to the field as soil nutrients. Apart from incineration, **composting** has been taken into consideration as an alternative waste treatment option (*not anaerobic digestion*). However, farmers are of worrying that the pest infection from previous season might spread out through the use of compost in the later season. Therefore, incineration remains as the only waste treatment option and composting is not applied.

For edible parts in the factory

- The destinations for edible fraction in the factory of Company A include the small local markets, its own fishery farm, and surrounding animal farms.
  - 70% of the vegetable wastes in the factory are sold in the small local markets at a third of the price sold to the supermarkets.
  - 15% of the wastes in the factory is utilised as fish food in the fishery farm of the company A.
  - The remaining 15% is given away to the neighbouring farmers as animal foods.

For edible parts in the outbound transportation and supermarkets

- Any expired or deteriorated foods in the supermarkets are sold to the industrial canteens.
- Supermarkets set a reject rate of 15-20% on the purchased quantity to offset the expired or deteriorated foods on the presented shelf.
-

Conclusions

This research has presented the main causes of food wastes for three different types of vegetable products in Ho Chi Minh City market in Vietnam. The causes of waste are different in different stages of the supply chain, in which harvesting and grading stage are the hotspots for food waste generation. Dominant causes include preliminary packaging ,motorbike transportation from the farm to the factory and the supermarkets' specifications in the grading process. Incineration remains as the dominant waste treatment option for inedible fractions of tomatoes and cabbages in the open field. Landfill is used for sweet peppers in the greenhouse plantation. The main limitation of the research is the focus on a single supply chain due to data availability. Further work is needed to expand the scope of the research to additional supply chains for perishable foods in Vietnam and Thailand with the involvement of more stakeholders particularly traditional wholesale markets.

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REDUCING ENERGY COST IN WAREHOUSES VIA SMART LIGHTING SYSTEMS: A SIMULATION STUDY

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ABSTRACT
Purpose
Lighting influences private and working life. At the same time, it is a critical contributor to energy consumption. Although there exist manifold technical solutions for lighting to become "smart", today's lighting systems are often kept simple, and they are frequently not adjusted to the user's behaviour. This is especially the case for production and logistics facilities such as warehouses, where large areas have to be illuminated and where lighting is often fully turned on while the warehouse operates. This paper presents a simulation model that was developed to evaluate the cost benefits that may result from using smart lighting systems in warehouses. The simulation model considers different warehouse layouts, storage assignments as well as order batching policies and analyses how three alternative lighting strategies influence the cost of operating the warehouse.

Design/methodology/approach
The paper first proposes a concept for a simulation model and then implements the concept in the software Plant Simulation by Siemens PLM Software. The simulation model allows varying warehouse design and order picking process parameters, such as the length and number of aisles and cross aisles or the number of order pickers working in the warehouse at the same time. In addition, three different operating strategies for the lighting system have been implemented. A structured simulation study allows gaining insights into how smart lighting systems interact with system design and process parameters and how both, collectively, influence warehouse operating cost.

Findings
Preliminary results indicate that the two investigated smart lighting systems have a great potential to reduce energy consumption in warehouses compared to conventional lighting; the absolute savings strongly depend on the parameters of the simulation model. If the number of pickers increases in relation to the size of the considered warehouse, for example, energy savings decrease. More sophisticated lighting systems that stronger adjust lighting to the order picker's user behavior lead to higher energy savings, but may be associated with higher investment cost. The proposed model supports evaluating these tradeoffs.

Value
This paper is the first to evaluate the cost reduction potential of smart lighting systems in a warehousing context. It evaluates different configuration levels for the lighting systems and thus supports a (gradual) shift from traditional lighting to smart lighting in warehouse practice.

Research limitations/implications
The proposed model could be extended to include further warehouse layouts and order picking strategies currently not covered in the model implementation. In addition, benefits of smart lighting systems that extend beyond reductions in energy cost, such as human

centric lighting and visible light communication, need to be considered in addition to fully evaluate the potential smart lighting systems may offer in a warehousing context.

Practical Contribution
The results of the paper support companies in operating such systems, as well as when deciding on whether or not a smart lighting system should be implemented.

1. INTRODUCTION

Warehouses are key nodes in each supply chain. Within warehouses, order picking has often been considered as a significant contributor to internal logistics costs (Tompkins et al., 2010). For some companies, especially in the e-commerce sector, it may, in fact, be one of the largest cost drivers altogether (Boysen et al., 2019). In many sectors, efficiently executing order picking processes has become a key contributor to the performance and the competitive success of companies (van Gils et al., 2018). To improve the efficiency of order picking, prior research has focused on the development of mathematical models that assign products to storage locations, that re-structure customer orders into so-called batches that can then be picked in individual tours, and/or that route the order pickers through the aisles of the warehouse (see, e.g., de Koster et al., 2007). The objective of these models usually is to generate the shortest possible routes for a given set of orders, which enables the order pickers to complete the set of orders as quickly as possible (and which, simultaneously, contributes to maximizing warehouse throughput).

What has received less attention in the literature so far is that further costs (despite those directly associated with the order picker) may depend on how warehousing processes are organized. One example are the costs of lighting that may account for up to 65% of the facility's total energy consumption, and that are therefore a main contributor to the energy costs of a warehouse (Dhoorna and Baker, 2012; Richards, 2014). While traditional lighting systems often made it necessary to fully turn on lighting during the operating hours of the warehouse, smart lighting systems now enable companies to provide the very lighting intensity required by the warehouse workers. Artificial light provided in the warehouse could hence be adjusted based on the amount of daylight available in the facility or based on user preferences or the presence of the workers in the picking area (Yasodha et al., 2015; Liu et al., 2016). The presence of the workers in the warehouse, however, depends on how the warehousing processes are organized, and it is therefore subject to management control. The use of smart lighting systems could lead to a significant reduction of energy consumption and costs and may thus also contribute to a reduction of warehousing-related emissions contributing to environmental sustainability (Bartolini et al., 2019).

Given that the installation of smart lighting systems often leads to high investment costs, the profitability of such systems needs to be carefully evaluated before the investment is made. In an industrial context, such an evaluation is, however, not easy because of the at times complex interactions between the lighting system's functionality and the operational processes taking place in the facility. If a warehouse manager, for example, decides to organize warehousing in a way that leads to warehouse workers being present in the aisles of the warehouse almost permanently, using presence sensors to adjust lighting would not lead to a substantial reduction in the required lighting energy. If workers would visit certain zones of the warehouse only relatively infrequently, in contrast, automatically dimming light in the affected zones during periods where workers are not present could contribute to lowering energy consumption and saving costs. Warehouse managers could even decide to change storage assignments, batches and picker routes to intentionally generate zones where a reduction in the lighting intensity can be beneficial to the company, even though this may affect the throughput of the warehouse. The interdependencies mentioned here have, however, not been investigated in a scientific study so far.

The purpose of the paper at hand is to investigate the cost savings potential of smart lighting systems in a warehousing context. A simulation model was implemented in the software Plant Simulation by Siemens PLM Software for the purpose of our research. The simulation model allows varying warehouse design and order picking process parameters, such as the length and number of aisles and cross aisles or the number of order pickers working in the warehouse at the same time. In addition, three different operating strategies for the lighting system have been implemented. A structured simulation study allows gaining insights into how smart lighting systems interact with system design and process parameters and how both, collectively, influence warehouse operating costs.
The next section presents a brief overview of the related literature. Section 3 then describes the simulation model, and Section 4 presents a selection of results. The paper concludes with an outlook on future research opportunities in Section 5.

2. LITERATURE REVIEW

2.1.Management of manual warehousing operations

Prior research on manual order picking focused on developing mathematical models that aim on minimizing order picking time or the distance that needs to be traveled in the warehouse to fulfill a set of customer orders. To achieve these goals, researchers developed solution approaches for the different planning problems that occur in order picking. This includes procedures that determine shortest routes through the warehouse (e.g., Scholz et al., 2016; Celik and Süral, 2019), that assign items to storage locations (e.g., Glock and Grosse, 2012; Calzavara et al., 2019), or that determine which customers order should be accumulated to form batches (Grosse et al., 2014; Zulj et al., 2018). Recent research on manual order picking started to include human factors in the development of integrated planning models that aim on improving both performance and human well-being (e.g. Grosse et al., 2015). A second stream of research that has recently emerged considers the implications of digitization on order picking (e.g., Hanson et al., 2017). Besides mathematical modelling and optimization, a method that has been quite popular in order picking research is simulation. Simulation studies were conducted to gain insights into the impact of picker blocking on warehousing performance, for example by using agent-based simulation models (Heath et al., 2013; Franzke et al., 2017). For a more detailed overview of the literature, we refer to the recent reviews of Boysen et al. (2019) and van Gils et al. (2019).

2.2.Characteristics of smart lighting systems

In most warehouse applications, lights are switched on when work begins and spaces are often unnecessarily illuminated, e.g. during breaks (Park et al., 2015). Smart lighting systems that adjust the intensity of artificial light to the user behavior or available sunlight can lead to substantial energy savings in such applications. One basic building block of most smart lighting systems are light emitting diodes (LEDs) that have different advantages for many lighting applications (Shur and Žukauskas, 2011). One key advantage of LEDs, as compared against traditional lighting systems, is their high luminous efficiency with up to 200 lm/W in industrial applications. In comparison, incandescent bulbs have approx. 15 lm/W and fluorescent lamps approx. 100 lm/W. In addition, LEDs have a long lifetime with up to 100,000 hours (Chang et al., 2015; Schratz et al., 2013), provide the possibility to customize spectral power distribution, provide fast modulation rates, and are robust and stable (Shur and Žukauskas, 2011). The electrical control of LEDs and the opportunity for networked lighting systems, can make traditional lighting 'smart'. Basically, smart lighting systems are based on the intelligent interplay of light sources, sensors and external influences (such as daylight and the behavior of the users), which becomes a closed system through regulation (Chew et al., 2017). These systems are energy efficient and can be adapted to a complex and changing situation as needed.

Sensor-based lighting provides the possibility to reduce energy consumption based on motion or daylight sensing. These sensors enable the system to switch off or dim lights to a lower level if no motion is detected for a predefined time or sufficient sunlight is available, which saves energy (Chung and Burnett, 2009; Chun et al., 2015). A lot of scientific research investigated the potential energy savings resulting from motion, occupancy and daylight sensing in office or street lighting applications (e.g., De Bakker et al., 2018; Leccese, 2013; Chun et al., 2015). The literature reports a wide range of energy savings resulting from the use of smart lighting systems. Through the combined use of daylight and occupancy sensors, average energy savings ranging from 13% (Higuera et al., 2015) to 73.2% (Nagy et al., 2016) that can be achieved compared to traditional lighting systems have been reported. It is important to note that these savings depend on occupant usage patterns and other external factors (von Neida et al., 2001).

Besides the potential to reduce energy consumption, LEDs in combination with smart lighting control can lead to an increase in light quality, an improved regulation of the circadian rhythm and an increase in productivity (Hye Oh et al., 2014; Karlicek, 2012). Studies also reported that lighting adjusted to the workers' needs contributes to the well-being of employees and to preventing accidents at work (Pandharipande and Caicedo, 2015). The ability to network enables the integration of smart lighting systems into the existing building management technology, and hence it can be centrally monitored and controlled (Vanus et al., 2016). Beside the visual and non-visual effects, smart lighting systems enable wireless network access due to the visible light communication (VLC) technology. VLC consists of a transmitter (e.g. LED), a propagation channel and a receiver, e.g. smartphones or tablets which detect the signals due to a photodiode. The LED is switched on and off quickly, following a modulation scheme, to transmit data by using intensity modulation. Since the communication between transmitter and receiver can only take place in the line of sight, the LEDs must be arranged accordingly (Haas et al., 2016). Closely linked to VLC are indoor positioning systems (IPS). IPS enable the localization of objects or people in buildings comparable to GPS-based positioning in outdoor environments (Sharma et al., 2018; Karunatilaka et al., 2015). This enables to define activity zones around workers and to tailor lighting towards the workers' need by simultaneous data transmission.

3. THE SIMULATION MODEL

Simulation is a powerful tool for analyzing different design alternatives or control strategies with practical feedback for real-world systems. It allows evaluating the correctness and efficiency of a design or control strategy before the system is actually established or in operation. Simulation models are therefore often used to determine the performance of warehouses under different layouts and operating policies to evaluate processes (Verriet et al., 2013). The simulation model developed for the purpose of this research aims on evaluating the energy savings potential of smart lighting systems in warehouses for different warehouse layouts and operating policies. We assume a conventional, rectangular warehouse with parallel aisles and multiple blocks (illustrated in Figure 1), as this is the warehouse layout that has most frequently been analyzed in the literature (e.g., Masae et al., In Press) and that can also be very frequently observed in practice. The dimensions of the warehouse (number of shelves and levels per shelf, width of the aisles, height of the shelves etc.) and several process parameters can be flexibly adjusted in the simulation model. We consider three different lighting strategies for evaluating the benefit of smart lighting systems:

a) *Traditional lighting* (TL): This strategy assumes that all aisles (picking aisles and cross aisles) of the warehouse are fully illuminated while the warehouse operates, regardless of whether or not the aisles are empty. This strategy works with traditional light sources (fluorescent lamps) that are still frequently used in many warehouses (Ries et al., 2017).
b) *Sensor-based lighting with cross aisles fully illuminated* (SLCAFI): In this case, cross aisles used by the order pickers for travelling from one picking aisle to the next are always fully illuminated. Picking aisles are only fully lighted while an order picker works in an aisle; aisles that are empty are operated at 20% of the regular lighting intensity. This lighting strategy is illustrated in Figure 1a.

c) *Sensor-based lighting with activity zone* (SLAZ): Here, the lighting system tracks the warehouse worker and fully illuminates an activity zone with a radius of 20 m around the worker; all areas of the warehouse not covered by an activity zone are again operated at 20% of the regular lighting intensity. This lighting strategy is illustrated in Figure 1b. The implementation of smart lighting strategies (b) and (c) is realized using LED light sources.

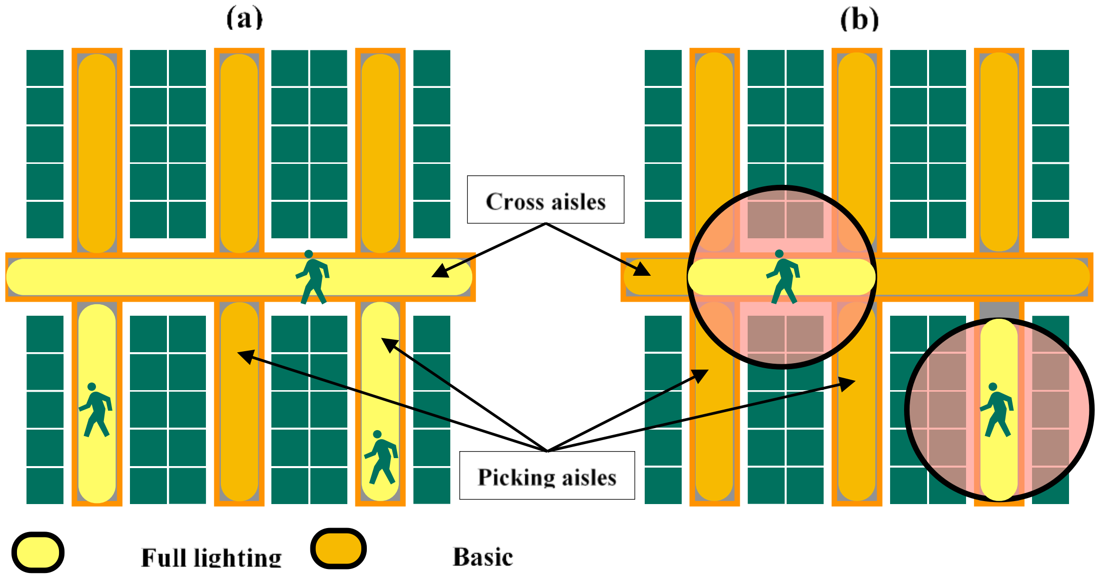

Figure 1: Sensor-based lighting systems considered in the simulation model

Orders arriving at the warehouse are assumed to consist of 50 items each, and a Pareto distribution is used to generate the demand for the items stored in the warehouse. To evaluate the performance of the three lighting strategies for alternative warehouse operations policies, we implemented the following managerial decisions into the simulation model:

a) *Storage assignment*: Assigning items to the storage locations of the warehouse according to a particular pattern may generate zones in the warehouse that are more frequently visited by the warehouse workers than others, which may make it beneficial to reduce the lighting intensity in less frequented zones. We consider two different storage assignments, namely I) random storage and II) demand-based storage. If the random storage policy is used, items are assigned randomly to storage locations in the warehouse. If the demand-based storage policy is used instead, then frequently-requested items are stored in close proximity of the depot, and items that are requested only infrequently are assigned to storage locations farther away from the depot.
b) *Pick policy:* We implemented two different pick policies, namely pick-by-order and pick-by-batch. If the pick-by-order policy is selected, each order arriving at the warehouse is assigned to an order picker, who then collects all items contained in the order. If the pick-by-batch policy is used instead, then batches are generated from the available orders according to their distance from the depot. The latter policy entails that warehouse workers work only in specific zones of the warehouse, and it avoids cases where (many) workers have to travel through large parts of the warehouse. This may help to concentrate the activity of workers into specific zones of the warehouse, which could enable the system to reduce the lighting intensity in less frequented warehouse zones.
c) *Number of order pickers*: If several workers work in the warehouse in parallel, this could lead to situations where there is work activity in several aisles at the same time, such that the light intensity can be reduced only in a few aisles. We therefore consider the case where multiple order pickers work in parallel in the warehouse.

It is worthwhile to note that there are interdependencies between the three managerial decisions that will be investigated in more detail in Section 4. To evaluate the performance of the three lighting system, we track the following three performance measures during our simulation runs: I) electricity usage in kWh, II) electricity cost in €, and III) the time required by the warehouse worker(s) to complete the given set of orders. Table 1 summarizes the parameters assumed in the simulation study (the entire simulation experiment can be obtained from the authors upon request). The simulation model was implemented in the software Plant Simulation by Siemens PLM Software and run on an Intel Core i5-6300HQ CPU with 2.30 GHz and 16 GB RAM.

Warehouse parameters	Description
Number of aisles	Fixed; 16 picking aisles, 6 cross aisles
Aisle width	Fixed; 2m
Number of shelves and shelf levels	Fixed; 160 pcs. with 6 levels
Height, length, width of every shelf	Fixed; 6m tall, 20m long, 1m deep
Number of products	19,200 pcs.
Surface to be illuminated	3200 m^2 (picking aisles), 720 m^2 (cross aisles)
Number of order pickers	Variable: 1, 3, 5 or 7
Order size per order picker	Fixed; 50 pcs.
Average walking speed of order picker	Fixed; 1 m/s
Pick policy	Pick-by-order or pick-by-batch
Picking time	Normal distribution with expected value 10s
Storage assignment	Demand-based storage or random storage
Order creation	Pareto distribution
Lighting parameters	
Electricity consumption	Fixed; 7 W/m^2 for TL, 4 W/m^2 for SLCAFI, SLAZ
Light intensity in empty aisles	Fixed; 20% of regular light intensity
Electricity costs	Fixed; 0,18 EUR/kWh
Illumination radius	Fixed; 20m radius

Table 1: Parameters assumed in the simulation experiment

The parameters introduced in Table 1 show that the simulation model assumes a fixed warehouse layout with a clearly defined number of products. However, due to different numbers of order pickers, pick policies and storage assignments with different picking times and product demand, 14 scenarios can be considered to evaluate the energy demand by the three different lighting strategies.

4. RESULTS

Considering the case of one order picker and demand-based storage, the simulation model revealed that the energy consumption and electricity costs can be reduced by 64% with SLCAFI and by 79% with SLAZ. 42% of the reduction in energy consumption, in both cases, is due to the refitting of fluorescent lamps to LED lighting. Still, a remarkable reduction of 22% and 37%, respectively, results from making warehouse lighting smart. In the case of random storage, the relative reduction for the different lighting strategies are the same, but the absolute reduction in energy consumption increases by around 39% compared to demand-based storage. The reason for this result is that workers need more time to retrieve all products when a random storage allocation is used, which leads to longer operating periods that can benefit from reducing light intensity. Furthermore, we observed that the results do not depend on the pick policies.

For the case with more than a single order picker, random storage combined with pick-by-batch leads to lower energy consumption compared to the pick-by-order policy. Demand-based storage in combination with pick-by-order achieves lower energy consumption compared to pick-by-batch and always outperforms the random storage assignment with regard to energy savings. At the same time, the cost increase that results from a higher number of order pickers is lower in this case than for the other policies. The simulation results also show that, under the assumed parameters, the number of order pickers does not impact energy consumption substantially. Illuminating just a small activity zone around every order picker requires not as much energy as compared to illuminating an entire cross or picking aisle.

Figure 2 finally presents the energy costs of all scenarios for one run of the simulation, outlining a clear reduction in energy costs that can be achieved by using smart lighting systems. The average costs across all scenarios is 62.56% lower for the SLCAFI and 77.07% lower for the SLAZ scenario than for the TL case. The simulation experiments show that the energy consumption of the three different lighting strategies considered are approximately linear in their development over time. The difference in the energy consumption between any two of the systems increases linearly as well. This is caused by a large share of energy waste due to illuminating unused aisles, for example cross aisles where no order picker is present. The simulation results demonstrate that smart lighting systems can reduce this kind of energy waste resulting in lower energy cost.

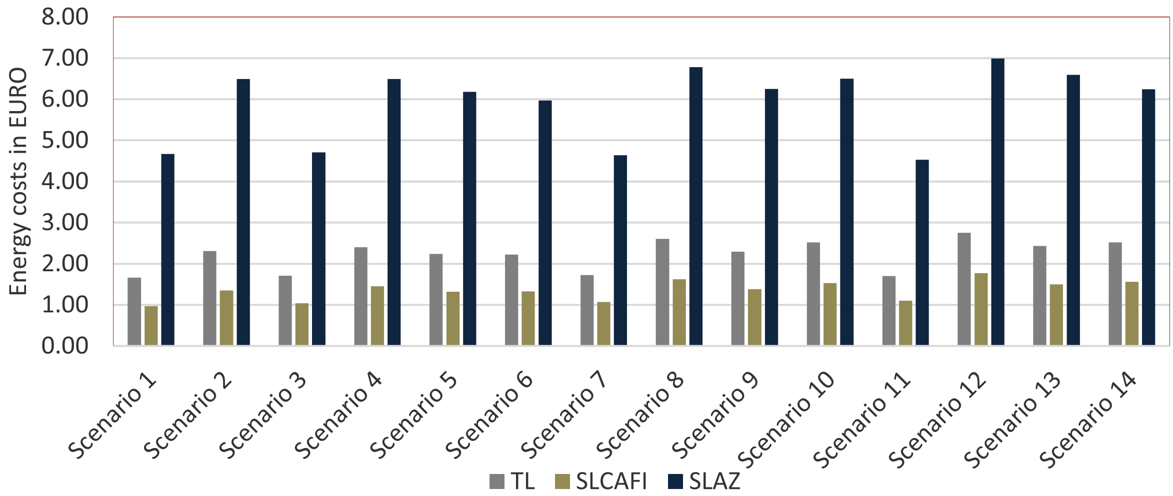

Figure 2: Energy costs of the simulated scenarios for all three lighting strategies

5. CONCLUSION

This simulation study evaluated the cost reduction potentials of smart lighting systems in an order picking warehouse by considering different warehouse operating policies, a variable number of order pickers, and three different lighting strategies. The results showed that smart lighting systems can achieve energy savings up to almost 80% compared to the traditional full-time illumination of warehouses. Besides a significant cost reduction, smart lighting systems can reduce carbon dioxide emissions due to lower energy consumption and thus contribute to reducing the environmental footprint of warehousing.

The proposed simulation model could be extended in future research to include further warehouse layouts and order picking strategies that are currently not covered in the model implementation. In addition, the potential benefits of smart lighting systems that extend beyond reductions in energy costs, such as human centric lighting and visible light communication, need to be studied in detail to fully evaluate the advantages of smart lighting systems in improving warehouse operations. One promising direction for future research is the development of an indoor positing system based on visible light communication, which can also be used to identify activity zones to support managerial decisions regarding storage reassignments. These and other promising ideas that consider the application of smart lighting in industrial settings can be addressed in an extension of this paper.

ACKNOWLEDGMENTS

Supported by the Federal Ministry for Economic Affairs and Energy on the basis of a decision by the German Bundestag.

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A MANUFACTURER-REMANUFACTURER–MULTIRETAILER SYSTEM WITH EMISSIONS, ENERGY, AND SCRAP

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ABSTRACT
Purpose: This paper revisits and modifies the work of Bazan et al. (Comput. Ind. Eng., vol. 88, pp. 307-316, 2015) by considering a more realistic network that includes N-retailer with an integrated inventory system and scrap. It assumes that used items are collected by each retailer and then are shipped to the manufacturer (or a third party) for inspection and later remanufacturing. Here, a portion of the returned used items is remanufactured to as-good-as-new with the rest disposed of responsibly into the environment.
Research approach: A new model is developed based on the integrated model proposed by Bazan et al. (2015a) by adding a policy for scraping manufacturing and remanufacturing items. In addition to inventory-related costs, greenhouse gas (GHG) emissions and energy costs, it accounts for unit costs to dispose of scrap and to transport items from the provider to the retailers. Numerical examples are provided with the results discussed. The behaviour of the developed model was also investigated for varying values of parameters to stress the importance of accounting for retailer costs and a portion of defective items.
Findings and Originality: A higher portion of defective items in production increases the supply chain total cost, including energy, and the number of times to remanufacture an item. The results show there is an optimal portion of defective that minimizes the sum of GHG emissions and that it should be higher than that of collected items. It is essential that the disposal of collected items is kept to a minimum as the remanufacturing process becomes nonviable.
Research impact: This paper emphasises that product design is key in improving the quality of newly produced and subsequently collected used items, which minimizes the amount scrapped in both processes. Of course, companies should also strike a balance between environmental concerns and supply chains. This paper contributes in the direction that an economically sustainable supply chain could also be so environmentally.

Keywords: Closed-loopy supply chain, N-retailers, emissions, energy, scrap

1. INTRODUCTION

Reverse Logistics (RL) is a concept that has been adopted for some time to extend the life of a product through repair and remanufacturing and other practices. The reuse of end-life products and its components has been done my manufacturers mainly for its economic benefits (Bazan et al., 2016). A well implemented RL should reduce the cost of material and will enable the company to become environmentally efficient and sustainable that enhances competitiveness in today's market. According to Ricther (1996), RL is one of the better indicators for companies to meet customers' needs and expectations. RL research has focused on different aspects. Richter (1996) developed an economic order/production quantity (EOQ/EPQ) RL inventory model. Bazan et al. (2016) reviewed the literature for RL inventory models that stemmed from the work of Richter (1996). Prakash and Barua

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(2016) analysed the optimum solutions for the choice and development of reverse logistics partners.

The phenomenon of repairing end-of-life products or items is not new. Schrady (1967) proposed an EOQ model with prompt manufacture and repair rates and zero disposal. Hasanov et al. (2012) developed a production, remanufacturing and waste disposal model in which repaired and newly manufactured items are incompatible, i.e., customers perceive them to have different quality and functionality. This also reduces solid waste disposal into the environment (Matar et al., 2014).

An insightful work by Bonney et al. (2011) discussed inventory performance metrics that also addressed environmental concerns. They emphasized the importance of "environmentally friendly" inventory systems for modern producers and pointed out to the necessity of developing inventory models that capture costs associated with environmental impact. Jaber et al. (2013) developed a two-level supply chain model with a coordination mechanism while addressing greenhouse gas emission from the vendor's manufacturing process. Their model minimized the sum of the supply chain inventory-related and emission costs with penalties imposed for exceeding CO2 emissions limits, resulting in a cost function of a piecewise convex form. Bazan et al. (2015b) proposed two supply chain models that considered energy usage and greenhouse gas emissions resulted from both production and transportation operations of a vendor and a buyer under an emission taxing scheme.

The model developed in Bazan et al. (2015a) considered the energy used by CO2 emitted from manufacturing and remanufacturing subject to emissions tax. They also accounted for emissions from transportation activities. They proposed the model based on a network in which a single manufacturer produced and shipped the product into the market and used items that are no longer of service to customers are collected from the market and returned to the single remanufacturing facility to be remanufactured or disposed of properly. They develop a total cost function with the numbers of manufacturing remanufacturing batches per cycle, and the number of times an item can be remanufactured as decision variables.
This paper extends the work of Bazan et al. (2015a) by considering a network consisting of N-retailers. Apart from this contributory extension, it assumes that the retailers collect the used items that reached their end of useful lives from their customers and ship them to a manufacturer or third party. Further, this paper adds a policy for scrap from manufacturing and remanufacturing processes to the studied model by considering waste the costs of disposing and transporting them.

The paper is organized as follows. The notations and assumptions are described in section 2. Section 3 presents numerical examples and discusses the results, finally, section 4 provides a summary and conclusion.

2. ASSUMPTIONS AND NOTATIONS

The notations and assumptions in this paper are the same as in Bazan et al. (2015a) except for those related to the retailers, which are from Chiu (2013). A notation list of the decision variables and input parameters is given below:

Assumptions: (1) A single product case, (2) Repaired items are as good as new, (3) Infinite production and recovery rates, (4) Demand known and constant, (5) Constant collection rates for previously used manufactured and remanufactured items, (6) Lead-time is zero, (7) Unlimited storage capacity is available, and (7) Infinite planning horizon

Notations:

Decision variables

n : number of manufacturing batches per cycle and integer ($n \geq 1$)

m: number of remanufacturing batches per cycle and integer (*$m \geq 1$*)
ζ : number of times an item is remanufactured where $\zeta \geq 0$ and integer

Decision variables dependent parameters

q_p: production batch size per cycle (units)
q_r: remanufacturing batch size per cycle, where $q_r = \frac{\beta_\zeta n q_p}{(1-\beta_\zeta)m}$ units
T_r: length of a remanufacture interval
T_p: length of a production interval
T : cycle time, where $T = T_p + T_r$
t_{1r}: remanufacturing uptime for the proposed system in an *interval* T_r
t_{1p}: manufacturing uptime for the proposed system in an interval T_p
t_{2r}: time required for delivering all quality assured finished remanufacturing products to retailers *in an interval* T_r
t_{2p}: time required for delivering all quality assured finished manufacturing products to retailers in an interval T_p
t_m: fixed interval of time between each installment of finished products delivered during remanufacturing downtime t_{2r}
t_n: fixed interval of time between each installment of finished products delivered during remanufacturing downtime t_{2p}
$I_k(t)$: on-hand inventory of perfect quality items at time t, where $k = r,p$
$I_{ck}(t)$: on-hand inventory at the retailers at time t, where $k = r,p$
β_ζ: actual proportion of items returned for recovery purposes when an items is recovered for a limited ζ number of times, where $\beta_\zeta = 1 - (1-\beta)/(1-\beta^{\zeta+1})$
w: wholesale price
p: sales price

Input parameteres

d: production rate
v: remanufacture rate
λ_i: annual demand rate for reailer i, where $\lambda = \sum_i^s \lambda_i \quad (i = 1,2,..,s)$
h_r: holding cost for a remanufactured item in serviceable stock ($/unit/unit of time)
h_p: holding cost for a manufactured item in serviceable stock ($/unit/unit of time)
h_{2i}: holding cost for the retailer ($/unit/unit of time)
h_u: holding cost for the repairable stock ($/unit/unit of time)
x: portion of defective items at a production rate d
y: portion of defective items at a remanufacturing rate v
β: normal proportion of items returned for remanufacturing when an items is remanufactured for an unlimited number of times, where $0 \leq \beta < 1$
c_{inv}: annaul investment in the design process of the product to, theoretically, be able to remanufacture it for an indefinite number of times
θ: investment increment factor that governs the ratio of investment for each remanufactured generation, where $0 \leq \theta < 1$
c_w: unit disposal cost ($/unit)
c_{ec}: carbon emissions tax for per ton of GHG emissions ($/ton)
a_p: emissions function parameter for manufacturing (ton·year^2/unit^3)
b_p: emissions function parameter for manufacturing (ton·year/unit^2)
c_p: emissions function parameter for manufacturing (ton/unit)
a_r: emissions function parameter for remanufacturing (ton·year^2/unit^3)
b_r: emissions function parameter for remanufacturing (ton·year/unit^2)
c_r: emissions function parameter for remanufacturing (ton/unit)
g_t: number of gallons per truck per distance travelled (gallons/truck)
e_t: amount of GHG emissions from one gallon of diesel-truck fuel (ton/gallon)
C_0': coefficient of the inverse model (the required energy at the machine to manufacture one unit) (kWh/unit)

C_1': coefficient of the predictor (the required energy per year when manufacturing is idle) (kWh/year)
C_0'': coefficient of the inverse model (the required energy at the machine to remanufacture one unit)(kW h/unit)
C_1'': coefficient of the predictor (the required energy per year when remanufacturing is idle) *(kWh/year)*
c_{en}: cost of energy($/kWh)
S_r: set up cost per remanufacturing batch($)
S_p: set up cost per production batch($)
K_{1i}: fixed delivery cost per shipment delivered to retailer i ($)
C_i: unit shipping cost for item shipped to retailer i ($)
H_1: maximum level of on hand inventory in units when regular production process ends
H_2: maximum level of on hand inventory in units when regular remanufacturing process ends
Δ: remanufacturing cost savings ($)
A: acquisition cost ($)
η: reverse logistics cost coefficient ($)
k: scale economies coefficient
b: payment received per collected (unit/transfer price)
c_m: unit cost of manufacturing a new product ($/unit)
c_{re}: unit cost of remanufacturing product ($/unit)

3. MATHEMATICAL MODEL

This model is similar to that of Bazan et al. (2015a) except for considering N-retailer integrated inventory system with scrap. Remanufactured and manufactured items (finished products) are screened, and those of acceptable quality are delivered to retailers, whom each has an annual demand rate λ_i. The retailers sell the items directly to customers. Remanufactured (repaired) and produced items are stored in the serviceable stock, while the used items in the second shop. The model assumes that collected used items are first screened, those considered not repairable are disposed of before reaching the repairable stock and useful ones are returned to the system, remanufactured and sent back to the market to fulfil demand (Fig 1.). There are m remanufacturing and n production cycles in interval T. The constant production rate P satisfies the condition $(P - d - \lambda) > 0$ or $(1 - x - \lambda/P) > 0$ and the constant remanufacture rate Y satisfies the condition $(Y - v - \lambda) > 0$ or $(1 - y - \lambda/Y) > 0$. These conditions ensure that the production and remanufacture do not go short on stock (where $d = xP$ and $v = yY$). The mathematical model was developed by adding some environmental costs such as GHG emissions and energy costs for manufacturing and remanufacturing to minimize the total cost of systems. The cost terms (1)-(6) were taken from Chiu et al. (2013). The on-hand inventory of scrap items during production and remanufacturing uptimes, t_{1p} and t_{1r}, are given as:

$$dt_{1p} = Pxt_{1p} = xq_p \text{ and } vt_{1r} = Yyt_{1r} = yq_r \quad (1)$$

The holding cost during production uptime t_{1p} and holding cost for finished products kept by the manufacturer during the delivery time t_{2p} is given as:

$$H_{sp} = h_p\left(\frac{H_1 + dt_{1p}}{2}\left(t_{1p}\right) + \left(\frac{n-1}{2n}\right)H_1 t_{2p}\right) \quad (2)$$

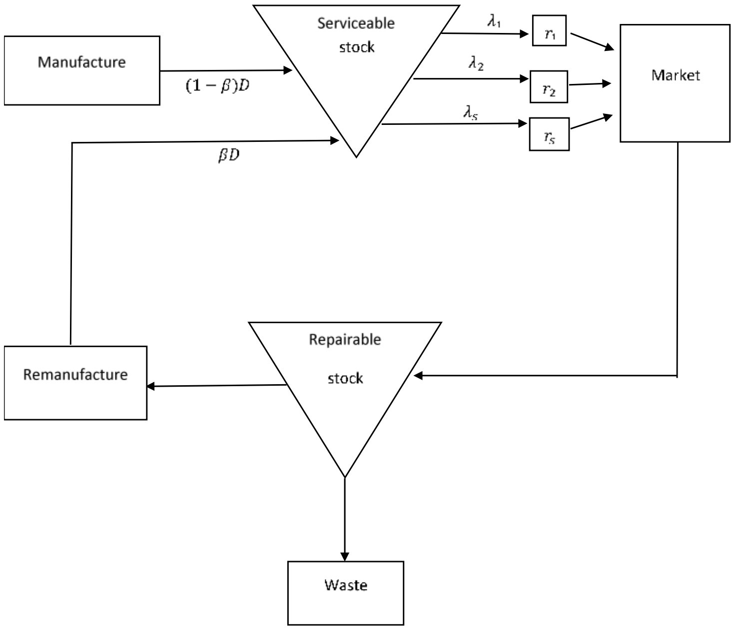

Fig 1. Flow of production and remanufacture products in the described system

Holding cost for finished products kept by the retailer for production and remanufacture during the delivery time t_{2p} and t_{2r} are given as:

$$H_{rp} = \frac{1}{2}\sum_{i=1}^{s} h_{2i}\lambda_i \left(\frac{T_p t_{2p}}{n} + T_p t_{1p}\right) \tag{3}$$

$$H_{rr} = \frac{1}{2}\sum_{i=1}^{s} h_{2i}\lambda_i \left(\frac{T_r t_{2r}}{m} + T_r t_{1r}\right) \tag{4}$$

The annual disposal cost of scrap form production and remanufacture is:

$$TW = \frac{c_w\left[xq_p + yq_r\right]}{T} \tag{5}$$

Total annual delivery costs from production and remanufacture to the retailers is given as:

$$TR = (n+m)\left(\sum_{i=1}^{s} K_{1i}\right) + \sum_{i=1}^{s} C_i\lambda_i T \tag{6}$$

The terms (7) to (12) were taken from Bazan et al. (2015a). The total annual holding cost for the repairable stock for production and remanufacture per cycle is given as:

$$HR = h_u \frac{nq_p}{2}\left(\frac{(\beta-\beta^{\zeta+1})}{(1-\beta)}\right)\left[\left(\frac{(\beta-\beta^{\zeta+1})}{(1-\beta^{\zeta+1})}\right)\frac{1}{m((1-x)+(1-y))}\left(1-m-\frac{\sum_{i=1}^{s}\lambda_i}{d}+1\right)\right] \tag{7}$$

Total annual set up cost for production and remanufacture per cycle and that for production cost are given, respectively, as:

$$S = \frac{mS_r + nS_p}{T} \tag{8}$$

$$C_p = C_p(\zeta) = \frac{c_m n q_p + c_{re} m q_r}{T} \quad (9)$$

Manufacturing batch size (Bazan et al., 2015a) is calculated as $q_p = \sqrt{A/(B + C)}$, where $A = \frac{\sum_{i=1}^{s}\lambda_i}{n}[(1-\beta)/(1-\beta^{\zeta+1})](mS_r + nS_p)$, $B = \left(1/2(1-\beta^{\zeta+1})\right)[h_p(1-\beta)(1-\sum_{i=1}^{s}\lambda_i/v) + h_r\left(n(\beta-\beta^{\zeta+1})^2/m(1-\beta)\right)(1-\sum_{i=1}^{s}\lambda_i/d)]$, and $C = h_u \frac{n}{2}\left(\frac{(\beta-\beta^{\zeta+1})}{(1-\beta)}\right)[\left(\frac{(\beta-\beta^{\zeta+1})}{(1-\beta^{\zeta+1})}\right)\frac{1}{m}\left(1 - m - \frac{\sum_{i=1}^{s}\lambda_i}{d} + 1\right)]$.

The annual costs of GHG emissions from production and remanufacturing activities, transportation and energy used for manufacturing and remanufacturing are given, respectively, by the following equations:

$$C_{GHGe} = C_{GHGe}(\zeta) = c_{ec}\frac{\sum_{i=1}^{s}\lambda_i}{(1-\beta^{\zeta+1})}[(1-\beta)(a_p P^2 - b_p P + c_p) + (\beta-\beta^{\zeta+1})(a_r Y^2 - b_r Y + c_r)] \quad (10)$$

$$C_{GHGt} = \left[\frac{\sum_{i=1}^{s}\lambda_i}{t_c}\left(1 + \frac{(\beta-\beta^{\zeta+1})}{(1-\beta^{\zeta+1})}\right)\right] g_t e_t c_{ec} \quad (11)$$

$$C_N = C_N(\zeta) = \frac{\left[\left(C_o' + \frac{C_1'}{P}\right) n q_p + (C_o'' + \frac{C_1''}{Y}) m q_r\right] c_{en}}{T} \quad (12)$$

The annual investment in the design process is given by El Saadany et al. (2013) as:

$$C_{inv}(\zeta) = c_{inv}(1 - e^{-\theta\zeta}) \quad (13)$$

Total annual cost can be written as:

$$TC = H_{sp} + H_{sr} + H_{rp} + H_{rr} + S + TR + TW + HR + C_p + C_{GHGe} + C_{GHGt} + C_N + C_{inv} \quad (14)$$

4. NUMERICAL EXAMPLE

In this section, the values of the input parameters were taken from Bazan et al. (2015a) and Singa et al. (2013) and are used to illustrate the behaviour of the developed model above, which is investigated for different values of scrap items x and y. Assume now a producer can manufacture a product at an annual rate of 60,000 and remanufacture 60,000 units. The annual demands for five different retailers are λ_i = 400,300,200,250, and 350 units, respectively.

The fixed delivery cost per shipment for five retailers are K_{1i} =\$ 100,200,300,400, and 500, respectively. The unit transportation costs to retailers i =1, 2, 3, 4, and 5 are C_i = \$ 0.5,0.4,0.3,0.2,0.1, respectively. The unit holding costs for the five retailers are h_{2i} =\$ 75,70,65,60, and 50. The optimal solution occurs at TC=\$125,682,745,where production and remanufacturing batches are n = 1 and m = 1, respectively, the number of times to remanufactured is ζ = 3, the total GHG emissions cost is \$12,340,617 (GHG_p =\$8,605,402+ GHG_r = \$3,735,215)the total energy cost is 7,453,855 (Cn_m = \$6,127,210 + Cn_r =\$1,326,645) and q_p =53.03 units, q_r =85.97 units. This example was solved for different values of x and y. The results are summarised in Table 2. It is shown that $GHG_p \geq GHG_r$ and $Cn_m \geq Cn_r$ while there have 0.3 of defective items for production and remanufacture. If the portion of defective items for production x increases, the total cost of the supply chain and the number of times remanufactured (ζ) increase, the sum of GHG emissions decreases and that of energy used increases. This indicates that if more defective items, x increases, are generated during production, remanufacturing becomes economical and have more environmental benefits for a firm. Vice versa, if y increases, it is optimal not to remanufacture ζ=0.

Table 1. List of input parameters (Bazan et al., 2015a)

Input Parameter	Value	Units	Input parameter	Value	Units
β	0.67	(%)	a_r	0.000000833	(ton/year^2/unit^3)
d	4,000	(units)	b_m	0.0012	(ton/year/unit^2)
γ	16,000	(units/year)	b_r	0.002	(ton/year/unit^2)
v	16,000	(units/year)	c_p	1.4	(ton/unit)
S_m	1100	($/setup)	c_r	1.4	(ton/unit)
S_r	400	($/setup)	c_{ec}	18	($/ton)
h_p	300	($/setup/year)	$C_0^{'}$	57.96	(KW h/unit)
h_r	100	($/setup/year)	$C_1^{'}$	1,855,744	(KW h/year)
h_u	100	($/setup/year)	$C_0^{''}$	18.9	(KW h/unit)
c_m	60,000	($/unit)	$C_1^{''}$	605,110	(KW h/year)
c_r	40,000	($/unit)	c_{en}	0.0928	($/KW h)
c_w	600	($/unit)	g_t	375	(gallons/trucks)
c_{inv}	18,000,000	($/year)	e_t	0.01008414	(ton/truck)
θ	0.2	(-)			
a_m	0.0000003	(ton/year^2/unit^3)			

Table 2. The behaviour of the model for different values of x and y.

y	x	TC	ζ	n	m	GHG_p	GHG_r	Cn_m	Cn_r	q_p	q_r
0.3	0.3	125,682,332	3	1	1	8,605,402	3,735,215	6,127,210	1,326,645	53.03	85.97
	0.5	141,772,545	5	1	1	2,306,000	4,047,925	9,645,922	7,530,612	46.77	86.37
	0.7	160,391,424	8	1	1	4,460,205	4,167,718	8,696,231	8,527,308	45.18	86.17
	0.9	183,334,520	10	1	1	7,360,428	4,228,306	8,670,525	9,739,000	43.65	86.22
0.5	0.3	141,253,276	0	1	0	2,079,000	0	3,278,342	0	125.65	0
0.7		141,253,276	0	1	0	2,079,000	0	2,302,543	0	125.65	0
0.9		141,253,276	0	1	0	2,079,000	0	1,450,346	0	125.65	0

5. CONCLUSION AND SUMMARY.

The purpose of governmental regulations is to enforce firms to make their supply chain systems sustainable. Modelling such systems, therefore, require considering additional costs to those of holding, setup, and ordering, such as GHG emissions, energy usage, and transportation, where Bazan et al. (2015a) was the first to do so in a reverse logistics context. The paper revisited and modified the work of Bazan et al. (2015a) by considering multiple retailers and scrap in manufacturing remanufacturing processes. The results showed that accounting for defective items for production significantly impact the total supply chain costs such as GHG emission, energy usage, remanufacturing and inventory policies. Manufacturers of electronic devices (cell phones, computers) realized the economic and environmental benefits of reusing disassembled parts in producing new products. The results also showed that a mixed strategy (remanufacturing and manufacturing) is more economical for both sides (vendor and retailers). Excessive scrap in remanufacturing may devoid it from its primary purpose of being an environmentally sustainable option. This work could be extended to consider energy from renewable resources, and for random retailers' demand, which, among other limitations, are left for future work.

ACKNOWLEDGMENTS

M.Y. Jaber thanks the Natural Sciences and Engineering Research Council of Canada (NSERC) for supporting his research activities. The second author thanks the FEA Dean and the MIE Chair at Ryerson University for partially supporting his travel.

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LOGISTICS AND THE FUTURE: FROM DEMATERIALISATION TO DEGROWTH

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ABSTRACT

Purpose
The purpose of the paper is to do an extensive literature survey of the current trends that are driving macrologistics with a special focus on dematerialisation in the context of the fourth industrial revolution and how this can facilitate a shift towards more sustainable logistics. We hope that this narrative can serve as an invitation to further debate and research on the future role of logistics in sustainability on national and global scales.

Design/methodology/approach
The literature review is conducted using a desktop research methodology with Google Scholar as the main literature source. The nature of the research outputs is qualitative and exploratory in order to enable the development of a discussion document to serve as basis for further debate and research around the topics of logistics and future sustainability on national and global scales.

Findings
The concept of sustainability regained prominence with the 1987 Brundtland report prepared for the United Nations. Towards the turn of the 21st century the concept of economic dematerialisation came to the fore again, underscoring the anticipated inability of the earth to sustain the material needs of the exponentially-increasing population. Significant technological innovations have made the concept of dematerialisation more achievable. The anticipated economic impact of this is labelled the fourth industrial revolution which naturally heralds a similar revolution in logistics for dematerialising its resource requirements and use. In order to realise the potential benefits of this revolution in a triple bottom-line sense a fourth pillar of sustainability is called for. This refers to a cultural revolution, which can already be seen on some grassroots levels, where demand itself is reduced, we truly get by with less and that which we get by with is sourced, moved, consumed and circularised equitably and sustainably.

Value
Logistics has started to make a major shift towards sustainability, but little work exists on how to prepare for logistics' role in becoming an enabler of sustainability on national and global scales. In order to prepare a new generation of logisticians we need to begin this discussion

INTRODUCTION
Logistics has been on a global material march of vast increases in tonne-kilometres and freight movements, supporting exponential global trade growth in excess of GDP growth since the 1950s. This growth incurred insulated from being charged for the environmental and societal damages incurred due to the increased logistics footprint. On micro- and meso-economic scales there have been significant advances in logistics efficiencies, this now needs to be expanded to a national scale. The transport sector contributed 22% to global emissions in 2015 (International Transport Forum, 2018), while the improvement in road freight energy intensity over the period 2000-2016 was zero percent and that of international shipping 2%, compared to economy-wide improvements of 12%

(International Energy Agency, 2018). In addition, transport 'enables' emissions in the rest of the economy by facilitating specialisation, forcing ever longer distances between supply and demand (Van den Berg and Lewer, 2007).

Whilst some economists still echo Robertson's (1938) sentiment that trade is the "engine of growth" or Kravis' (1970) emphasis that trade is the "handmaiden of growth", these views are changing to questioning unchecked increases in trade and growth as society's measures of wealth. Logistics is entering a new age with the focus shifting from being the great enabler of trade to the enabler of sustainability.

The purpose of this paper is to create a discussion document regarding the role of logistics in enabling sustainability in the fourth industrial revolution and onwards. The paper is based on a comprehensive literature review and is structured as follows. At the outset, the basic principles of sustainability are recapped, followed by a description of how increasing dematerialisation can support this. Subsequently, the emergence of the 4th industrial revolution is described, leading to the question whether this could herald a movement towards degrowth. This is followed by an understanding of how logistics can both benefit from and support these trends, with specific mention of challenges and opportunities in the developing world. A potential driver for the limited progress in sustainability impacts on the ground is discussed, as well as how this plays out in the logistics arena. We hope that this narrative can serve as an invitation to further debate and research on the future role of logistics in sustainability on national and global scales.

METHODOLOGY

The literature review is conducted using a desktop research methodology with Google Scholar as the main literature source. Google Scholar is an extensive academic indexing source, drawing material from academic publishers, professional societies, online repositories, universities and other web sites, and includes peer-reviewed publications, theses, books and industry publications. It therefore encompasses resources associated with practitioners as well as academics (Francis et al., 2017). Furthermore, the reference lists of relevant sources were interrogated to expand the review.

Given the nature of the research topic, a very broad literature survey was undertaken, not limiting the search to predefined search terms. At the outset, aspects such as "key drivers of logistics", "future trends in logistics", "sustainability" and "externalities" were searched. Based on learnings from these results, further searches centred around "dematerialisation", "Industry 4.0", "4th industrial revolution", "Logistics 4.0", "decarbonisation", "degrowth", "climate change", "developing world", and various combinations of these search terms. Many of the sources are publically available. Subscription-based sources were obtained via Stellenbosch University Library and Information Service located in Stellenbosch, South Africa.

The nature of the research outputs are qualitative and exploratory, with the intent to build a narrative around the potential future role of logistics in sustainability on national and global scales to serve as invitation to intensify debate and research, therefore a very broad range of literature was consulted and a keyword or publication-type analysis neither feasible nor the goal of the review.

THE SUSTAINABILITY IMPERATIVE

Sustainability moved into focus as economic growth ran rampant, depleting natural resources, harming the environment, concentrated welfare in but a few people and created a myriad of economic failures. Sustainability is defined as, at minimum, aiming for a balanced focus on the economic (profit), social (people) and environmental (planet) impacts of economic activity (United Nations, 1987):

- **Economic sustainability** talks to real growth and not speculation, i.e. to earn an 'acceptable' profit for long-term viability (as this has could have positive impacts on *inter alia* societal stability, job creation and work satisfaction), without having a detrimental impact on the environment or any stakeholders. Recent recessions resurfaced the debate whether a natural limit to economic growth has been reached and whether economic stabilisation is not more sustainable (King, 2013).

- **Social sustainability** imagines a world where welfare is distributed evenly, leading to an end in mass migrations and man-made disasters, and where there is effective natural disaster relief. Despite the exponential economic and technological advances in the past 50 years, the OECD (2015) reported that "global social inequality has hit a new record". Rogoff (2004) aptly stated that issues of inequality, rather than subsistence, will increasingly take centre stage in the poverty debate.
- **Environmental sustainability** refers to practices that do not compromise the environmental resources for current or future generations (Goel, 2010). A reduction in carbon emissions, one of the major contributors to climate change, is a key focus area of environmental sustainability. In 2018 global carbon emissions reached the highest levels on record (Dennis and Mooney, 2018). Piecyk and Björklund (2015) recognised the role of multiple stakeholders beyond business, such as regulators, governments, consumers and researchers to develop a global response to sustainability. The approach has therefore become transnational and cross-functional.

One of the most important contributions on a grand scale to mitigate against non-sustainable growth has been dematerialisation.

DEMATERIALISATION AND THE 4TH INDUSTRIAL REVOLUTION

Dematerialisation means doing more with less. The dematerialisation of manufacturing came to the fore when biotechnology, microelectronics and new materials lowered the weight and inventory of production material (Junnen et al., 1989). Schütz and Welfens (2000) redefined dematerialisation as the "reduction in the use of nature (material and energy) per unit of output". Riele et al. (2000) maintained that the emphasis should not only be on less material, but a reduced environmental impact of material flows. Santos (2011) also referred to dematerialisation from the demand-side as the "means to shift the relationship between consumer satisfaction and the need for materials to provide such satisfaction". To achieve this goal therefore requires a shift in paradigms from both the supply-side with organisations offering low resource products and services, and from the demand-side with consumers demanding such products and services.

The shift to creating a circular economy is an attempt to support these processes of reducing resource depletion by retaining as much as possible of the resource value embedded in products (Hannon, 2016). Liedtke (2018) maintains that this will only be sustainable if goods are as dematerialised as possible and allow for continued use or re-use, or, as a last resort, recycling with minimal material loss.

It is here where the advent of the 4th industrial revolution (or Industry 4.0) is pertinent, i.e. the convergence of dematerialisation and the digital revolution which is creating an exponential number of secure connections of machines, devices, sensors (the IoT) and people (through mobile technology) to create an Internet of Everything (IoE) with ubiquitous real-time information-sharing, communication and collaboration abilities. This creates the basis of a 3-way collaboration: human-to-human, human-to-machine and machine-to-machine (Hermann et al., 2016) to enable intelligent industrial operations using advanced big data analytics for transformational business outcomes (Industrial Internet Consortium, 2018). This is the first time an industrial revolution is predicted a priori, not observed ex-post, creating unique opportunities to actively shape the future, especially as the economic impact of this revolution is expected to be a game-changer in terms of increased operational effectiveness but also enabling the development of entirely new business models, services, and products (Hermann et al., 2016).

In terms of logistics this allows for a step change in demand forecasting, logistics efficiency, scheduling and inventory reduction, so-called Logistics 4.0.

LOGISTICS 4.0

Building on the principles of Industry 4.0, Logistics 4.0 can be defined as a fully integrated, collaborative supply chain that responds in real-time to meet changing demand and changing conditions in the value chain itself. Inbound and outbound flows can therefore be streamlined by intelligent systems, connecting shared information through an Internet of Things approach (Baretto et al., 2017). Ultimately it should result in the "connection of production and consumption using digitalised artificial intelligence" (Bukova et al., 2018). Logistics dematerialisation is therefore then delivering similar or more logistics outputs with fewer inputs. This translates into four steps:

1. **Lowering the demand for logistics services:** Reducing demand relative to economic output by accepting lower end-consumer choice both in terms of product variety and speed of delivery, reverting to geographical proximity of supply and demand through reshoring and nearshoring, and introducing a circular economy (where waste is minimised, if not eliminated). These choices need to be enabled by improvements in local supply chains which require societal adjustments and a reversal of the instant gratification enabled by technological advancements and cheap oil. Other developments that will reduce the demand for logistics are recycling at source, additive manufacturing (or 3D printing) (Attaran 2017) and shared use of transport and logistics infrastructure (Kagermann, 2015).
2. **Reconstructing supply chains:** From a policy perspective one of the most important strategies is for the direct user of a service to pay the full cost of that service, including the externality damage caused (McKinnon, 2015). Through bearing the full costs of externalities consumers who insist on a wide variety of choice delivered at speed over vast distances will find these items exponentially more expensive than locally produced items. This will empower decision-making towards supply chains with less externality damage. Common amongst these could be the shift from road to rail or waterways.
3. **Improvements in logistics' productivity:** Once demand is understood, supply chains are networked with manufacturing facilities in real-time (through the IoE) so that the supply chain can respond instantaneously to supply variability. This will enable efficient and reliable organization of transport between different locations and throughout the entire life cycle of goods through real-time tracking in order to speed up processes, reduce waiting times, distances travelled, handling and empty loads, which all cut out unnecessary costs (Kagermann, 2015).
4. **Improved logistics efficiency**: A reduction in the consumption of production factors per unity of activity such as less fuel, fewer driver hours and reduced emissions. Disruptive technologies such as driverless trucks and last-mile drone delivery come to the fore (Connolly & Coughlin 2017; Van Meldert & De Boeck 2016). The unitisation of shipments into globally standardised 'packets' through the use of modular 'black-box' containers (meaning that goods will only be handled at points of supply and demand), referred to as the physical internet, is also being considered (Crainic & Montreuil 2016). The IoE will enable the physical internet. Real-time information will also make supply chains more robust as it will allow early detection and location of any disruption to the system, thereby enabling a rapid response (Kagermann, 2015).

In the hierarchical process toward logistics dematerialisation, the goal is then to induce the lowest possible level of demand, select the most sustainable supply chain to service this demand, engineer optimum productivity of this chain, and then deliver this with the minimum resources. However, typically the fourth initiative (increased efficiencies) receives the most attention, i.e. aspects such as fuel efficiency for road vehicles.

There are major differences in logistics policy, infrastructure development, dematerialisation and the need for macrologistics policy between the developed and developing world. Oosterhaven and Knaap (2018) argued that small returns on bottleneck removal can be expected in developed economies given that reasonable alternatives already exist. The impacts of new infrastructure in developing countries can however be considerable. With little competing transportation modes of often low quality, most improvements tend to result in large returns. Developing economies therefore have the opportunity to leverage the significant investments earmarked for rail, road, inland waterways and ports through central integrated infrastructure planning. This includes investing in logistics hubs, freight villages, port extended gates and dry ports, where freight is naturally consolidated, easily transferred between modes, and supply chain links are shortened with light manufacturing at the intermodal hubs. This in itself will contribute to dematerialisation as the most efficient supply configuration is engineered.

FROM DEMATERIALISATION TO DEGROWTH

Demaria et al. (2013) define degrowth as "a democratically-led redistributive downscaling of production and consumption in industrialised countries as a means to achieve environmental sustainability, social justice and well-being". Balatsky et al., (2015) concluded that a linear extrapolation of current consumption is unsustainable and that adjustments will have to be significant. The historic damage was obviously caused by the developed world, but future damage, due to especially population growth, will come from the developing world (Shi, 2002). Kallis (2017) illustrated that the required dematerialisation will have to lead to degrowth as the monetisation of dematerialisation will merely lead to new investments that will still have a material component. These ideas are however not new. A global think tank, the Club of Rome, revived this debate as far back as the 1970's (Meadows, et.al., 1972). They modelled the restraints on growth and forecasted that within a hundred years a collapse of the economy and the ecosystem could be expected. It is now halfway through their prediction horizon, but over this period their predictive timeline has been uncannily accurate and the quest for a turnaround between of conspicuous consumption continues (Turner, 2008).

Part of the debate is highlighted by the case against the 'great measure' of economic growth, GDP. Daly and Posner (2011) summarised this in terms of the three pillars of sustainability. In growth terms, GDP does not distinguish between speculative gains and real economic value and does not measure non-market activities contributing to growth. In social terms, GDP does not measure growth distribution at a household level; it measures quantity and not quality and does not distinguish between 'positive' welfare spending and 'defence' spending. Social well-being indicators such as poverty, literacy, life expectancy and sustainability issues are largely ignored. Alternative indicators such as the 'genuine progress indicator' (GPI) have been proposed which aims to measure the welfare generated by economic activity, 'counting the depreciation of community capital as an economic cost' (Kubiszewski et al. 2013). The existing Gini coefficient can also be used as a well-being index (Barro's, 1999).

THE FOURTH PILLAR OF SUSTAINABILITY

Ever since Fouvier (1768-1830) explained the greenhouse gas effect on the planet (Kellog, 1987), mankind's response has been less than satisfying. Paulson (2017) enquired why all the interventions of the past 50 years led to more or less no change in our habits. She contended that by "appealing to individual reason, scientists and policy-makers disregard systems of culture and power" and that "individuals' ability and willingness to moderate their involvement in expansionist practices and institutions involves more than rational decision-making". The challenge is that an awareness has to be created that the "the whole is other than the sum of the parts" (Koffka, as quoted in Wong, 2010). This was aptly described by Hardin (1968) as the 'Tragedy of The Commons Effect'. To combat this effect many researchers, such as Sustainable Aotearoa New Zealand (2009) propose that environmental protection and social development should take precedence over GDP growth. The challenge is how to reach this goal.

Yencken and Wilkinson (2000) propose a fourth dimension of sustainability, i.e. in the words of Hawkes (2001) "that a sustainable society depends upon a sustainable culture where "cultural vitality is as essential to a healthy and sustainable society as social equity, environmental responsibility and economic viability". The challenges experienced with developing a shared sustainability construct could be this missing element.

One of the drivers of this cultural apathy could be fear about the future. Many observers portray a positive view of the human role in the 4th industrial revolution. IBM (2014) sees the role of humans shifting towards strategic decision-makers and flexible problem solvers, with key roles such as community managers, mobile developers and big data analysts. Complexity will therefore increase due to the highly networked, interdisciplinary working environment and the requirement for the autonomous execution of diverse tasks (Kagermann, 2015). Yet, despite the visions around upskilling and lifelong, customised learning, it will probably not be possible to provide jobs for all. While still controversial, this brings discussions around a universal basic income to the fore again. The intent is to reduce both insecurity (in meeting basic needs) and, over time, inequality within a population which could be almost self-funding due to welfare savings, the abolishment of personal tax allowances, and reduced bureaucracy around current state assistance schemes. A sociological rationale for this is that it can, over time, induce more positive choices as basic needs are met and people have the freedom to engage in educational activities or charitable activities that have positive spill-over effects (Nettle, 2018).

LOGISTICS AND THE FUTURE

Ceniga and Sukalova (2015) made a strong case for logistics' contribution to a sustainable low-carbon economy to reverse its historical impact. The authors expect various stakeholders to pressurize logistics: customers will insist on carbon footprint knowledge, investors will require sustainable business models, employees who have adopted sustainable approaches at home will insist on the same in the workplace, political leaders will charge for externalities and industry alliances will develop standards. Logistics can be part of this discussion and lead the way or be a 'victim' of circumstance.

Tokar (2010) maintains that it is logistics' lack of behavioural research that causes it to be a follower rather than leader, stating that "the practical nature of logistics and the vast amount of human interaction in supply chain management instead implies that these fields should be at the forefront of such research". This is echoed by Tsai et al. (2012). According to Nguyen (2017) human resource development will remove implementation barriers and improve performance, but real change management goes much further than this. The logistics of the future will have to acquire a much more "human face". The march of dematerialisation, digitalisation and disruptive technologies in the developed world is real. The industrialisation and massive growth developments in the developing east is also real. Logistics, however, has two major shortcomings in both areas:

- Logistics failed to understand human behaviour and need to engage with the human psyche in a much more organised, deterministic and scientific way.
- Logistics failed to guide infrastructure and policy in the developing world. The theory was "owned" by the developed world where logistics was mostly seen as a market economy construct. It is largely absent in the macro-economic development discussions of the developing world where the issues of new infrastructure and policy required more entrenched and developed macrologistics theory.

Correcting these shortcomings can enable logistics to play a leading role in addressing the seemingly unavoidable consequences of climate change and the impact of increasing natural and man-made disasters (such as over-extraction of groundwater and food imbalances between the developed and developing world) (Houghton, 2005). In these scenarios, trade-offs will not be monetary, but in terms of benefits to human health and the environment.

CONCLUSION

Material logistics is on the decline, more so in the developed world, but as the developing world acquire new technologies and a larger middle class it will happen there as well. There is a technological background to this driven by digitalisation, lighter materials, better and smarter logistics, disruptive technologies and industry 4.0 in general. There is, however, also a sustainability background that talks to “less”. Less end-consumer demand, better and ecologically more sustainable supply, fewer activities (kms and handling) and using less resources (fuel, driver hours, externalities) to deploy these activities. Eventually, however, we will be faced with reduced growth and eventually degrowth where logistics, in the next 100 years, will be required to be measured on contribution to survival rather than economic growth.

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A REVIEW OF SUSTAINABLE SUPPLY CHAIN MANAGEMENT IN THE TEXTILE AND CLOTHING INDUSTRY OF ASIAN EMERGING COUNTRIES

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ABSTRACT
Purpose: The increasing awareness of SSCM issues within the textile business in Asian emerging countries (AEC), with different recent occurrences like devastated accidents of Rana Plaza and Tazreen Fashions in Bangladesh, the inhuman working conditions of Vietnam and contaminations of the local environment of India, has encouraged research into this area. However, there now exists a need to consolidate existing knowledge, and this influenced the researchers to present a consolidated view of sustainability in the current landscape. Therefore, the purpose of this research is to retrieve, scrutinize and synthesize the available research and get an in-depth knowledge about the SSCM in textile and clothing (T&C) industry and identify thefruitful areas for future research within the AEC context.

Design/methodology/approach: A systematic literature review method, as proposed by Denyer and Tranfield, (2010), along with a self-developed framework is applied to assess the existing research papers available in selected 18 Asian emerging countries. Reviewed papers are collected from 5 scholarly databases and a pre-defined research protocol established and maintained for the quality assurance of the selected 41 reviewed papers.

Findings: This research revealed an in-depth insight of SSCM of the AEC countries in terms of T&C industry. The review argues that SSCM could leverage the sustainable competitive advantage among business along with their sustainable factors like-environmental/green issues, carbon emission/foot print in SCs while different types of models like – fuzzy inference system, TQM, LP played a vital role in the operations. Moreover, it portrayed that factors like green mind set, attitude, leadership and management style of individual organization actors are also responsible for the sustainable practice in T&C industry and highlighted that, the AEC countries are focused on more government legislation and trade barriers for their sustainability rather than anything else in case of T&C business.

Value: This paper synthesizes the available research papers of SSCM in T&C industry within the AEC context, identifying future research opportunities. The recommendations could provide guidelines for the academic and practitioners to focus on more targeted areas for efficient and effective use of SSCM within the context and also provide an important basis for reporting available research in the field of SCM.

Research limitations/implications: The practical contribution of this research is to support the understanding of SSCM in textile business. Therefore, future research should consider evaluating a focal firm's comparative SSCM by measuring the functional and relational aspects of T&C industry and as well as comparing findings from other industries.

INTRODUCTION

Consumers, legislation bodies and other interested parties are creating pressure for better environmental, social and economic performance from organizations through the responsible management of products, processes and services. The textile and clothing industry (T&C) is not excluded from this wave. More precisely, the current adverse global conditions of the T&C industry, such as - the Dhaka disaster in 2013, where more than 1100 workers were killed, the inhuman working conditions of Vietnam, and contamination of the local environment of India- were frequently mentioned as a problems in relation to the sustainability of T&C business'es (Huq et al, 2014; Chowdhary and Quaddus, 2015;

Yadlapalli et al., 2018). These events also highlighted the need for a sustainable strategy which should guide todays T&C business. Therefore, with the triple bottom line (3BL) view (Elkington, 1997), an organization's strategy should simultaneously consider and integrate various supply chain paradigms, in order to meet current consumers' demand efficiently, effectively and sustainably (Seuring and Muller, 2008; Caniato et al., 2012; Choi and Chiu, 2012). The literature has also suggested that sustainable supply chain management (SSCM) is now a parameter for the continuity of T&C businesses, and aligned with the philosophical and cultural beliefs of consumers (Rajeev et al., 2017; Pagell and Wu, 2009).

The majority of research regarding the sustainability of the T&C industry has taken place in a developed country context (Luken, 2006; Hussain et al., 2015), despite clear relevance to developing countries. Yadlapali et al, (2018) and Huq et al, (2014) suggest an immense need for additional research to be carried out on the developing country context and especially on the Asian emerging countries (AEC) context which are gradually becoming a hub for clothing export (Chowdhary and Quaddus, 2015). To support such endeavors, this paper aims to present a consolidated view of SSCM in the AEC textile and clothing industry through a systematic literature review (SLR), leading to the development of a conceptual framework for future research.

THE T&C INDUSTRY IN AEC COUNTRIES

Being a relatively low-cost labour-intensive activity, T&C and its value-added service industry is one of the leading sectors where emerging (i.e. developing and least developed) countries can offer a comparative advantage in business (Christopher et al.2004; Wiils and Hale, 2006). Moreover, this industry has been considered as a development lynchpin for governments and entrepreneurs as a gateway for foreign investment (Luken et al., 2008; Amaeshi et al., 2008). The below Figure 1- shows T&C exports for the AEC region in 2015 (WITS, 2018). It is clear that some Asian countries (e.g. Bangladesh, Cambodia, East-Timor, Nepal, Pakistan and Sri Lanka) greatly depend on textile business for their total economic development, while others like Afghanistan, India and Vietnam are placing a higher emphasis in this business than before. As the textile manufacturing sector is expected to continue its rapid growth, the balance between adaptation of SSCM and economic growth has become a critical issue that requires more attention rather than previously (Maisam & Abbasi, 2017; Huq et al, 2014).

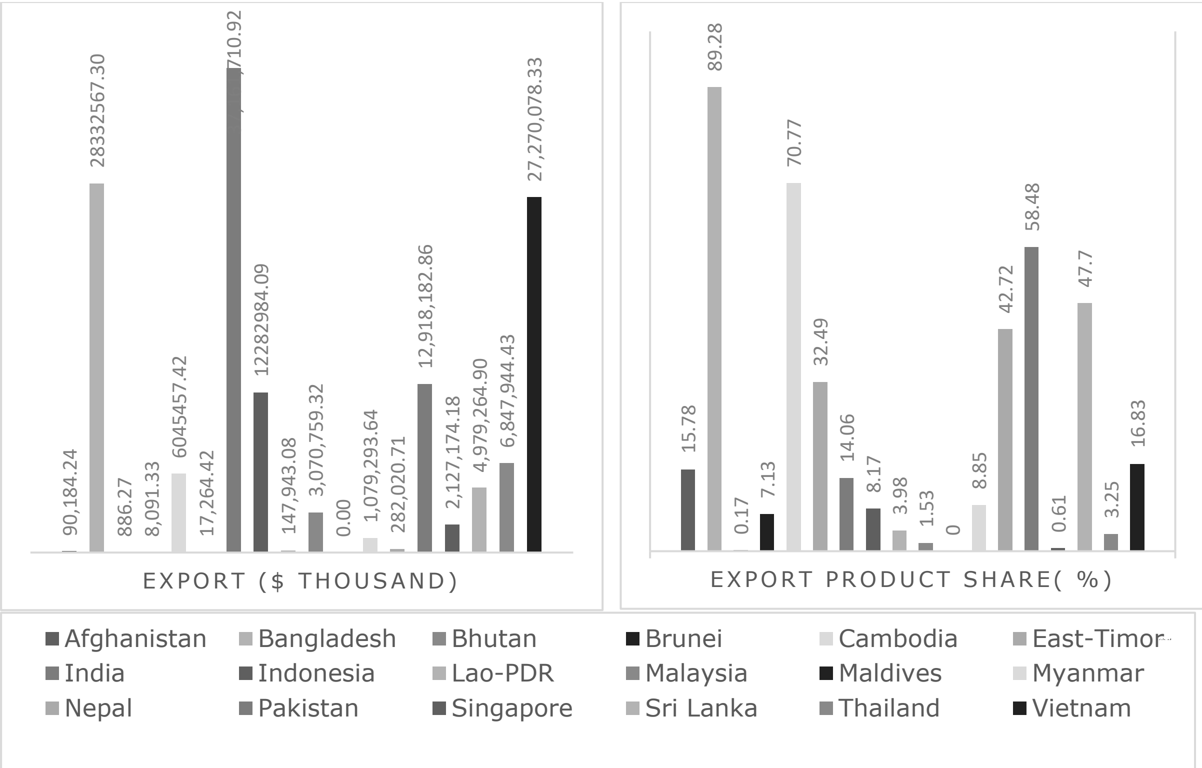


Figure 1: T&C exports for AEC countries, 2015 (WITS, 2018)

Recent literature has shown that the drivers of and barriers to the adoption of SSCM practices in the T&C industry have been driven by multiple factors (Kannan, 2018; Gards et al., 2018; Deepika et al., 2017; Chowdhury and Quaddus,. 2015). In the AEC context, firms have started adopting SSCM practices due to an increase in motivational derivers from stakeholders to consumers (Perry and Towers, 2013), legislation bodies/authorities (Amindoust and Saghafinia, 2017), and other interested parties like suppliers (Yadlapalli et al, 2018).

METHOD

This research adopts a SLR approach, covering articles published up until 2018. A SLR relies on a rigorous and well-defined approach to reviewing the literature in a specific subject area (Vom Brock et al., 2009) and the prescribed output of such literature review could consolidate and evaluate the intellectual territory of a certain fields as well as can identify knowledge gaps to be filled in order to develop the existing body of knowledge further (Tranfield et al., 2003). For this paper, the researchers follows the same stages given by Seuring and Gold (2012) and shape the work along three steps:

1. Journal/material selection: setting the approach by providing a self-developed framework for selecting the papers by defining the exclusion and inclusion criteria as well as their adopted searching string(s).
2. Descriptive analysis: descriptive analysis provides information about the available definitions of SSCM, the number of publications per year and their geographical distribution of the reviewed papers and their methodological viewpoint to illustrate the emerging trend of sustainability among publications. Descriptive analysis will be presented in the form of a histogram.
3. Thematic analysis: presenting the summated themes derived from the main findings of the SLR (i.e. evaluations and propositions of the material to establish future research paths/query).

Figure 2 shows the stages followed in the selection of the papers for this study. In the first step the initial set of papers was collected based on structured keyword search string(s) and the screening of the titles to retain papers that appear to be aligned with the general research topic. To ensure the validity of this research project, the 1st cluster of reviewed papers have been coded primarily. Later on, the coding file and the summated papers (1st cluster of the reviewed paper) have been cross-checked by the authors to ensure reliability and consistency.

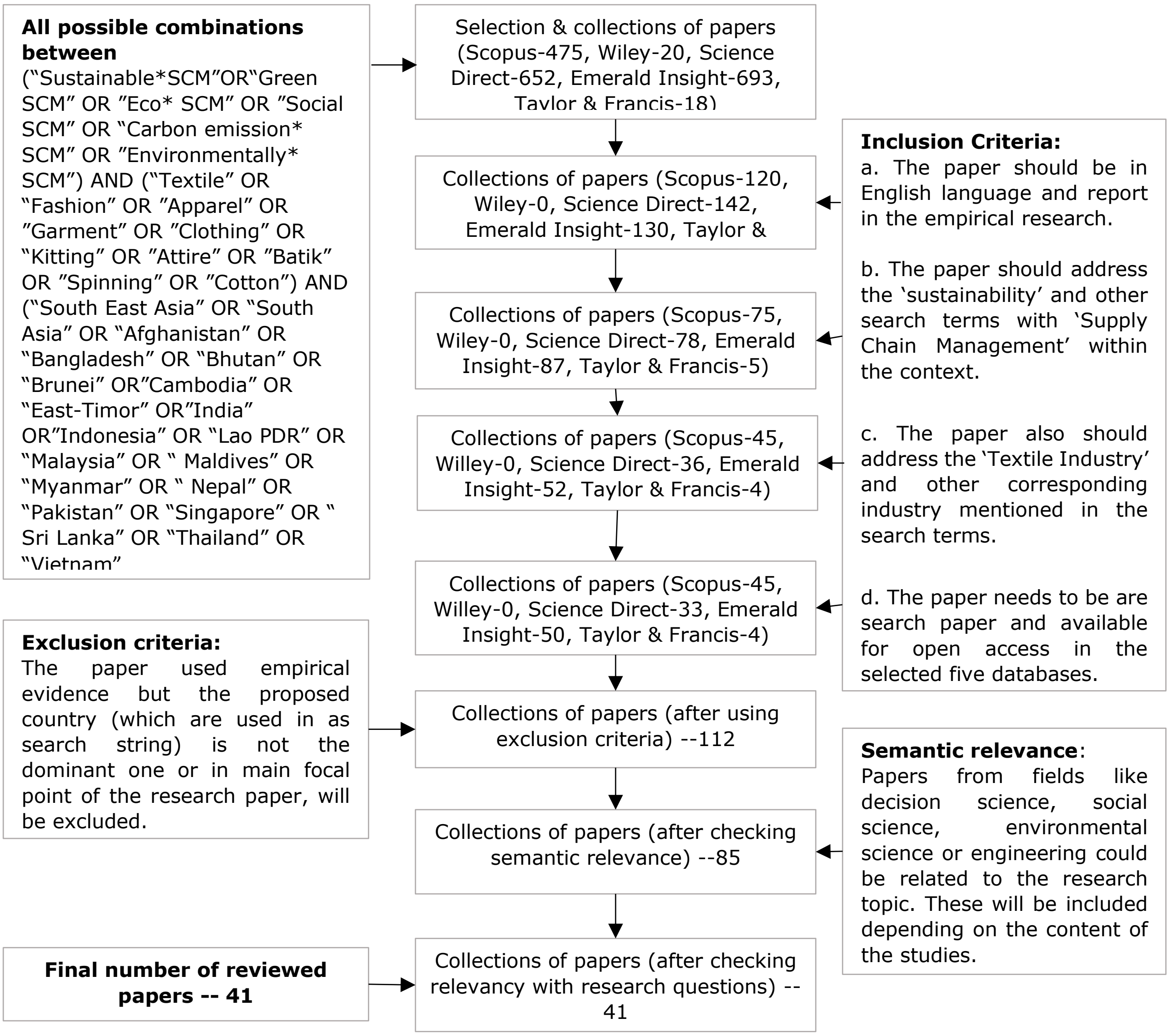


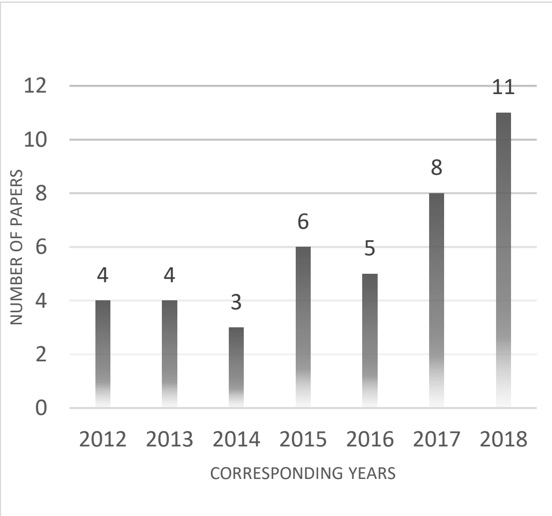
Figure 2: Systematic literature review process

DESCRIPTIVE ANALYSIS

'Sustainability' issues in supply chain, especially in T&C industry emerged as a popular body of literature since 2000 (Baskaran et al., 2012). However, as Figure 3a, shows SSCM in the T&C industry in AEC were neglected until 2012.Hence, a growth trend from 2015 onwards is also visible in Figure 1. It depicted the fact that the trends of the papers in T&C industry in the proposed context significantly increased within the last five years. More prominently, with nearly 60% of the research papers published in last three years (2016 to 2018). This clearly represented the increasing significance and urgency of this context as a research topic and indicated the increasing focus on the sustainability between SSCM and firm performance of T&C businesses, in the AEC context. Further, Figure 3b- illustrates the countries reviewed in this research study. A good number of the journals papers has focused on India (19 papers) and Bangladesh (9 papers). By contrast, it is apparent that

11 AEC countries identified in Figure 1-, have no papers focused on T&C industry context, especially in the SSCM field. There are several potential reasons why India and Bangladesh has received the most attention (nearly 68%). For India, 3.7% workforce are engaged in this industry and it represents 13.8% of their total national export earnings (Baskaran et al., 2012) while the industry is characterized by power and skill shortages as well as inadequate financial investment (Baskaran et al., 2012). Clothing exports in Bangladesh increased nearly ten-fold over recent years (Chowdhary et al., 2015) and the deadly occurrences (such as the Rana Plaza collapsion and fire accident at Tazreen Fashion) encourage SSCM research (Maisam & Abbasi, 2017).

Yet, a good number of papers also focused in Sri Lanka (5 papers) and in Vietnam (5 papers). In case of Vietnam, the T&C industry is growing by 15% per year which contributed to 15% of their total GDP (Lim et al., 2017). Nevertheless, this country still faces lack of supply abilities which create a significant difference in value- added activities (Ngai et al., 2014). In the case of Sri Lanka, this industry is the country's largest foreign exchange earner, generating nearly 43 % of their total export earnings (Loker, 2011 and Kelagama, 2005). However, the industry is focused only on the core basic garments rather than the high street fashion trends (Yatawara, 2007). Though these countries- possess huge importance in the T&C sector, there may be biases in academic research as a result.



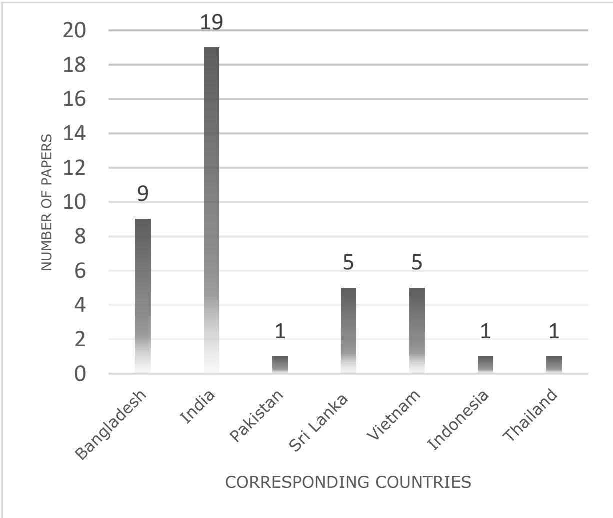


Figure 3a: Year of Publications Figure 3b: Geographical distributions of the papers

Further, the reviewed papers have taken diverse perspectives to define SSCM and these definitions can be distinguished according to their emerging characteristics. Table 1, illustrates some of the key characteristics of these definitions. Often, authors the reviewed papers- incorporate a specific/ single aspect of sustainability rather than combine all dimensions of 3BL. Another, interesting fact is that some of the definitions are driven by the notion of the pressure from stakeholders and resonate with the concept of stakeholder theory and resource-based view (Hasim et al., 2017; Mahmoudi and Barzoki, 2018; Jayanta and Azhar, 2018). From a more operational outlook, it seems that a great deal of them used SSCM definitions for considering the underlying internal and external business of T&C industry with a specific emphasis on the role of relationship between SC partners (Perry and Towers., 2013; Amindoust and Saghafinia., 2017).

Type of definition	Characteristics of definition	Number of Papers
Functional/ Operational	SSCM is cornered about the current use of raw materials (e.g. energy, working force and equipment) which are mostly used in procurement and support firms to continue their operations and creates value while compromising conventional SCM constructs.	7
Transformational and Ecological	SSCM represents an evaluation of firm's activities which continually address the economic sphere with environmental/ eco-logical/ green aspects over long term orientation.	3
Relational	SSCM mostly relies on the relationships between suppliers, intermediaries, stakeholders, government and other members of the SC while focusing on the economic and environmental aspects of SCs.	5
Social	SSCM is concerned about the societal magnitude of surrounding environment and engage to truly sustainability oriented advancement while improving the firm's employee's sustainability	8
Strategic marketing	SSCM represents an evaluation of firm's activities which continually address firms' operation's direction for the forth coming planning with its after selling service, performance retention and potential leverage for competitive advantage	2

Table 1: Key characteristics of SSCM definitions

THEMATIC ANALYSIS AND DISCUSSION

The third step is to identify the variables for literature coding, which tends to explore the research gaps of the literature review. The papers were coded to identify the key themes of SSCM from a 3BL perspectives: economic, social and environmental. The results can be seen in below Figure 4.

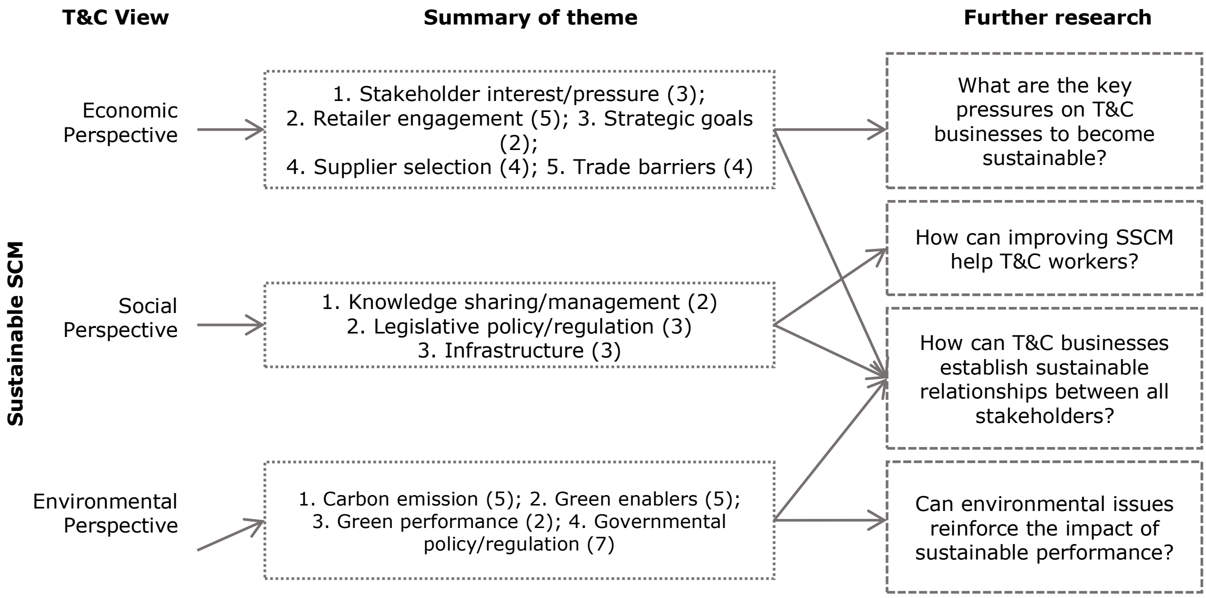


Figure 4: An integrated framework for SSCM in the T&C industry of Asian Emerging Countries.

In case of economic perspectives, stakeholders' interests for being sustainable (Kannan, 2018), identified that firms'- can gain competitive advantage by analysing their stakeholders while Huq et al., (2014) suggested that in the absence of intense stakeholder pressure, buyers can improved their performance by using their own strategies with suppliers. Although potentially contradictory, these two findings suggested that stakeholder'-s' interests and corporate interest are guided jointly for the development process of sustainability and created immense pressures on firms (Freeman, 2010). With supplier selection, firms have to consider numerous critical success factors including inventory level reduction, pollution control, quality management, shorter delivery time, quality, social equities, labour health, and work safety in their decision making process (Khurana & Ricchetti., 2015).

With the social perspective, Lim et al (2017) highlighted the positive relationship between knowledge management and stakeholder's pressures towards SSCM. Sivaprakasam et al, (2014) and Soundararajan et al., (2018) focused on the meaning of knowledge management while discussing its effect on SSCM. Yadlapalli et al (2018), argued that the supplier qualification mechanism is a critical for T&C stakeholders'- while price and quality of the product are engaged with the manufactures and child labour involved with the retailer. In terms of government policy, Rashid et al (2016)-, investigated governance and ethical policies associated with the process of economic exchange among firms and their SC members in Bangladesh.

The environmental perspective is most frequently adopted with, 5 papers focused on carbon emission/carbon footprint and firm's green performance to deal with SCs (Pal & Gander., 2018; Xio et al., 2017; Mohon et al., 2016; Xu et al., 2013; Krishnendu et al., 2012). Islam et al, (2018) provides one approach to doing this, by changing the transportation mode from high to low carbon intensity modes. Others green enablers include employment stability (Diabat, Kannan and Mathiyazhagan, 2014), health and safety issues (Tighe, 2016), green purchasing (Majumdar & Sinha., 2018), and eco-design (Tseng & Bui, 2016). These enablers are often influenced by national culture and government support - Gards, Raut and Narkhede, (2018) highlighted that a lack of effective government policy and poor infrastructure were the most significant barriers for achieving sustainability.

FUTURE RESEARCH

The findings of the study revealed that many different sustainability issues involved within T&C businesses in the AEC context. Traditional primary stakeholders (i.e. manufactures, suppliers, retailers etc.) and secondary SCM partners (i.e. trade barriers, strategic goals of the firms, management)-, are now accompanied with the sustainable performance. Hence, the key characteristics of reviewed papers definitions explained that SSCM shares more on operational/functional sustainability at the beginning but it started to adopt transformational/eco-logical aspects with passing time. More precisely, these traditional SSCM aspects started to identify solutions to achieve competitive advantages over markets and advance to firm'-s' environmental performance, with a focus on long-run planning. In contrast, the review exposed that the social sustainability aspects of T&C industries in the AEC countries less well researched, with the potential for using diverse research methods.

Additionally, potential research avenues have also emerged from this research study. Initially, a more in-depth investigation using qualitative research studies, such as case study or ethnography could be upholding the textile and clothing industry's SSCM research in AEC countries. For example, questions include:

- How SSCM can measure company's employee's performance?
- Is there any alignment between the social sustainability (e.g. described by the individual organization) and the employee retention?
- How government legislation and others impact SSCM and under what circumstances do companies empower their employees to derive sustainability in SCM?

CONCLUSION

In this research study, the researchers focused on different aspects of SSCM which might give a better understanding about the T&C industry within the research setting. Most noticeably, the findings from both the analysis reveal a clear lack in research and explored the inner knowledge about the T&C industry, thus could be transferable to calls for more research within the context.

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OPTIMAL COLLECTION POLICIES FOR RETURNED PRODUCTS IN THE REVERSE SUPPLY CHAIN

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ABSTRACT
Purpose
With the emergence of e-commerce and increasing customer service expectations, a growing number of firms are leveraging return policies to drive a strategic competitive advantage.

Methodology
This presentation focuses on the development and comparison of two collection models that reduce the firm's inventory and transportation costs by leveraging economies of scale and optimizing the collection period across multiple initial collection points (ICP) before transshipping the returned products to a centralized return center (CRC).

Findings
The optimal collection policies for the case of multiple ICPs and a single product is presented: 1) individual shipment policy and 2) combined shipment policy. Mathematical models in terms of collection periods are developed for calculating the combined inventory and transportation costs of both policies, and an optimization approach is designed to minimize the number of computations required to reach the optimal collection period. Finally, the results are presented with an experimental dataset.

Value
This work demonstrates the added complexity of dealing with two ICPs and develops mathematical models for the resulting collection policies.

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3PL'S LOW-CARBON SUPPLY CHAIN INTEGRATION: ANTECEDENTS AND CONSEQUENCES

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ABSTRACT
Despite the great challenge of Greenhouse Gas (GHG) emission reduction on third-party logistics service providers (3PLs), there is insufficient attention on logistics value co-creation in low carbon supply chain. Motivated by the evolving role of 3PLs from service providers to resource integrators, this paper applies service-dominant logic (SDL) to propose a theoretical framework on low-carbon supply chain integration (LCSCI), through which 3PLs can co-create value with their customers in low carbon supply chain. Using data from 348 Chinese 3PLs, we show that 3PLs' sustainability strategy and buyer requests to reduce GHG emissions are positively related to 3PLs' LCSCI. It is also found that 3PLs' LCSCI has positive effects on 3PLs' firm performance as well as the supply chain performance, where 3PL's firm performance also has a positive effect on supply chain performance.

INTRODUCTION
In the background of global climate change, there is growing attention on decarbonizing supply chains (Koh et al., 2013). With the increase of logistics outsourcing, logistics companies are under great challenge to reduce GHG emissions in the supply chain (Liu, 2014). Although many researchers have examined 3PLs' roles in sustainable supply chain (Abbasi and Nilsson, 2016; Jayaram and Tan, 2010; Maas et al., 2014), it remains unknown how 3PLs can co-create logistics value with their customers in low carbon supply chain.

Based on service-dominant logic (Vargo and Lusch, 2004), we argue that 3PLs' sustainability strategy and users' outsourcing need have positive effects on 3PLs' LCSCI, since both factors are operant resources that are the fundamental source of competitive advantage (Vargo and Lusch, 2008b). Further, we propose positive relationship between 3PLs' LCSCI and their firm performance and supply chain performance. This research is the first attempt at applying SDL to low carbon supply chain management from 3PLs' perspective. It contributes to the understanding of low-carbon supply chain management by highlighting the importance of supply chain integration from 3PLs perspective. It also enriches the existing theory on SDL by providing empirical evidence on value co-creation in low carbon supply chain.

LITERATURE REVIEW AND RESEARCH FRAMEWORK
Low-carbon supply chain management
With increasing pressure on reducing Greenhouse Gas (GHG) emissions worldwide, there is an increasing trend of research on low carbon supply chain management (LCSCM), integrating GHG emissions into supply chain management (Damert et al., 2018; Touboulic et al., 2018; Zhang and Wang, 2014; Zhu and Geng, 2013). Although the majority of these research focuses on functional and operational aspects of supply chain management, there have been empirical attempts at exploring the drivers, barriers and performance outcomes of LCSCM practices. For example, Zhu and Geng (2013) found that normative drivers motivated Chinese manufacturers to implement sustainable purchasing and mimetic drivers promoted both sustainable purchasing and sustainable customer cooperation, but coercive drivers did not really motivate energy saving and emission reduction. In contrast,

Damert et al. (2018) showed that climate change regulation and buyer requests to reduce GHG emissions were the key determinants of LCSCM practices.

Based on a comprehensive literature review on LCSCM, Das and Jharkharia (2018) found that supply chain collaboration, such as collaboration with suppliers, collaborative product design, collaborative transportation and inventory allocation, could be effective and efficient in reducing overall GHG emissions. In this line of literature, Zhang and Wang (2014) found empirical evidence that inter-firm collaboration on carbon emission reduction was positively related to both environmental and economic performances in the supply chain. Drawing on research on supply chain integration (SCI) and green supply chain management, Vachon and Klassen (2006) found positive effect of SCI on green supply chain practices. Similarly, Mao et al. (2017) investigated the performance outcomes of low carbon supply chain integration (LCSCI), which was viewed as the extent of supply chain integration in order to reduce the GHG emissions; they empirically showed that the focal firm's LCSCI with its suppliers and customers had positive effect on its environmental performance and financial performance. However, empirical studies on LCSCM are still limited so that the theoretical relationship between LCSCM practices and management theories is yet to be understood.

Environmentally sustainable logistics from 3PLs perspective

Given the great environmental impact of logistics activities, environmentally sustainable logistics has gained increasing attention from both researchers and practitioners (see Marchet et al. (2014) for a review). However, the majority of research in this area focuses on the manufacturer or the retailer perspective, and there are few research focusing on the role and perspectives of 3PLs in environmental sustainability of logistics (Lieb and Lieb, 2010; Perotti et al., 2012; Colicchia et al., 2013; Abbasi and Nilsson, 2016). For example, Perotti et al. (2012) showed that 3PLs with proactive attitudes toward environmental sustainability benefited from the adoption of green supply chain practices. Using a combination of case studies and literature review, Abbasi and Nilsson (2016) identified challenges from 3PLs perspective for environmentally sustainable logistics activities and called for more research on collaborative interrelationships between 3PLs and their customers in the development of sustainable logistical solutions.

Meanwhile, many researchers have shown that the role of 3PLs in supply chains has evolved from providing logistics capabilities to supply chain orchestrators that create and sustain a competitive advantage (Selviaridis and Spring, 2007; Zacharia et al., 2011; Piecyk and Björklund, 2015). For example, 3PLs can help facilitate SCM best practices, offer complete distribution management and network design, and coordinate value-creating network. The evolving role of 3PLs is, on the one hand, motivated by the connectivity and communication requirements of leading supply chains, and on the other hand, driven by the enhanced capabilities to manage, coordinate and focus on value-creating network (Zacharia et al., 2011).

In the literature on supply chain management, some researchers have highlighted the importance of SCI from the perspective of 3PLs. For example, Shang (2009) showed that 3PLs' integration capability and learning capability were positively related to their service performance and financial performance. Liu and Lai (2016) also demonstrated a positive relationship between 3PLs' external integration capabilities and resource efficiency. Liu and Lee (2018) examined the effects of three types of integration (internal integration, customer integration and logistics collaborator integration) used by 3PLs on supply chain resilience. As shown above, the performance outcomes of 3PLs' SCI examined in the existing literature are limited to the operational characteristics of 3PLs; it remains unclear about the effect of 3PLs' SCI on environmental sustainability of logistics.

Service-dominant logic (SDL)

Since the seminal work of Vargo and Lusch (2004) which introduced SDL as a fundamental shift in worldview of marketing, SDL has attracted extensive attention from researchers in marketing and extended management areas. In SDL, "service" (rather than goods) is the fundamental basis of exchange, which is defined as "the application of specialized competences, through deeds, processes, and performances for the benefit of another entity or the entity itself" (Vargo and Lusch, 2008a, p. 26). Hence, "service" is a process rather than an output. Regarding the determination of value, SDL maintains that value is perceived and determined by the customer and on the basis of "value-in-use", whereas firms can only make value propositions (Vargo and Lusch, 2004). Vargo and Lusch (2010) extended SDL from marketing to SCM, suggesting that supply chains can be viewed as value co-creation networks. Vural (2017) provided a systematic literature review on SDL and supply chain management interface.

A substantial amount of research has examined value co-creation in supply chains from a SDL perspective (Adams et al., 2014; Flint et al., 2014; Mass et al., 2014; Yazdanparast et al., 2010; Zhang et al., 2016). This stream of research is based on a key distinction between operant and operand resources, in that operant resources are capable of acting upon another actor or resource to create value, whereas operand resources cannot create value without the influence of at least one operant resource acting upon it (Constantin and Lusch, 1994). Thus, operand resources are often tangible and static, whereas operant resources are often intangible and dynamic. For example, there exists empirical evidence showing that supply chain integration is an operant resource that is important in value co-creation (Adams et al., 2014; Zhang et al., 2016).

Also, there exist some attempts at exploring sustainable value co-creation in supply chains from a SDL perspective. For example, Liu et al. (2014) proposed a conceptual framework of an SDL-based integrated product service system (IPSS) business model that satisfies the TBL criteria of sustainability. Using case studies, Lacoste (2016) examined how B2B companies embraced the concept of sustainability to co-create value, showing the importance of sustainability awareness as well as knowledge integration in the process of sustainable value co-creation. However, there is a lack of empirical research on sustainable value co-creation from the perspective of SDL. Furthermore, although Yazdanparast et al. (2010) proposed the first conceptual framework from the SDL perspective for value co-creation in a logistics context, to the best of our knowledge, there has been no research on logistics value co-creation that considers environmental sustainability.

Based on the extant literature, we developed a conceptual framework of 3PL-initiated LCSCI in the case of 3PLs' sustainability strategy and users' outsourcing need, as shown in Figure 1.

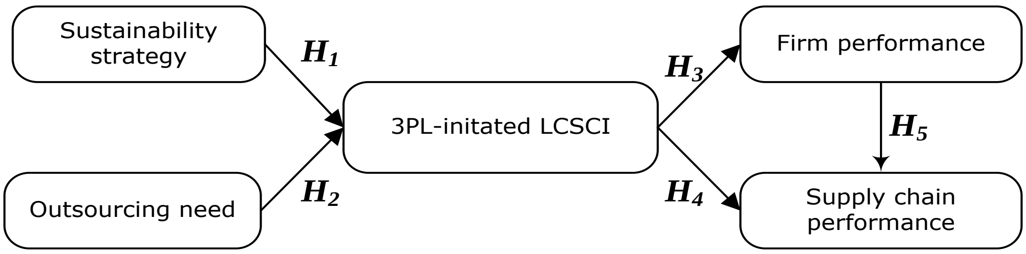

Figure 1 The research framework proposed

METHOD

The empirical investigation was carried out in China. A questionnaire survey data of 348 Chinese 3PLs were used for the analysis and a structural equation modelling (SEM) was applied to analyze the data collected. The construction of "outsourcing need" comprised of 5 items, referred to in the studies; "sustainability strategy" was measured according to 5 items; "3PL-initated LCSCI" was examined with 5 items; "firm performance" was evaluated with 4 items; and "supply chain performance" was investigated using 4 items.

RESULTS AND CONCLUSION

As to the antecedents, data analysis shows that 3PLs' sustainability strategy and users' low-carbon outsourcing need have positive effects on 3PL-initiated LCSCI. As to the consequences, it is found that 3PL-initiated LCSCI has positive effects on 3PLs' firm performance as well as the supply chain performance, whereas 3PLs' firm performance also has a positive effect on supply chain performance. From a research perspective, this study highlights the strategic role of 3PLs in decarbonizing supply chains, and provides empirical support for using integration as a way to achieve low-carbon supply chain. From a practical perspective, the study suggests 3PL-initated LCSCI helps to improve firm performance and users' supply chain performance. 3PL managers might proactively select a low-carbon action when implementing supply chain operations. In addition, in order to further 3PL-initated LCSCI, 3PL managers should be cognizant of different roles arising from both internal and external factors.

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A MODEL TO ASSESS THE ENVIRONMENTAL IMPACT OF B2C E-COMMERCE IN THE CONSUMER ELECTRONICS INDUSTRY

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ABSTRACT

Purpose

B2C e-commerce has been growing in all of the main western markets over the last years, both in terms of market value and penetration rate, i.e. online sales as a percentage of overall retail sales. From an environmental sustainability viewpoint, it is unclear whether the online shopping has an higher or lower environmental impact if compared to the traditional offline purchase. Among the various retail sectors, the consumer electronics industry is the most developed one with the largest online penetration rate (i.e. from 24% up in the most advanced markets such as USA, UK, China, Germany, France and Italy) and a consequent significant number of sold – and then home-delivered – products. This work aims to assess the environmental impact of the purchasing process in the consumer electronics industry, in order to evaluate the significance of the environmental impact in a sector that has achieved a relevant level of development and, more generally, to understand what to expect from e-commerce growth in the coming years.

Design/methodology/approach

This work is based on an activity-based model. The traditional shopping is compared to the online purchasing in terms of CO_2e emissions. The generic e-commerce process considered by the model is composed of five phases: pre-sale and sale, order picking and assembly, stock replenishment, delivery (only intended by courier) and post-sale. The offline shopping differs from the online one in several ways, including the main ones such as the absence of the picking and assembly phases, which are performed by the customer himself at the point of sale. The model determines the environmental impact of each activity carried out in each process phase. Interviews with logistics operators and secondary sources were used to develop and feed the model. The developed model is applied to the Italian context.

Findings

The environmental impact in the online purchasing process is about 30% lower if compared to the offline shopping. In particular, emissions in the online and offline processes are respectively 3.03 and 4.31 kg CO_2e per order, which is generally made of few pieces (i.e. about 1.2). The impact of logistics is generally high in both the purchasing processes. In particular, logistics-related activities cause almost all the emissions in the online shopping (i.e. 98%) and about the 75% in the traditional purchasing. The results are affected by

several parameters, in particular by transport-related activities (e.g. the average distance travelled by the customer in the traditional purchase, or by the van in the online shopping).

Value

The model presented in this work has both academic and practical implications. From the academic viewpoint, the model represents a theoretical contribution in the definition of the online and offline purchasing processes, in the quantification of the environmental impact for each process phase and in trying to solve an open debate in literature. From a practical perspective, the model is intended to be an easy-to-use tool for merchants who aim to quantify the environmental impacts of their business and identify areas of action to reduce them

INTRODUCTION

B2C e-commerce has been growing in all of the main western markets over the last years, in terms of both market value and penetration rate (i.e. online sales as a percentage of overall retail sales). The e-commerce market is worth about € 2,500 billion worldwide in 2018 (+20% if compared to 2017). In Italy, the e-commerce market reached € 27.4 billion in 2018, out of the € 600 billion of the European market, which is the third biggest market after the Chinese and American ones (B2C eCommerce Observatory, Politecnico di Milano, 2018). Among the various retail sectors (e.g. apparel, consumer electronics, books, grocery), the consumer electronics one is the most developed with the largest online penetration rate (i.e. from 24% up in the most advanced markets such as USA, UK, China, Germany, France and Italy) and a consequent significant number of sold – and then home-delivered – products.

Broadly, the implications of B2C e-commerce include effects on the economy, the society as a whole and the environment. Even though many studies have been dedicated to the understanding of the effects of the online commerce, there is still unclarity. From an environmental sustainability viewpoint, and in particular from a logistics perspective, it is unclear whether the online shopping has an higher or lower environmental impact if compared to the traditional offline purchasing process. The deep and accurate investigation of this topic is necessary both to increase the awareness of customers on the topic and to push companies towards the inclusion of sustainability considerations in their distribution network choices.

This work aims to assess the environmental impact of the purchasing process in the consumer electronics industry, in order to evaluate the significance of the environmental impact in a sector that has achieved a relevant level of development and, more generally, to understand what to expect from e-commerce growth in the coming years. More precisely, the environmental impact is measured in terms of CO2e (i.e. CO2 equivalent) emissions. This objective is pursued through a model developed to assess the environmental impact of both the online distribution channel and the traditional "brick and mortar" distribution in this specific industry. In particular, precise data are necessary to feed the algorithms of the model. In this regard, data from companies need to be collected, thus the Italian context is considered by the present study.

The reminder of the paper is organised as follows. The next section provides the literature review, with a focus on environmental impact of B2C e-commerce from a logistics perspective. Then, the objective and the methodology adopted within the study are described. The next section reports how the model was developed. Results are shown and, in the final section, conclusions are drawn and research limitations are identified.

LITERATURE REVIEW

The scope of the literature review is to detect the main contributions on the environmental implications of B2c e-commerce, specifically from a logistic perspective. Literature offers a wide range of contributions with different employed research methods (e.g. conceptual frameworks, case studied, modelling, simulation). Several contributions in the literature measure the environmental impact of e-commerce processes in comparison to the traditional offline channels. As an example, Edwards et al. (2010) proposed an analytical method for the assessment of the carbon intensity of e-commerce, with a specific focus on last-mile delivery and personal shopping trips. Herein, they also recognised that home delivery is likely to generate a decrease in emissions with respect to traditional shopping. Moreover, Mangiaracina et al. (2016) formulated an activity-based model for the assessment of the carbon footprint of the purchasing process in the apparel industry, with also a sensitivity analysis highlighting the huge impact of logistics on the total emissions. Similarly, Bertram and Chi (2018) analysed the environmental effects of apparel e-tailing versus traditional retailing in terms of carbon emissions, waste, and energy usage, concluding that online shopping is better for environment. However, attention is put on the fact that some intervening factors such as excessive packaging, shipping speed and apparel returns add more carbon footprint and waste to the environment (Bertram and Chi, 2018). According to Williams and Tagami (2002), that analysed B2C e-commerce against the traditional retail for the Japanese book sector, with a focus on urban areas, e-commerce seems to use more energy per book than conventional retail because of the high impact of packaging. Another study compares two competing DVD rental networks against the traditional business option (i.e. customers going to rental stores) (Sivaraman et al., 2007) with a city in the USA taken as a reference. Contrarily to the previous case, the e-commerce alternative is preferable, as less energy is used, and CO2 emissions are lower. In addition, Yi et al. (2017) employ Life Cycle Assessment (LCA) approach to examine the environmental impacts and energy consumption of delivery packages. Types of packaging taken as a reference are corrugated boxes, plastic bags and tapes for binding and sealing purposes. The least environmentally friendly stages of packaging supply chains seem to be production and usage. Recycling is promoted as the best method for handling waste packages. Another publication (Fan et al., 2017) estimates the environmental load of express packaging materials consumed in the processes of production and distribution of express delivery in China.

In this broad context, literature does not provide a general consensus on the environmental impact of the online and offline purchases. Results of the studies – i.e. whether the online purchasing process or the offline shopping has an higher environmental impact – depends on many context factors. Among factors described by the authors, the most mentioned are:

- customer density or customer location in an urban or extra-urban area (Mangiaracina et al., 2016; Williams and Tagami, 2002; Wygonik and Goodchild, 2011; Zhao et al., 2017);
- customer behaviour, e.g. probability of returned products, frequency of the customer trips for shopping purposes or willingness to combine shopping trips together, as well as the preferred delivery solution (Bertram and Chi, 2018; J. B. Edwards et al., 2010; Weber et al., 2010; Wiese et al., 2012; Xu et al., 2009; Zhao et al., 2017);
- number of items purchased at a time (J. B. Edwards et al., 2010; Van Loon et al., 2015);
- means of transport used by customers to reach the point of sale in the offline purchasing process (McLeod et al., 2006; Williams and Tagami, 2002), e.g. use of electric or hybrid vehicles (Wygonik and Goodchild, 2011; Zhang and Zhang, 2013) or use of public transport (J. B. Edwards et al., 2010; Wiese et al., 2012) as an alternative to traditional diesel or petrol means;
- means of transportation employed by the delivery companies, e.g. use of electric or hybrid vehicles (Sivaraman et al., 2007) as an alternative to diesel vans;
- distance from the carrier hub to the delivery area (Brown and Guiffrida, 2014; McLeod et al., 2006; Wiese et al., 2012);
- type and amount of packaging used (Bertram and Chi, 2018; Sivaraman et al., 2007; Van Loon et al., 2015);
- delivery failures and policy adopted in case of failed delivery (Cárdenas et al., 2017; McLeod et al., 2006);
- product features, e.g. fresh food or fragile products (Zhao et al., 2017).

In recent years literature provides contributions proposing innovative low-carbon distribution networks. As an example, Ji and Sun (2017) attempt to design and assess a sustainable book delivery system, with the objective of having a positive impact on resource consumption and emissions. Moreover, omnichannel retailing has been recently tackled from an environmental sustainability perspective. Melacini and Tappia (2018) recognise a new phase of the retail industry, called omni-channel (OC) retailing, in which the distinction between traditional and online channels disappears. An assessment model of the operational costs and greenhouse gas emissions for three distribution configurations in OC retailing is developed and applied to a real case in the consumer electronics industry. The results highlight that the search for synergies between online and traditional flows is a key factor for the economic and environmental sustainability of OC systems. Another contribution uses instead a game-theoretic approach to make a comparative study of the environmental impacts of single-channel (i.e. traditional channel) and dual-channel (i.e. online direct channel added to the traditional channel) supply chains (Zhao et al., 2017). Numerical analyses take into consideration factors such as the product characteristics, customers' density and customers' behaviour.

Quantitative models for the assessment of environmental impact have employed more than qualitative models as research methods in the last years, giving useful information about the slit of the impact between the various actors in the supply chain. Among the different industries, the apparel sector has been explored extensively by means of quantitative models, highlighting the positive impact of e-commerce on environment, with respect to traditional channels (e.g. Mangiaracina et al., 2016). Anyway, the consumer electronics industry has been studied only partially by authors. Melacini and Tappia (2018) used it as a reference in their paper about the omni-channel distribution – without anyway considering just online channel – as they retrieved the model input data from an Italian retailer operating in the customer electronics industry. Nevertheless, considering the widespread distribution of electronics e-commerce, more attention should be dedicated to the understanding of the factors that determine environmental impacts of such industry.

OBJECTIVES AND METHODOLOGY

Given the identified gaps, the present study aims to contribute to the extant literature on environmental sustainability of B2C e-commerce in the consumer electronics industry. The main objective is to develop a model to assess the environmental impact of both online and offline purchasing processes in the consumer electronics sector, with a particular focus on logistics activities. The core of the research is represented by an analytical model developed according to a three-step methodology.

Phase I - The first phase involved a preliminary definition of the reference process for both e-commerce and traditional channel. Each of the two processes is divided in macro-phases and the macro-phases are further divided into activities. Each activity generates a resource consumption and therefore an environmental impact. In particular, the activities can be clustered in five categories: communication, management, purchasing, transportation and warehouse/handling. Processes are also impacted by the distribution network structure. The present study considers, for the e-commerce case, a distribution network made of a picking dedicated-warehouse, whereas for the traditional purchase, the network is made of points of sale replenished by a central warehouse.

Phase II – The second step regarded the construction of an analytical activity-based model, which computes the environmental impact of e-commerce and of traditional online shopping in terms of emission of carbon dioxide equivalents – which is the chosen unit for the analysis.

Phase III – The third step is the application of the model and the analysis of the results. It is possible to compare the impact of an order shipped through the online channel with the impact of a purchase in the traditional channel.

MODEL DEVELOPMENT

The development of the model grounds on the definition of the purchasing processes.

E-commerce purchasing process

The definition of the e-commerce process relies on some assumptions. The main ones are:

- The order picking and assembly phase takes place in a central warehouse, which serves both the online and the offline channel.
- The central warehouse is composed of three areas: (i) a storage area, which is divided into a reserve stock, kept at the upper levels of the racks, and a picking area, kept on the lower levels; (ii) a sorting area, where only flows coming from the traditional channel are managed; (iii) a shipping area for the management of online orders.
- The replenishment only involves transferring the goods from the reserve storage area to the picking area.
- Pick-up from merchant's warehouse, last-mile delivery route and returns pick-up are carried out through a diesel van (payload = 1,5 t).
- The line haul is carried out through an articulated truck (payload = 28t).
- The delivery point is the customer's home.
- 100% first time delivery success.

The generic e-commerce process is composed of five phases:

1. Pre-sale and sale – The customer collects information about the product. After the purchasing decision, the payment is performed.
2. Order picking and assembly – The order is received and managed by the merchant. Later, the picking list is created, and the picking activity takes place in the picking area of the merchant's warehouse, whose capacity is usually limited. Before the delivery of the order, the product is packed manually or automatically, and the waybill is emitted.
3. Stock replenishment – Most of the merchant's stock is kept in the reserve storage area. For this reason, a replenishment of the picking stock takes place. During this replenishment, the goods are transferred from the reserve storage area to the picking storage area.
4. Delivery – After the order is fulfilled in the merchant's warehouse, it is shipped to the customer. The product can be shipped directly, or it can go through one or more points of the distribution network. Two layers of transit points between the warehouse and the delivery point are assumed by the study (i.e. the typical configuration of the distribution network of the express couriers). Transit points optimize the transportation activities: in the first transit point the orders are consolidated in order to saturate the vehicles capacity; in the second one, they are sorted and prepared for last-mile delivery.
5. Post-sale – the most peculiar aspect of post-sale process in the e-commerce case is the return of goods. The return process implies that the goods are brought back to the merchant's warehouse, which manages the return flow.

Each of the five macro-phases is further divided into activities, in order to compute the environmental impact on the basis of each single activity.

Traditional purchasing process

The main assumptions regarding the traditional purchasing process are:

- The replenishment of the points of sale starts from the same central warehouse described in the e-commerce section. The warehouse managing both online and offline channel is divided in three areas: storage, sorting and shipping. In this case, the goods are handled in the sorting area before the delivery.
- The point of sale replenishment is carried out through rigid truck (payload = 19t).
- The consumer goes to the point of sale by car. No use of public transport is considered.
- Only one point of sale is visited by the customer before purchasing.

Similarly to the e-commerce process, the traditional commerce process is divided into macro-phases and activities. The macro-phases are kept similar to the e-commerce ones, in order to make the comparison robust. A substantial difference involves the lack of an order picking and assembly phase, as it is performed by the customer himself at the point of sale. The macro-phases are the following:

1. Pre-sale and sale – The customer leaves home with the intention of making a purchase and reaches the point of sale. There, after searching for the desired product, the customer tries and then pays it. The pre-sale and sale phase does not only involve communication and purchasing, but also transportation activities.
2. Replenishment – When the stock level in the point of sale decreases, it is necessary to emit a replenishment order towards the merchant. The order is received and managed in the merchant’s warehouse and the goods are sent to the point of sale.
3. Delivery – The delivery in the traditional commerce process is equivalent to the return trip on the way back home of the customer from the point of sale after the purchase.
4. Post-sale – Also in the traditional process, the post-sale phase includes the return process. If the customer wants to return the product, he goes back to the point of sale, requests the change and returns back home with the new product.

Model structure

The model is organised into five sections.

I. General input data – this section collects the input variables that can be modified by the user. The main clusters of data are: (i) *customer data*, both in terms of customer profile (e.g. number of interactions with the merchant, number of websites visited, return rate) and average distance between customer house and point of sale; (ii) *purchase profile*, e.g. items per order, lines per order; (iii) *packaging*, e.g. type, size, capacity, weight, amount of raw material; (iv) *features of the retailer warehouse*, e.g. size, number of orders fulfilled per day, energy performance; (v) *features of the retailer store*, e.g. size, energy performance.

II. Activity data – this second section includes all data regarding duration of activities (i.e. online, warehouse, transit-point, point of sale and transportation activities).

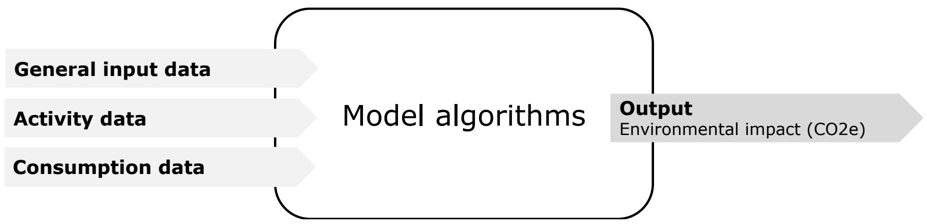
III. Consumption data – it gathers all data regarding (i) *energy consumption* (kWh), in terms of conversion factors and (ii) *consumption of facilities* (i.e. building, machinery, means of transport) measured as kgC02eq.

IV. Model algorithms – it collects all the mathematical formulas connecting sections I,II and III to the output.

V. Output data – the output is the environmental impact generated by a purchase (i.e. kgCO2e/order), either online and offline, in the consumer electronics industry. The overall result can be broken down by macro-phase and by activity type.

Figure 1 summarises the model structure.

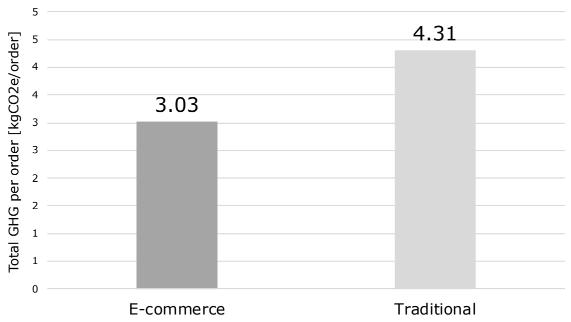
Figure 1 – Model structure

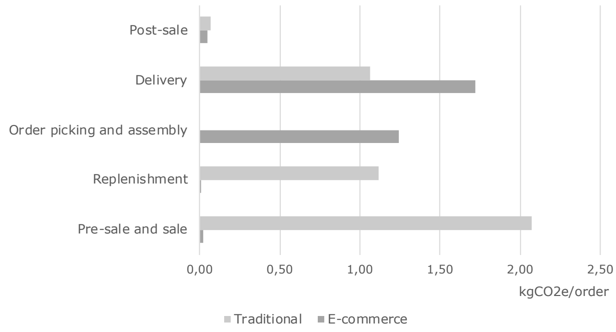


RESULTS

The environmental impact in the online purchasing process is about 30% lower if compared to the offline shopping. In particular, emissions in the online and offline processes are respectively 3.03 and 4.31 kgCO2e per order, which is generally made of few pieces, i.e. about 1.2. Figure 2 reports the emissions (measured in kgCO2e) in both the processes divided by phase. Figure 3 illustrates instead the percentage repartition of the five macro-phases emissions. Finally, figure 4 shows the percentage repartition of the emissions based on the main clusters of activities.

Figure 2 - Total GHG per order and total GHG per order by phase (kgCO2e/order)





In the traditional shopping the pre-sale and sale is the activity causing most of the emissions, i.e. 58%. Replenishment and delivery represent respectively the second and the third source of emissions in the offline purchase, each accounting about 25% of the total impact. The three mentioned phases, i.e. pre-sale and sale, replenishment and delivery, are in particular related to transportation activities, which account for about 50% of the total emission. In the online purchase, the most impacting phase is the delivery (i.e. 57% of the total emissions), followed by order picking and assembly activity (i.e. 41%). Transportation activities represent a huge source of emissions also in the online process, resulting in 45% of the total emissions. Anyway, the first source of emissions is represented by warehousing activities, which accounts for slightly more than 50%. Broader, considering logistics activities, they cause almost all the emissions in the online shopping (i.e. 98%) and about the 75% in the traditional purchasing. Logistics activities in general are responsible for most of the emissions but, among them, transportation has a key role in the assessment of the environmental impact. Transportation is so crucial especially because of the employed mean of transportation, i.e. the conventional diesel van as considered by the present study. Other more environmental sustainable means of transportation, e.g. electric van employed in the last mile delivery, would strengthen the environmental sustainability of e-commerce.

Figure 3 – Percentage repartition of GHG per order by phase

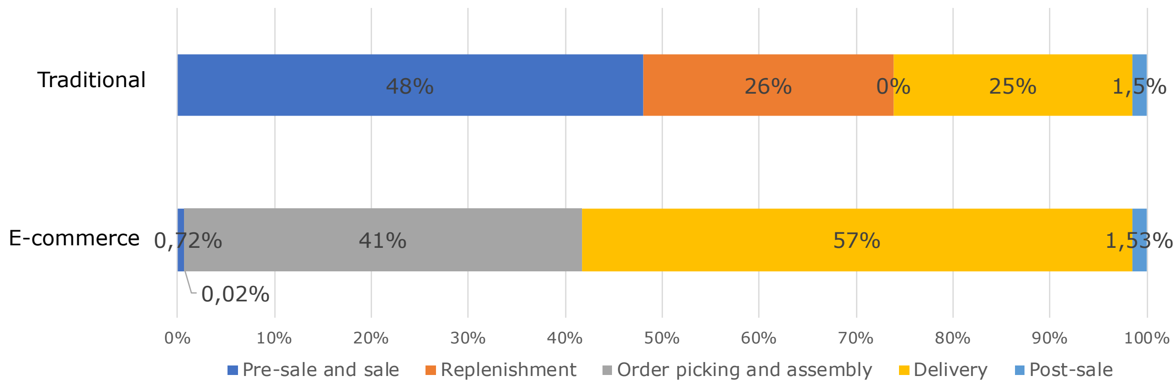
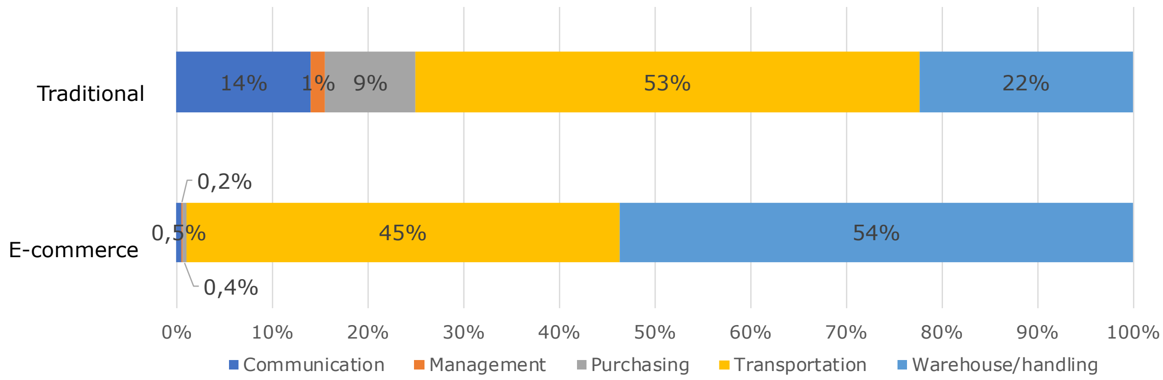


Figure 4 – Percentage repartition of GHG per order by activity



CONCLUSIONS

This work presents an activity-based model that can be used to assess the environmental impact of the purchasing process in the consumer electronics industry, comparing the traditional offline shopping with the online purchase. Some key findings emerged. First, in the case applied by the present study the e-commerce process resulted to be more sustainable than the offline one. Second, the impact of logistics resulted to be high in both the analysed processes, i.e. respectively 98% in the online purchasing and 75% in the offline shopping. Third, transportation activities cause almost half of the emissions in both the cases.

The model presented in this work has both academic and practical implications. From the academic viewpoint, the model represents a theoretical contribution in the definition of the online and offline purchasing processes, in the quantification of the environmental impact for each process phase and in trying to solve an open debate in literature. From a practical perspective, the model is intended to be an easy-to-use tool for merchants who aim to quantify the environmental impacts of their business and identify areas of action to reduce them. As an example, what emerges from the results – particularly from the third mentioned key finding – is that companies may act on transportation in order to make the online process even more sustainable (e.g. by using more sustainable vehicles).

However, the model presents some limitations. In particular, a number of assumptions was necessary to build the model and make calculations. Moreover, the values used to feed formulas are considered as deterministic without envisaging their variability. Anyway, sensitivity analyses on key variables (e.g. related to transportation activities, which emerged to be crucial) can make the result more robust.

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CREATING VALUE FROM RETURNS BY CLOSING THE INFORMATION LOOP: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Purpose
Product returns contain a substantial amount of valuable information within them (Schenkel et al., 2015). However, organizations both undervalue this information (Krikke et al., 2013) and are struggling to create value from it (Röllecke et al., 2018). While research exists, it is scattered among various research stream making it hard for practitioners to utilize it and for researchers to systematically built upon it. Therefore, the aim of this literature review is to understand how organizations can utilize information embedded in product returns for value creation.

Design/methodology/approach
We conduct a systematic literature review, bringing together relevant research from multiple streams of research. More specifically, this research reviews the literature on circular economy, reverse logistics, closed loop supply chains, and product returns management that focuses on information systems, knowledge management, organizational learning, and information sharing. Content analysis is conducted on 57 papers.

Findings
The findings of this study confirm the importance of information systems and their management in a closed loop supply chain. Nonetheless, businesses cannot simply invest heavily in information systems and hope to reap the rewards from product returns information. Rather, focused investments with overall goals in mind should be emphasized. Moreover, this research shows the potential of learning and knowledge management processes and the potential of technologies such as RFID tags and data mining in a closed loop supply chain context.

Value
This is the first literature review that systematically brings together and synthesises relevant research works on how to create value from product returns information. The main contributions of this literature review are to clarify the current knowledge on this topic, to form a basis upon which further empirical work can be built upon, and to identify gaps in the extant literature thus paving way for fruitful avenues of research.

Research limitations/implications
Relatively small amount of research has been carried out regarding this topic. Much of the research has focused on technological and operational issues. However, the potential benefits of returns information go beyond operational issues and creating value from this information requires more than technological solutions. Therefore, more research drawing

from organizational learning theories and strategic management theories are required to shed light on how firms can utilise returns information for continuous strategic learning.

Practical Contribution

The main practical implications of this research come in the form of a starting point for practitioners for thinking about implementing practices and processes aimed at creating value from returns information. Moreover, this research highlights the strategic potential of product returns information.

INTRODUCTION

Product returns contain a considerable amount of valuable information (Schenkel et al., 2015; Röllecke et al., 2018). Importantly, the value of this information is not limited to operational issues but has strategic importance as well (Jayaraman & Luo, 2007). Therefore, for the purposes of creating value and organizational change from the information, it is beneficial to put product returns management to its wider context of reverse logistics (RL), and more importantly, closed loop supply chain (CLSC) management. CLSC is defined as "the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time" (Guide & van Wassenhove, 2009). Researchers have identified four types of value that can be created in a CLSC as follows; economic, customer, environmental, and informational (Schenkel et al. , 2015). What makes returns information particularly valuable is the fact that it offers a window into the use of a product by its end customer. Therefore, when properly utilised, this information can serve as a source for customer, economic, and environmental value ultimately leading to increased performance through process and product improvements.

There exist, however, several impediments for reaping the rewards of this information in practice. Firstly, many companies still under-value the informational aspects of CLSC (Krikke et al., 2013). Moreover, they lack the capabilities to make the most of the information. For instance, a recent study found that most online retailers lack the data and learning capabilities to properly manage product returns information (Röllecke et al, 2018). Academic research is one avenue for improving the situation. However, while relevant research exists, most of it is unfortunately scattered among different research streams making it hard for practitioners to implement based upon the findings and for academics to cumulatively build upon the existing insights.

Considering this lack of clarity, our literature review aims to brings together insights from several streams of research, using a content analysis based inductive literature review, in order to clarify how organizations can utilize the information embedded in product returns and CLSC activities for value creation. Accordingly, the aim of this literature review is to understand *how organizations can utilize information embedded in product returns for value creation.* Additionally, this literature review provides directions for further research by clarifying what is currently known on the topic, what theories and frameworks have been applied in order to address the topic, and by identifying gaps in the literature.

METHODOLOGY

In order to answer the formulated research question, this study follows the methodology of systematic content-based literature review. This ensures that the review is systematic, reproducible, and scientifically rigorous (Seuring & Gold, 2012).

Material Collection

Two search engines were used to find suitable papers for this review: Web of Science and EBSCO (databases Academic Search Elite, GreenFile, Business Source Premiere). Combined, these databases offer a substantial coverage of high quality research in terms of management and organizational research and are frequently used in literature reviews.

Keywords were formulated with the aim of finding research works from a variety of relevant research strands. In order to choose the correct set of papers, several underlying assumptions were articulated. This research takes aboard a wide range of theoretical perspectives and research streams in order to best answer the research questions. It is assumed that superior ability to handle information flows requires information systems (IS) but IS alone is not enough alone to understand how information is best utilized (Jayaraman & Luo, 2007). Therefore, the aim is to identify the studies that best illuminate our understanding on how is the valuable information collected, processed, shared along the agents who need it most, and ultimately how to implement changes based upon the information.

With this in mind, we choose the key words "closed loop supply chain", "circular economy", "product return*", "reverse logistics". For each of these AND function was used to pair it with each of the following; "information management", "information sharing", "information systems", "knowledge management", and "organizational learning". Combined, 20 unique searches were made using each search engine, totaling 40 searches. At this stage, only peer reviewed journal articles written in English were considered. After removing duplicate papers, a total of 190 unique English language peer reviewed papers were retrieved.

The remainder of the process was conducted in three phases. First, titles and abstract of each paper was read and articles that were outside of the scope of RL, CLSC, and product returns management were excluded from the study. Moreover, papers that did not have a component of information, data, or knowledge in the reverse supply chain or CLSC context were removed. Thus, the papers included are English language peer reviewed research works that deal with the creation, storage, usage, etc. of information/data/knowledge from reverse supply chain related activities. After these phases a total number of 55 papers were included. Lastly, during the analysis process, two papers were added using a snowball process when relevant papers not yet included were identified from the ones cited by the included papers. Thus, 57 papers were included in the final analysis. Full list of papers analyzed can be requested from the author.

An inductive content analysis method was used to analyze the selected papers. Inductive analysis was used due to the involvement of several different research streams where the results of various research works will not fit neatly into any one existing framework.

DECRIPTIVE RESULTS

The 57 papers analyzed fall under the time period of 2000-2018. Great deal of the papers is published during the more recent years, 2012-2018 while the early 2000s rarely have more than one paper published in a given single year. Thus, it is clear that this topic is garnering increasing attention from the research community.

The most papers on the topic of our research are published by International Journal of Production Research (5), European Journal of Operational Research (3), and International Journal of Physical Distribution & Logistics Management (3). Other journals include only one or two relevant papers. The journals cover topic areas such sustainability, information systems, marketing, and production.

The analyzed studies show a substantial amount of diversity with respect to the methods used. A majority of the papers are empirical, 25 case studies and 10 surveys. The rest of the papers (22) are not empirical and fall under conceptual, mathematical, and simulation. The prevalence of case studies can be understood to reflect the relatively new topic of research along with its complexity and multitude of stakeholders involved. Moreover, most of the studies are RL related studies and a smaller number of papers take the CLSC view. While these concepts are related, it is important to note that there are differences between the way these concepts are used by various authors. It is also interesting to note that the majority do not explicitly rely on management theories.

THEMATIC RESULTS

Four themes emerged from the analyzed set of studies. These are Strategic IS decisions, technological solutions, learning, and information sharing. Several of the studies include aspects that fit into more than one theme. Strategic IS decisions includes IS capability, logistics IS, partnership and information sharing IS, customer centered IS, and IS resource commitment. Technological solutions for CLSC consists of RFID and data mining. Learning involves studies on CLSC learning and knowledge management. Finally, Information sharing sums up the current body of knowledge on under which conditions information sharing is beneficial and how to gain benefits of CLSC information sharing.

Strategic IS Decisions

IS play a significant role in CLSC management and the results of this study confirm that creating value from product returns information is no expectation. The use of information systems in the context of CLSC chain has seen increased attention recently. It is clear that IS related resources and capabilities are critical for the collection, processing, and sharing of product returns and other RL related data.

IS capability, the ability for the IT systems to deliver quality information that supports RL operations, and its importance to various outcome measures have been studied by multiple surveys. The earliest of such survey (Daugherty et al., 2002) found no relationship between IS capability and financial performance nor management satisfaction in the context of mail catalogue retailers. Another early survey indicates that IS capability positively influences both economic performance and service quality (Daugherty et al., 2005). A more recent survey (Mahindroo et al., 2018) found no relationship between IS capability and economic RL performance nor IS capability and RL operational performance. However, IS capabilities are critical for setting RL goal metrics and monitoring goal attainment (Hazen et al., 2015) leading to better RL performance through goal setting. Another survey shows that IS capability does positively influence attainment of strategic goals by maximizing the value of the information embedded in product returns (Mahindroo et al., 2016). Similarly, a case study shows that when moving to value creating CLSC, organizations require more sophisticated IS, especially when it comes to customer value and environmental value creation where an organization not only requires internal IT but must be proficient on external focused IT, involving partners and end customer, as well (Koppius et al., 2014). Therefore, the studies indicate that for a business aiming at maximizing value created and strategic benefits of CLSC it is necessary for them develop there is capability but for an organization simply seeking to reduce costs whereas an organization simply looking to reduce cost and maximize operational efficiency, emphasizing IS capability development might not be as beneficial in all cases. Nonetheless, it is clear that a minimum level of IS capability is required in order to collect and process information efficiently leading to efficient RL operations, as was demonstrated by a recent study in Africa where the lack of RL IS remains among the biggest barriers to effective RL (Meyer et al., 2017).

What seems to be more crucial for operational and financial CLSC performance are more targeted IS related factors. Logistics IS has been shown to improve economic performance (Hazen et al., 2014; Mahindroo et al., 2016), operational performance (Zhou & Reid, 2006; Sharif et al., 2012; Chouinard et al., 2005; Mahindroo, et al., 2016), and strategic performance (Mahindroo et al., 2018). However, a survey on Chinese mobile companies found no relationship between logistics IS and RL performance (Vlachos, 2016).
IS for partnership is another important aspect. By facilitating information sharing and efficient operations between supply chain partners, businesses can use IS to improve operations (Morgan et al., 2015; Olorunniwo & Li, 2010) IS can be utilized to deliver increased value for the customer. By focusing on customer centered IS developments businesses can increase their performance in several ways. Recent surveys show that IS for customer value creation is associated with increased economic and operational performance (Mahindroo et al., 2016), and attainment of strategic benefits (Mahindroo et al., 2018). A recent case study confirms the benefits of having an IS extending to

customers along with supply chain partners (Koppius et al., 2014). Similarly, IS resource commitment should be RL focused rather than general IS investments (Daugherty et al., 2005). RL IS resource commitment can lead to strategic benefits, (Mahindroo et al., 2016), and imrpoved third party RL (Sharif et al., 2012).

Learning

Several studies show the beneficial role of organizational learning processes. Compared to the amount of IS and IT related research on CLSC and RL, learning and knowledge management research is relatively scarce. However, the few studies that do exist illustrate some of the ways businesses can learn and create further value from the CLSC related information, including product returns data and operational data. Moreover, insights from these studies can serve as a starting point on research on how businesses should complement their technical solutions with learning processes.

RL knowledge creation allows firms to better handle product returns, reducing costs and increasing value recovered from returns (Mihi-Ramirez, 2012). It also increases firm performance and decision-making quality (Mihi-Ramírez & Morales, 2011) and increases information creation and distribution leading to strategic change and innovation (Mihi-Ramirez & Girdauskiene, 2013). Case studies have also shown that qualitative returns information can be disseminated throughout a firm and used for new product and process development (Jaaron & Blackhouse, 2015), codification of returns information leads to increased performance (Aitken & Harrison, 2013), and that a CLSC expert system allows managers to detect problems in their CLSC operations (Kumar, 2014).

Information Sharing

Information sharing has is a widely research issue in CLSC and RL. It is closely related to CLSC IS as information is in the most cases shared using IS. However, information sharing is not simply a technical issue and involves other barriers such as decisions regarding under what circumstances to share information, what information to share, when and how.

The earliest study found on RL information sharing is a case study developing a web-based demand planning system (Edwards et al., 2004) for a case company. Unsurprisingly, web-based system proved to be more efficient as compared to phone or fax. Since then, information sharing has proven to be beneficial in CLSC. These benefits include real time information sharing (Edwards et al., 2004), simplified returns policies (Yao et al., 2005), improved profitability (Huang & Wang, 2017; Olorunniwo & Li, 2010), better operational performance (Zuluaga et al., 2017; Morgan et al., 2015; Zheng et al., 2017). Additionally, sharing of returns information is specifically beneficially for a manufacturer who might not otherwise have the same access to returns information as retailers do (Hosoda et al., 2015). Information sharing is also very important for product recovery efficiency and responsiveness (Wadhwa et al., 2009; Madaan et al., 2012; Insanic & Gadde, 2014). However, the manufacturer and retailer might have different preferences and incentives for sharing information (Chen & Bell, 2013). Therefore, it is very important for organizations to understand the conditions when sharing information becomes profitable for the network, how to align incentives, in order to create win-win situations (Toyasaki, 2013; Chen, 2011).

Technological Solutions

Many studies have been conducted on specific technologies that be used to collect, process, and utilize CLSC information. These range from RFID tags for real information collection to planning systems, to data mining approaches. Many of these studies show the potential of applying newest technologies to the CLSC context.

RFID technology has been shown to be beneficial tool in CLSC (Cassina et al., 2009). More precisely, RFID can increase information accuracy and precision (Kim et al., 2017), provide real time data (Jarayaman & Luo, 2008), improve inventory management (Nativi & Lee, 2012). Overall, the use of RFID in a CLSC can at best lead to reduced costs, more efficient operations, and provides organizations increased information in the form of life-cycle information and item and module level information.

Another technological solution relevant for CLSC is data mining. Yu and Wang (2008), design a hybrid data mining approach that can be used to analyze product returns data in order to classify customers and products into different segments which can be used to target specific returns policies and new marketing strategies for these specific segments in the hopes to increase profitability. Another solution is put forward by Temur et al. (2014) in the form of a fuzzy expert system that uses returns data to predict quantity of returns to a satisfactory degree in order to reduce uncertainty in reverse logistics (Temur et al., 2014). Wang (2013) develop an expert system that by using data on product returns and other data along the supply chain, provides many opportunities for business. In their view, product returns activity can be viewed as a customer interaction, leading to competitive advantage if handled well. Moreover, the expert system analyses the data and recommends sets of actions for returns administrators to take accordingly. This can be useful in predicting and preventing returns (Wang, 2013). Similarly, Fu et al. (2016) illustrate with an experiment how an algorithm can be used to identify most likely returns events and reasons for product returns based on the buying phase and product problems. Ideally, this allows an organization to identify products likely to be returned along with customers and customer segments likely to return products.

It is clear that data mining opens the door for insights hard to attain without it. However, contrary to RFID applications, most organizations have not so far achieved the most salient advantages of RL data mining, such as marketing and product development opportunities and other advanced insights (Mahindroo et al., 2016). This development may occur for many reasons, such as lack of capabilities, not having access to proper data to mine, not a priority to businesses currently, organizational issues, etc.

DISCUSSION

The findings confirm that IS are an essential part of a CLSC. However, it is also clear that it is not enough for an organization to invest in IS capability and top end IT alone and expect to increase performance. Rather, it is important to understand what is the overall CLSC strategy and how IS fits into it. For instance, the results suggest that value creation oriented CLSC may require better overall IS as compared to cost reduction focused ones. Additionally, the results indicate that IS specifically tailored for CLSC may be beneficial for businesses. Moreover, studies show that IS alone is not enough and other factors should be studied along with it. Future research should thus include applying organizational learning theories along with strategic management theories to illuminate how CLSC and RL information can be used to develop a competitive advantage. In practice, this could mean conducting surveys that include not only IS related factors but learning and other non-technical factors. We elaborate on the four themes we distilled from the literature.

RFID and data mining techniques have been studied in the extant literature. RFID has been shown to be beneficial for many CLSC processes by providing real time data on many product aspects. Similarly, data mining has been demonstrated to be able to use to analyze product returns data to gain insight into a variety of factors such as customer segments and product information. However, many technologies introduced in the literature have not been demonstrated empirically in a business context and thus it is not entirely sure how well these technologies work in practice. For instance, costs might be an issue along with implementation. Moreover, management support might be a critical factor along with existing organizational capabilities. More research should be conducted in the form of surveys and case studies. For instance, one could conduct longitudinal case studies on the implementation of data mining and big data projects in CLSC. In addition, qualitative studies could shed light into how the insights mined from the returns data can be put into action inside organizations.

Research on CLSC learning remains scarce. However, the little research that does exist illustrate the potential of learning from returns information. More systematic research is needed to understand what can be learned from returns, under which circumstances, and what are the most important enablers of learning from returns information. Moreover, inter-organizational learning, together with information sharing might lead to shared understanding in a CLSC. However, such research is missing.

Another interesting observation has to do with the nature of CLSC, RL and the analyzed studies. The majority of the studies are explicitly studying the concept of RL, instead of the more expansive concept of CLSC. Some have argued that to truly enable the value creation and strategic benefits of CLSC, it is necessary to take the CLSC view rather than be limited to RL perspective. Similarly, research focusing on RL might be at a risk of limiting the scope of their study to not include some of the most transformative benefits value oriented CLSC can bring to a business. Similarly, the extant literature highlights individual aspects on the informational value of product returns, but a systematic research is missing on how to treat product returns information as strategic source of knowledge regarding products, services, and perhaps most importantly, the end customer. Being a strategic issue, more research is needed that situates product returns in the context of strategic management theories such as dynamic capabilities, knowledge-based view of the firm, along with organizational learning in order to systematically highlight the antecedents, outcomes, and moderating variables of continuous improvement from product returns information.

CONCLUSIONS

Developments in the fields of supply chain information systems, organizational learning, value creation and closed loop supply chains gave rise to the following research aim: To understand *how organizations can utilize information embedded in product returns for value creation?* In order to answer this research question, we decided to conduct a systematic literature review on the current body of knowledge from a multidisciplinary perspective. Although extant literature is relatively limited, some new insights were obtained.

This literature review illustrates the large variety of valuable information that can be attained from product returns and related activities. Information systems and technologies such as RFID, big data, and data analytics techniques allow organizations to collect and process data from product returns for business insights. This is where most of the research has focused on thus far. The potential of information sharing and learning has been showcased by the limited research available. Yet, much more work is needed to be done in order to understand how to truly close the information loop in order to drive continuous adaptation from the knowledge available.

Clearly, returns are the 'mirror' of the forward supply chain. Closing the information loop can and must be used to improve processes, products and services. Still, there is a world to be won. Returns information offers a view into the use of a product by its end user thus offering plenty opportunities to improve products, processes, and strategic decision making. Therefore, returns information is not simply a matter of products returns management or of RL where it is used to optimize related processes. Rather, organizations need to be able to collect, store, and disseminate the insights from product returns in order to adapt their business continuously.

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IMPACT OF PRODUCT RETURN POLICIES ON REVERSE LOGISTICS MANAGEMENT IN OMNICHANNEL RETAILING

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ABSTRACT
Purpose of the Paper:
Current research and contemporary business practices on product returns management predominantly focus on products returned exclusively through either brick-and-mortar (or offline) or online sales. Comparatively less attention has been given to products returned from omnichannel retailing, a multi-channel retailing practices, which has changed the structure of the supply chain. As more businesses embark on omni-channel retailing, options for product returns have become essential and could be a key differentiator in creating a seamless customer experience. This study identified three main return options offered by omnichannel retailers, return to store, courier pick-up, or self-arranged. These multitude of return options offered by omnichannel retailers could have significant implications on the management of reverse logistics activities and potentially increase operations costs.

INTRODUCTION
The growing significance of product returns in e-commerce retailing has been widely reported (Dennis, 2018). With the rise of omnichannel retailing, which allows customers to move seamlessly across channels to research products, compare prices and return damaged or unwanted items, the significant scale of product returns has been skyrocketing in recent years (Banjo, 2013). Partly, this is due to consumer affairs legislation which requires retailers or businesses to accept returns within a reasonable time period post-purchase. Partly, it is also because retailers and product suppliers, especially those operating under the omnichannel retailing environment, are trying to use product returns as a means to entice buying since consumers may not have a chance to physically review the products prior to purchase. The conditions under which purchased products could be returned and the means by which products could be returned are typically stated under the retailers' product return policies. Such policies could impact significantly on its product returns management costs (Shamiss, 2019)

While the importance of product returns management in omnichannel setting has been explicitly acknowledged in both academic literature (Piotrowicz and Cuthbertson, 2014; Bernon et al., 2016; Saghiri et al., 2017) and business news magazines (Ellis, 2017; Dennis, 2018), research on returns management in the omnichannel space remains sparse (Daugherty et al. 2019). Few studies how product returns policies impact on a retailers' reverse logistics operations or how retailers laid out the fine prints in their product return policy as a means to manage the logistics of product returns.

This paper reports on a desk research that examined the product return policies of 14 omnichannel retailers in Australia with a view to inferring how these retailers have resorted to using product returns policy as an instrument to manage the logistics of product returns. Our research question is:

How do the product return policies of omnichannel retailers impact their reverse logistics management?

The next section commences by looking into the logistical implications of product return management.

Logistical Operations for Omnichannel Retailing

Last mile delivery is a resource-intensive and time-consuming logistics component of the fulfilment process. In their attempt to be responsive, retailers develop innovative solutions to ensure the customers could receive their purchases within the expected delivery time (Lee and Whang, 2001). One way of improving fulfilment efficiency is to have retail outlets perform the "pick and pack" and ship it to the customers from the stores (Goodman, 2005). However, retailers often outsource their last mile deliveries to third party logistics service providers (3PLs), which have the necessary capabilities to ensure timely deliveries to customers. This is because customers are not concerned with which party manages the last mile, only that the goods are received on-time (Lim et al., 2018).

In omnichannel retailing, to entice consumers to purchase their products, retailers not only assure customers are able to receive the purchased products within the expected delivery time, but also allow customer to return the products in a painless manner (Lee and Whang, 2001). This means providing multiple options for customers to return purchased products. This is how the reverse logistics of returned products starts becoming messy in omnichannel retailing, creating additional costs compared with the sole return-to-store option offered by conventional brick-and mortar retailing.

Reverse Logistics for Efficient Returns Management

Forward supply chains typically receive the most attention since it is so important in terms of customer service, revenue, and cash flow. Flows in supply chain can move back through the supply chains due to a variety of reasons such as faulty products, or simply ordering mistakes. Reverse logistics (or supply chains) have often been regarded as a necessary evil or at best a cost centre that needs continual scrutiny (Genchev et al., 2011).

Traditionally, reverse logistics were not viewed as value-added activity for customers or revenue generation for businesses. In other words, product returns were viewed as a "waste stream" and, not as a potential value stream. Reverse logistic operations were often associated with increased cost that would have to be absorbed with subsequent lower profit or passed off to customers with higher prices or some combinations of the two. At times, it was also assumed that it could also mean an efficiency loss by placing businesses at a disadvantage (Govindan and Soleimani, 2017).

However, much progress has been made over the course of the last several decades in the development of reverse logistics approaches and systems. The popular terms such as reverse logistics systems, product recovery systems, product return networks, enterprise returns management, and others have been used to indicate the growth in the volume and importance of returns and the need for their efficient and effective management especially in the omnichannel retailing era (Rogers and Tibben-Lembke, 2001).

Australian Consumer Laws

In Australia, consumers are protected by strict Australian Consumer Law (ACL). Under ACL, businesses must ensure goods sold meet the following conditions: i) of acceptable quality; ii) fit for any purpose; iii) have been accurately described; iv) match any sample or demonstration model; iv) satisfy any express warranty; v) have a clear title; come with undisturbed possession; vi) are free from any hidden securities or charges; vii) have spare parts and repair facilities reasonably available for a reasonable period of time (unless advised otherwise).

If businesses failed to meet the ACL's consumer guarantees, they are required by law to remedy the issue/problem with the product via a repair, replacement or refund (subjected to the circumstances). The enactment of the ACL ensures that the customer rights are protected, but forces omnichannel retailers to design their logistical operations that are sufficiently flexible to accommodate to the customer rights (Bernon et al., 2016).

Management of Returns in Omnichannel Environment

Managing product returns in the omnichannel environment has increasingly become critical in recent years due to several reasons:

- Change in shopping behaviour – End-consumers have become more "IT-savvy" and have increasingly used smart mobile devices (e.g. smartphones, laptop) to make their purchases online (Piotrowicz and Cuthbertson, 2014);
- Awareness of consumer rights - Australians are also well informed of their rights and will also favour retailers that offer convenient ways of returning or refunding wrong purchases (Collett, 2018).

Retailers attempt to offer their customers a seamless purchasing experience (Cook, 2014) but face challenges in implementing this. (Bernon et al., 2016, p. 584) suggest that the adoption of omnichannel present new challenges as "product returns management move toward integrating returns, processes, information systems, inventories and performance measurement systems that have been typically operated as discrete entities within a multi-channel proposition". Organising product return management and process for a consistent seamless experience for their offline and online consumers has clearly been a challenge (Hübner et al., 2016). This exploratory study attempts to understand how Australian retailers manage their reverse logistical operations.

RESEARCH APPROACH

This research utilises a desktop research on 14 Australian omnichannel retailers, which are selected based on the nature of their business. Broadly, these retailers fall into five business groups: telco, electronics retailer, departmental store, stationery supplier and manufacturer. This study focuses on the return product policies of three types of high-value products: smart devices, home electronics and white goods.

We first developed a taxonomy of product return options, based on channel of purchase (online versus offline), physical dimensions of products (parcel-size versus non-parcel or bulk - size), return time window (days) and return options (return to store, courier pick-up or self-arranged) (see Figure 1). A parcel-size item refers to products less than 10kg in weight and capable of fitting into a postal parcel that can be managed by a courier service.

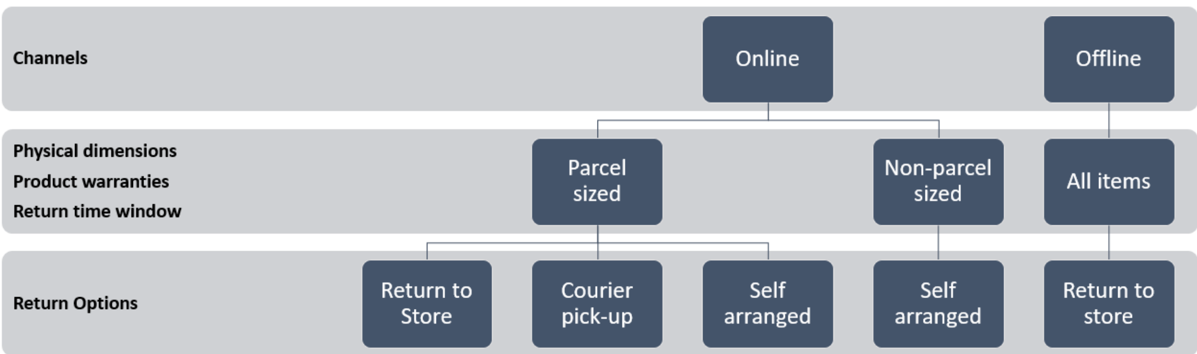

Figure 53: Return Options for Omnichannel Model

Using thematic coding techniques Miles et al. (1994), we analysed the 14 retailers' product return policies. Data containing descriptive or inferential information were labelled and categorized accordingly in Table 27. This is followed by a qualitative assessment of the implications flowing from the conditions and mode of returns to examine the range of reverse logistical activities incurred.

FINDINGS

This study investigates the reverse logistical implications of product returns policies in Australian retail businesses. It assesses the various available options including the points of return, the sorting and inspection processes involved, the mode of transport used for the last time. Despite recognising the importance for providing a "seamless experience" in the omnichannel context (Verhoef et al., 2015), not all retailers are concerned with providing a consistent process of product return for offline and online channels. This seems to be impacted by the reverse logistics implications arising from: i) the size of the returned products; ii) specified return time window in return policy or warranty; and iii) contractual arrangement with the last mile partner.

Bulk or Non-Parcel Sized Products Return Management

All seven retailers that sell bulk-sized high value products (e.g. washing machine, dish dryers, air-condition units etc) require consumers to lodge a claim with the retailer for any return claims. Instead of sending the product directly back to the retailer, the retailer would normally dispatch a technician to first assess the product for defects and rectify the issue, where possible. Failing that, the technician would decide whether the product warrants a return to the distribution centre or store for a refund or replacement. The approach taken by all seven bulk sized retailers indicate that this process seems to be configured to minimise the unnecessary costs associated with the managing the return logistics.

Specified Return Time Window

Despite the strictly regulated consumer rights, this study found that not all omnichannel retailers offer the same terms and conditions for return policies. In the case of the telecommunication sector, all three major retailers had differing time windows for returns, with the earliest at seven days. It was also identified that, due to the overlapping consumer laws and manufacturers' warranties, most electronic retailers tend to assess returns on a case-by-case basis, despite having transparent return claim terms and conditions.

The complexity further increases whereby online and offline share the same time window for return claims. Most of the retailer's return time windows commence at the time of product order, e.g., 28 days after purchase is made. In the case of offline (store) retailing, this window starts when the customer walks away with the purchase. However, online customers may be disadvantaged as they will receive the purchases at a later date (subjected to delivery time).

Contractual arrangement with the Last-Mile Partner

Although 11 of the 14 cases offered pick up service for returned of parcel-size products, not all were offered as a free service. Such service seems to be performed by the last mile 3PL partners based on contractual agreement between the retailers and 3PL.

Of the 11 retailers that offered free courier service show that a third-party courier service partnership is usually involved, e.g., Australia Postal Services or ParcelPoint (a third-party courier provider).

The utilisation of a third-party courier pickup service for return products tend to involve a similar process. This requires the customer to lodge and obtain a RMA (Return Authorisation Number) or a claim number. With the RMA/claim number, the retailer would then arrange an agreed pick-up time and collection location.

DISCUSSION

We have observed that Australian omnichannel environment for high value electronic products does not provide a consistent customer experience, logistical touchpoints and return options to the end consumers. In-store purchases have relatively straight forward return method, i.e., return to store. Online purchases, by contrast, tend to be more complicated. Although online products are mostly delivered to customers (in some cases pick-up), the same does not apply for product returns.

Our analysis of the 14 mini-cases indicate that parcel-size items tend to have more flexibility that included: i) return to store; ii) courier pick-up and iii) self-arranged return. Non-parcel-size (big) items tend to be restricted to self-arrangement, i.e. customers may incur out-of-pocket costs and pay for arranging a collection to return the product.

The difference of return options for parcel-size and non-parcel-size items means that customer making online purchases may not be necessarily have equitable return options. It seems the ability of retailers to offer more convenient return options to their customers, e.g. courier pick-ups, depends on their 3PLs partner reverse logistics capabilities.

Although more return options can be perceived as providing greater choices and convenience to customers, they also introduce greater complexities to the reverse logistical operations. The ability for customer to choose any return option makes it challenging for the retailers to have full visibility of the returned products, i.e., where they are stored or how they can be processed.

There is no doubt reverse logistics is more difficult to operate and/or harder to develop into a viable value stream (Ravi and Shankar, 2005). Our finding suggests that retailers that provide comprehensive return options will need to design robust processes, that promote closed loop supply chains. Increasing number of return options means adding more collection touchpoints thereby rendering processing and consolidation more difficult.

From any end consumer perspective, his/her last mile can be seen simply as returning the product back to any collection touchpoint that belongs to the retailer. For the omnichannel retailer, its last mile could be the collection of returned products from all return touchpoints (stores, 3PL etc) to a centralised distribution centre for processing.

For high valued electronic products, having a centralised gatekeeping view for return management is necessary to ensure defects are being monitored conscientiously and thereby providing a feedback mechanism to the suppliers. The gatekeeping and feedback mechanism is necessary for the promotion of a closed loop supply chain that would allow omnichannel retailers to build a proposition of cost reductions, and to recapture value associated with returned goods. This ultimately leads to waste reduction and improved revenue.

CONCLUSION

A successful omnichannel retailing model empowers customers to choose how, where and when they shop, then provides a consistent and seamless experience across a multitude of offline and online touchpoints. This study shows that the ways omnichannel retailers design their return management have impact on consumer’s experience. The return options do have the ability to offer convenience to online customers but is constrained by the type and size of the products as well at their manufacturer’s warranties. In additional, this study explores the complexity of the reverse logistical operations stemming from alternative product return options offered to the purchase of high-value products in an omnichannel retailing environment.

Effective omnichannel retailing strategy ultimately depends on the supply chain network structure and the support of the right 3PLs. The rise of omnichannel retailing has placed greater importance, not only on the ordering and fulfilment aspects of ecommerce but extends to the product return operations. The logistical and distribution networks involved in closed loop supply chains also needs to be agile to cater for the varieties of return options, and yet minimise the costs and resources.

In a rapidly changing omnichannel environment where retailers continue to offer flexible returns policies, and convenient return options, as a competitive advantage to attract consumers. This study offers insights on the cost implications of offering flexible return options it also reminds omnichannel retailers to be wary of the cost incurred for offering flexibility for product return options.

Research Limitations and Future Studies

This study is based on desk research, where information on product return options are sourced from publicly available company web-sites. Thus, the assessment of reverse logistical operations associated with different product returns options lacks empirical support. The next step of the study would require an in-depth multiple case study of omnichannel retailers in managing their product return logistics.

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	Company	Business Classification	Type of Electronics		Offline Purchase Return	Online Purc	Co
			Pacel-sized	Non-parcel-size	To Store	To Store*	Pi
01	**Telstra**	Telco	Y		Y	P	
02	**Optus**	Telco	Y		Y	P	
03	**Vodafone**	Telco	Y		Y	P	
04	**JB Hifi**	Electronics	Y	Y	Y	P	
05	**Good Guys**	Electronics	Y	Y	Y	P	
06	**Harvey Norman**	Electronics	Y	Y	Y	P	
07	**Bing Lee**	Electronics	Y	Y	Y	P	
08	**Myer**	Departmental	Y	Y	Y	P	
09	**David Jones**	Departmental	Y	Y	Y	P	
10	**Catch of the Day**	Departmental	Y	Y	Y	P	
11	**Officeworks**	Stationary	Y		Y	P	
12	**Samsung Mobile**	Manufacturer	Y		Y		
13	**Apple**	Manufacturer	Y		Y	P	
14	**Bose**	Manufacturer	Y		Y	P	

Table 27: Taxonomy of Products & Return Options

Note
***** denotes that consumers have to bear the return cost.
P denotes parcel-size, or small, item.
NP denotes non-parcel-size, or big, item.
NA implies information not available on retailer's website.

ENERY-SAVING MEASURES BY LOGISTICS CLIENTS

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ABSTRACT

Reducing energy consumption in logistics activities is a very important issue. The legislation in Japan to promote energy efficiency places the responsibility for reducing energy consumption not only on logistics companies, but also on those that produce and distribute large volumes of goods. Various measures have been adopted by product manufacturers and distributors (logistics clients). This paper intends to examine the measures that logistics clients have actually taken, and the degree to which their efforts have reduced energy consumption, as well as the current issues and hurdles they are facing in their energy-saving efforts. After analyzing the measures that companies took, we determined that the greatest progress was achieved by selecting more appropriate types of delivery vehicles, rationalizing distribution routes or the distribution process, conducting joint deliveries or mixed product deliveries to improve efficiency, and using more efficient commercial vehicles, particularly large-scale trucks, to conduct the deliveries. In order to make further progress, logistics clients will have to cooperate with the intended recipients, or adopt novel approaches to the problem.

FOREWORD

As the need to address man's impact on the environment becomes increasingly urgent, logistics has been identified as one important area where environmental impact can be addressed directly, by reducing the amount of energy consumed in shipping and distributing products. In Japan, companies began earnestly discussing ways to reduce energy consumption in their logistics activities around the turn of the century. The adoption of the Kyoto Protocol on Climate Change stimulated this process, with government, industrial groups and individual corporations adopting concrete measures to meet the targets set out in the Protocol.

In 2005, the Japanese government revised legislation on energy consumption to try to accelerate the trend, with companies in the transportation industry targeted directly by specific regulations. However, Japan's regulations on energy consumption do not target only transport companies; manufacturers and other companies that ship large volumes of cargo (hereafter "logistics clients") also have a responsibility to take steps to reduce their energy consumption. Logistics clients whose total transport volume over the course of a year exceeds 30 million ton-kilometers (including shipments between the company's own facilities) are identified as "designated logistics clients". These companies are required to adopt energy-saving measures, and to submit reports to the government on a regular basis, detailing their progress. By requiring logistics clients to address the problem, as well, the Japanese government succeeded in making this a high-profile issue. It has even prompted many logistics clients to cooperate with their logistics supplier to develop joint solutions.

This paper will examine the measures that logistics clients have adopted in order to reduce energy consumption in their distribution activities, and try to quantify the actual scale of energy savings they have achieved, over the ten years since legislation went into effect.

It will examine the specific energy-saving measures that these companies introduced, and attempt to identify any hurdles that they face in the effort to reduce energy consumption further. Since additional changes to the legislation were introduced in 2018, companies have begun to cooperate across industries to reduce the energy consumption of logistics activities further. The paper will examine some of these cooperative efforts, and the results.

The paper analyzes the activities of roughly 800 large-scale logistics clients which are required to submit reports on their energy-saving measures to the government, under the legislation introduced in 2005. It attempts to quantify the actual reductions in energy consumption, and identify issues that companies must address in order to make further reductions. We also conducted interviews with companies that achieved particularly large or creative reductions, in order to identify steps that might help to further reduce energy consumption in the logistics sector. The interviews focused on companies that have implemented concrete plans that have reduced energy consumption through cooperative efforts involving logistics clients, delivery recipients and logistics providers. Specifically, these plans include measures to revise order frequency and volume, reduce small-lot deliveries, adjust lead time and standardize deliveries. We interviewed 23 companies in total, including manufacturers, wholesalers, retailers and restaurant chain operators.

THE DISTRIBUTION SECTOR AND ITS IMPACT ON ENERY CONSUMTION

Historically, energy consumption in the transport (logistics) industry has fluctuated in response to economic growth trends, oil prices, changes in the composition of the industry and technological advances that reduce power consumption. Between the 1960s and the early 1990s there was a dramatic, 257% increase in the sector, from 0.47 x 10^{18} Joules in 1965 to 1.67 x 10^{18} Joules in 1996. Thereafter the figure has declined steadily, contracting by 24% to 1.27 x 10^{18} Joules in 2016. The decline partly reflects decrease in the volume of goods transported. But energy savings has also been achieved through outsourcing, as companies hire logistics providers rather than using their own vehicles, as well as efficiency improvements such as the use of larger trucks, and improvements in the fuel efficiency of delivery vehicles.

ENERGY CONSERVATION REGLATIONS AND THEIR IMPACT ON LOGISTICS

Japan's first energy conservation-related regulations were introduced in 1979, to address the impact of the so-called "Oil Shock". The first regulations only applied to company factories, but the rules have steadily been expanded to cover the transportation sector, commercial and office buildings, homes, and other structures.

The first rules governing the transport and logistics sector were introduced as a part of legislative revisions in 1998, and targeted improvements in the fuel efficiency of vehicles. In 2005, further revisions required companies involved in transport activity to adopt plans to reduce energy consumption in their overall operations. Specifically, these changes set guidelines to identify "designated transport businesses", based on the scale of operations (companies that operate 300 or more rail carriages, 200 or more trucks or busses, 350 or more taxis, ships with a combined capacity of over 20,000 tonnes, or aircraft with a combined capacity of over 9,000 tonnes). The designated transport businesses are required to formulate plans to reduce energy consumption, and submit reports to the government on a regular basis, detailing their total energy usage and the progress of these plans. In addition, it set guidelines to identify "designated logistics clients" – companies that ship a large volume of products or materials, either using their own resources or via a transport vendor. These companies are also required to submit regular reports on their energy consumption plans, and actual energy use. In cases where one of these designated companies fails to make adequate reductions in their energy use, the government may advise, publicly censure, order or levy fines against the company to compel action. Japan was one of the first countries to introduce this type of legislation to govern the logistics clients, as well as the transport operators.

ENERGY CONSERVATION CONDITIONS AT DESIGNATED LOGISTICS CLIENTS

At present, companies that ship products or materials (including in-house shipments) with a total volume of 30 million tonne-kilometers per year (cargo weight x transport distance) are identified as "designated logistics clients". The first step in our analysis is to look at the measures these companies are taking to reduce energy consumption, and how much progress they have made, to date.

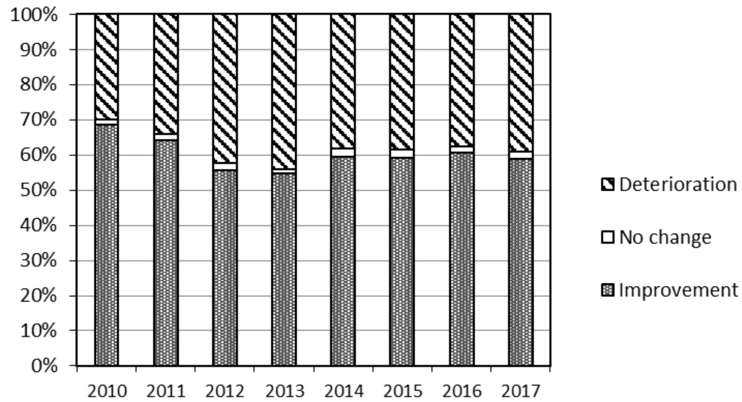
Trends in energy consumption by designated logistics clients

There are roughly 800 companies in Japan that fit the definition of designated logistics clients – 77% of these are manufacturers, 16% are wholesalers or retailers, and 7% are involved in other businesses. Between 2010 and 2016, total energy consumption by these companies remained at roughly the same level – 220 million gigaJoules. In 2017, however, this figure was reduced to just 192,367,000 gigaJoules.

Trends in energy consumption per unit of transport volume

In the regular reports submitted by designated logistics clients, each company is allowed to adopt their own internal standards for measurement, when providing detailed statistics on energy use in distribution activities, and calculating figures for energy use per unit of activity. As of 2017, 56% of companies adopted transport volume (tonne-kilometers) as the denominator, when calculating per-unit energy consumption, 19% adopted total weight, 17% used transport value as the denominator, and 8% used some other unit in their calculations.

In Figure 1, the data from these reports is used to shows the percentage of companies who made year-on-year improvements in energy consumption per unit. As the chart indicates, performance has not been particularly impressive. In 2010, 68.7% of companies reported a year-on-year improvement in per-unit energy consumption, but the ratio declined to 64.2% in 2011 and to around 55% in both 2012 and 2013. Since then, the percentage of companies reporting a year-on-year improvement has remained at around 60%.

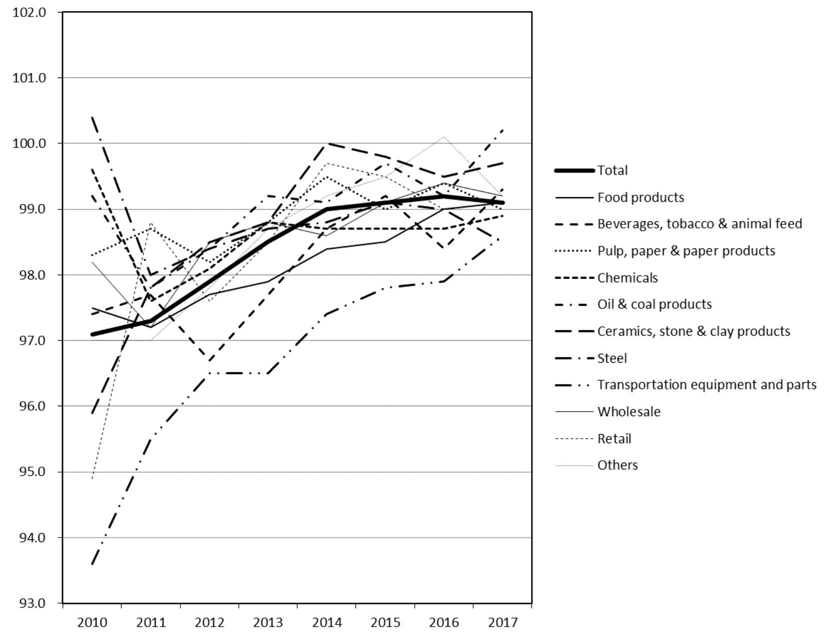


Source: Energy Conservation Center, Analysis of Successful Improvement in Standards by Logistics Clients.

Figure 1. Year-on-year changes in energy consumption per unit

When it passed the legislation requiring companies to report on their energy consumption trends, the government set the goal of a 1% average annual improvement in efficiency (energy consumption per unit) over the medium to long term. However, according to the data submitted in 2012, over 75% of companies indicated that they had met this target over the preceding five-year period, and performance has actually been declining in subsequent years. The ratio fell to around 60% in 2014, and about 30% reported that their performance had actually deteriorated. Figure 2 shows the average change in per-unit energy consumption over the previous five years. Using the average for all companies, 2010 energy consumption per unit was 97.1% of its level in the previous period (that is, efficiency had improved by 2.9% per year), and the figure remained around 97% through 2012. While this is a significant improvement, performance has weakened in subsequent years. In 2013, per-unit consumption was 98.5% of its previous level (a 1.5% improvement in efficiency), and since 2014 the figure has risen to over 99%. In other words, since 2014 companies (on average) have been failing to meet the government's target of a 1% annual improvement.

Looking at trends by industry, in the food products sector, the per-unit energy consumption in 2013 was around 97% of its base-year level. The figure rose to over 98% in 2014 and 2015, and has remained above 99% since 2016. As the figures suggest, the pace of improvement in energy efficiency (per-unit consumption) has been slowing, in all industries, and it is likely to be difficult for companies to continue making the 1% annual improvement that the government has set as a target.



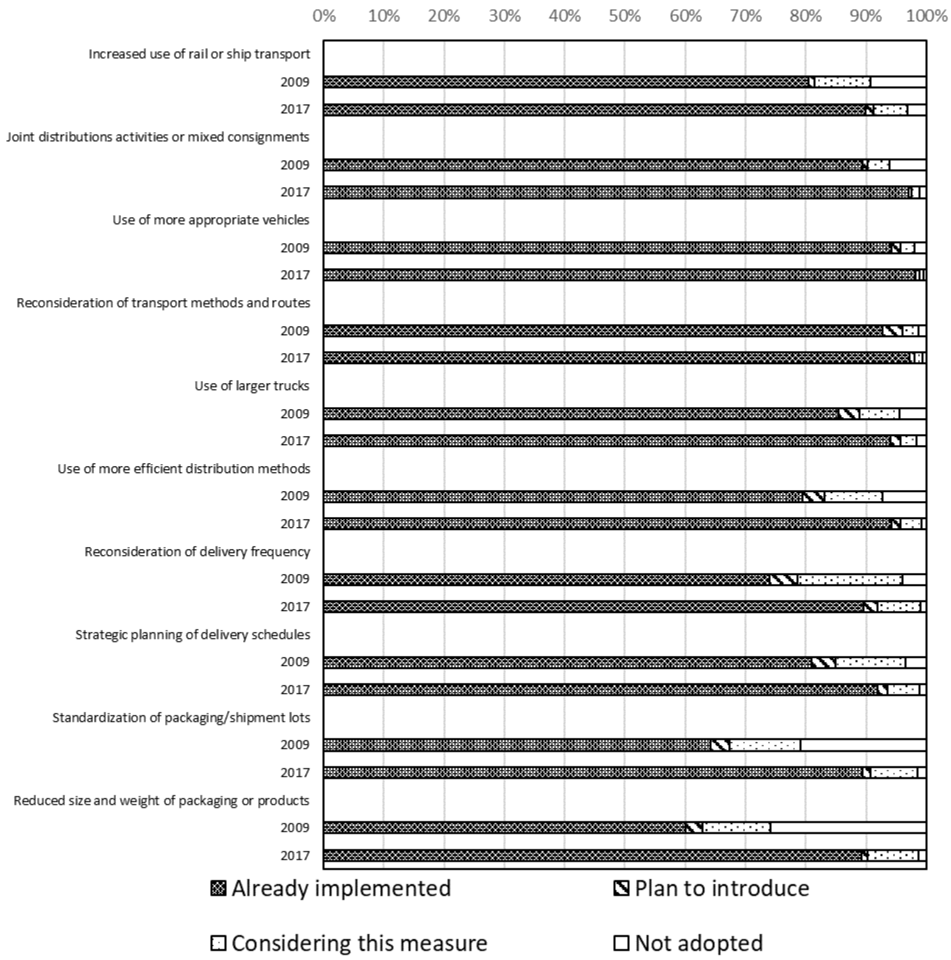
Source: Energy Conservation Center, Japan, Analysis of Successful Improvement in Standards by Logistics Clients.

Figure 2. Energy consumption per unit (average annual change over the previous five years)

Energy-saving methods adopted by designated logistics clients

In their periodic progress reports to the government, designated logistics clients have identified the measures they are taking to reduce energy consumption. Figure 3 shows the percentage of companies that have adopted each type of measure (excluding those who did not give any answer for a particular measure).

As of 2017, the most common measure adopted was to select the most appropriate type of distribution vehicle (e.g. heavier trucks), with 98.2% of respondents saying that they have already taken this step. Other common measures included improving distribution routes or methods (97.1% of respondents already adopted this measure), and conducting joint deliveries or sending mixed consignments (97%). In addition, 94.3% had begun using more efficient methods (such as third-party distribution), and 94.0% had begun using larger trucks. For most of these measures, a substantial percentage of companies had already adopted them in 2009. The above methods are all relatively easy for the distribution department of a major logistics client to adopt at their own initiative. By comparison, measures such as adjusting the frequency of deliveries – which would require some degree of cooperation with transaction partners - are less likely to have been adopted. As of 2009, just 73.9% of companies had adopted this measure, and the ratio was still just 89.6% in 2017. Careful planning of delivery schedules had been adopted by 80.9% of companies in 2009, and by 91.8% as of 2017. A particularly strong improvement was seen in the standardization of products and delivery format; 64.1% of companies had adopted this method in 2009, and by 2017 the ratio rose to 89.3%. Measures that require coordination with production facilities, such as reducing the size and weight of packaging or reduction in the size of products, had been adopted by 89.2% of companies in 2017, a sharp improvement from 60.0% in 2009. Finally, the use of rail or cargo ship to deliver products, rather than trucks, had been adopted by 89.9% of companies in 2017.



Source: Energy Conservation

Figure 3. Measures adopted by designated logistics clients to reduce energy consumption

LONG-TERM PLANS AND REVISED LEGISLATION

Japan has set a long-term goal of reducing total energy consumption by 13%, by 2030. This is equivalent to a pledge to improve energy efficiency (total energy consumption/real GDP) by 35% between 2013 and 2030. In order to move the country in the direction of meeting these goals, the government made revisions to energy-saving regulations in 2018, and has begun to re-examine the nature of its cargo transportation sector. The first step that needs to be taken is to encourage more cooperation between companies in order to reduce energy consumption. Prior to the recent revisions, information on and evaluation of energy usage was limited to the activities of each individual company. Thus, even if companies did find ways to reduce energy consumption through cooperative measures, they might not receive the full and proper credit for improvements. Revised legislation ensures that when energy savings is achieved through cooperative measures, all of the cooperating companies can take their fair share of credit, in their periodic progress reports.

The second change that is required is to properly assess the role and responsibility of logistics clients. In the past, legislation did not address companies that are the recipients of product deliveries, or assign them any responsibility for reducing energy use. From now on, companies that are the recipients of cargo deliveries will be responsible for cooperating with energy-saving efforts of logistics providers and logistics clients (recommended cooperation). Currently, shipment details such as the lead time, the date and timing of delivery, lot size and so on are largely at the discretion of the recipient. Furthermore, many plans to improve energy efficiency have a potential impact on shipment recipients, so cooperation from these companies is often the determining factor in whether the plan is feasible.

COOPERATION BETWEEN LOGISTICS PROVIDERS, LOGISTICS CLIENTS, AND SHIPMENT RECIPIENTS

When it comes to formulating plans to reduce energy consumption, there are a great many factors which are beyond the control of the distribution department of a logistics client. In most cases, details such as the lead time, the delivery date and time, the lot size, and so on are determined by the customer, not the company making the shipment. However, most companies that receive a large volume of shipments prefer to have deliveries closely match their actual demand for the products, making orders only when stock is almost depleted and trying to limit the risk of accumulating excess inventories. Generally speaking, these companies want a delivery system that is quick, frequent, and delivers items in small-lot shipments. These requirements all tend to increase the energy consumption of the overall system.

When companies set to work introducing plans that address environmental issues, they encountered many hurdles and difficulties. Based on surveys of companies regarding their distribution issues, and asking them to identify such hurdles, 68.0% answered that "since transaction partners will be affected, our company cannot resolve the problem on its own." This clearly shows that, when companies are asked to cut energy consumption, the impact on shipment recipients is a critical issue, and their cooperation will be essential if Japan hopes to reduce energy consumption further. Specific examples of cooperation between logistics providers, logistics clients and delivery recipients are outlined.

Cooperating to determine the lot size of orders/deliveries

By specifying the size of each order, increasing the size of each shipment and reducing the number of small-lot shipments, the efficiency of delivery vehicles (capacity utilization) can be increased. However, since these steps will tend to have the effect of increasing inventory volume for the delivery recipient, their cooperation is essential. For example, Calbee Inc., a snack food manufacturer used to have an automatic ordering system with its wholesale distributors which placed orders as soon as inventories began to decline. The revised system requires recipients to place orders for single pallets. In certain cases, less than a single pallet can be ordered if there is a way to adjust the load and ensure that it does not adversely affect the efficiency of delivery vehicles. After revising the system to increase minimum order size, the capacity utilization efficiency of vehicles improved. Similarly a processed food wholesaler, Mistubishi Shokuhin Co., Ltd., considered the capacity of delivery vehicles when placing orders with manufacturers, and carefully controlled order size, to ensure efficient use of capacity. In cases where an order was too large to fit in one vehicle, normal procedure would be to send two vehicles. However, when Mitsubishi Shokuhin recognized that an order would exceed the capacity of a delivery vehicle, the excess amount would be either shifted to an earlier or later order.

Reconsidering frequent, small-lot delivery practices

From the standpoint of many delivery recipients, there is pressure to limit inventory space, yet stock-outs may cause the company to miss a sales opportunity. Therefore, from the standpoint of their profitability, they want shipments to closely follow actual demand, limiting inventory but always keeping it above zero. This means that orders must be small and frequent. For the distribution system, however, these frequent small-lot deliveries erode delivery efficiency and make it very difficult to reduce energy consumption. There are examples of companies that have reduced the number of deliveries, or eliminated daily delivery service and instead deliver every other day, particularly in regions where total shipment volume is limited. McDonald's Japan, for example, has taken steps to standardize shipments. Some of the products that will be needed on weekends, when demand is high, are shipped a day or two earlier, on weekdays, and the weekday shipments are also adjusted to a more consistent size. The result is that deliveries have been reduced from five times a week to just four times.

Extending lead time and adjusting the scheduled timing of deliveries
For many types of daily consumer goods, lead time is very short. Products are shipped on the day following the order, and are expected to arrive before noon. This makes it very hard for suppliers and distributors to plan deliveries in ways that can optimize capacity utilization and delivery routes. In addition, many companies demand that deliveries be made before 10:00 AM. Often, they will demand a penalty payment from the distributor if the delivery is not on time. Therefore, in order to avoid the risk of getting stuck in heavy traffic, and to get the delivery unloaded and move on to the next location, most distribution companies send out their vehicles early in the morning, and if the customer does not have space or is not yet ready to unload the shipment, the vehicles waste a lot of time sitting around and waiting to be unloaded. This practice of specifying an exact time for delivery, in order to suit the convenience of the recipient, is a major factor in reducing the efficiency of logistics activities.

If shippers have more lead time, recipients are more flexible about the exact delivery time, and logistics providers are able to give greater consideration to the most efficient timing and delivery route, there would be considerable potential to improve distribution efficiency. One example of this sort of cooperation involves the food products manufacturer Kewpie Corp., its distribution provider KRS Corp., and wholesaler Kato Sangyo Co., Ltd. In the past, orders from Kato Sangyo were delivered the following day. By extending the lead time by an additional day, the companies were able to plan delivery routes strategically, eliminate waiting time and foregoing a product inspection at receiving time, resulting in a 5.9% reduction in CO2 emissions. Among processed foods manufacturers, the shift from next-day delivery to two-day lead time has become an increasingly common measure. Nissin Foods introduced this standard in January 2018, Ajinomoto plans to make the same change in August 2019, and many other major food manufacturers are considering similar plans. Although this may cause retailers' inventories to increase, manufacturers do not usually share this cost burden.

Standardizing distribution activities
Another factor that limits distribution efficiency is the fact that demand for these services tends to be irregular, and concentrated at specific times of the week, month or year. This not only applies to the well-known surge in activity at the end of the year, but also at the start and end of each month, on weekends, and on traditionally heavy business days such as the fifth and tenth day of the month. This makes it hard for logistics supplier to plan more strategic delivery schedules. It tends to reduce efficiency in capacity utilization and it forces companies to have larger fleets of trucks in order to deal with the peak demand period. If delivery recipients could provide information on their likely demand, in advance, it would be easier to standardize the process, but since they tend to place orders at the last minute, strategic planning is difficult.

The paper manufacturer Nippon Paper Industries Co., Ltd. and its logistics provider, Inui Global Logistics Co., Ltd., have asked wholesalers, printers and other major customers to standardize their orders and delivery schedule. In the past, roughly 80% of orders specified that delivery should be made before noon. By asking customers to place orders ahead of time, and ease their expectations about delivery time, the companies have been able to reduce variations in demand and improve efficiency. This succeeded in reducing the number of vehicles by 22.2%, reduce delivery runs by 9.8%, and cut CO_2 emissions by 5.7%.

CONCLUSION

Japan's 2005 revisions to legislation on energy consumption obliges large-scale logistics clients to make efforts to reduce their energy use. As a result, logistics clients have made considerable progress in reducing their energy consumption. The most common measures adopted include using more appropriate vehicles, adopting more efficient delivery routes and procedures, conducting joint deliveries or mixed-lot consignments, using more efficient distribution methods, and shifting to large-scale trucks. As a result, designated logistics clients succeeded in cutting energy consumption by 3% year on year in 2010, immediately after the regulations went into effect. This seems to reflect an effort by the companies to demonstrate that they were taking action.

However, the impact of the regulations has steadily subsided. In recent years, energy use by designated logistics clients has been declining at an average rate of less than 1% per annum. The companies explain this drop-off in performance by noting that "relationships with delivery recipients make further progress difficult, and further reductions cannot be achieved through the efforts of logistics clients alone." Since there is limited potential for independent action to result in significant reductions, future efforts to reduce energy use will require greater cooperation between companies, particularly between logistics clients and those that are large-scale recipients of merchandise deliveries.

Unfortunately, our interviews suggested that delivery recipients still have only a limited awareness of the importance of improving distribution efficiency, or reducing energy consumption. Many of the companies we spoke to identified this as a key hurdle. They indicated that delivery recipients generally specify the delivery conditions based on the efficiency of their own receiving operations, and have difficulty understanding or accepting changes that might adversely affect this efficiency.

With that in mind, the Japanese government made major revisions to the regulations on energy use, in 2018, in order to promote cooperation between companies. Specifically, the changes require large-scale recipients of merchandise shipments to cooperate in measures to reduce energy use. The most important step is to re-evaluate shipment and ordering conditions, such as the lot size and frequency of orders, lead time, specified delivery times, and the standardization of ordering and delivery schedules. There are already many concrete examples of companies that have adopted such measures. In the future, it is likely that this sort of cooperation can make meaningful progress to reduce energy consumption, but in order to achieve success, it will be necessary to evaluate the entire supply chain and optimize all delivery conditions, from the perspective of minimizing energy use.

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DIVERS AND BARRIERS TO SUSTAINABLE SUPPLY CHAIN MANAGEMENT IMPLEMENTATION IN EGYPTIAN INDUSTRIES

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Abstract
Purpose: Since sustainability and supply chain management are currently gaining more importance in the research fields. This study aimed to identify drivers and barriers to sustainable supply chain management (SSCM) implementation in Egyptian industries, and to provide recommendation for organizations operating in Egypt on how to overcome these barriers.

Design/methodology/approach: This study is considered an empirical study with a descriptive research approach using qualitative methodology. The primary instrument used for data collection was semi-structured interviews with an interview protocol developed on the basis of previous literature to enhance reliability of such instrument. Qualitative analysis was conducted through deductive coding and categorization. The population for this research was all industrial companies operating in Egypt, where non-probability–purposive judgment–sampling technique was used. So, a final sample included 14 organizations representing four different industries with 22 experts engaged in sustainability implementation within supply chain functions were interviewed.

Findings: This study had revealed multiple drivers and barriers to SSCM implementation in Egyptian industries and how those specific drivers and barriers might differ from the barriers and drivers mentioned in previous literature. Additionally this study helped in understanding the influence of drivers and barriers on sustainability implementation within supply chain functions. Additionally this study had recommended multiple explanations to overcome these barriers generated through organizations which successfully managed to deal with these barriers previously.

Value: Since there is a lack of prior studies on similar topic in Egypt, this study provided in-depth understanding for barriers and drivers for SSCM implementation in Egyptian industries as well as valuable recommendations to overcome these barriers.

Research limitations and implications: Limitations for this research were due to lack of availability of reliable sources of data which limit the sample size in multiple industries. Additionally, this study focused on large organizations hence results might vary for small and medium enterprises. Thus future research focusing on SSCM implementation among small and medium size enterprises in Egypt and analyzing data specific to each industry is recommended.

Practical implications: This study provides insights for managers of industrial organizations operating in Egypt about drivers and barriers to SSCM implementation in Egypt, as well as valuable suggestions and recommendations on how to deal with these barriers.

Keywords: Sustainability, Supply chain, Social sustainability, Economic sustainability, Environmental sustainability, Drivers, and Barriers.

INTRODUCTION

Sustainability and supply chain management are rapidly growing as important areas of research (Ashby et al., 2012). Managers are also aware of the idea that their social and environmental accountability is shared with their supply chain partners; hence managers are considering establishing strategic goals for sustainability in coordination with their supply chain partners (Winter and Knemeyer, 2013). A recent trend started since the beginning of 21st century focusing on protecting the environment, hence shortly the term SSCM evolved to include economic and environmental aspects (Deepak et al., 2014).

Organizations as well as their supply chain partners are facing pressures to engage in SSCM activities (Varsei et al., 2014). Those pressures or drivers arise as a consequence of internal and external influences affecting the organization; examples of internal factors are top management involvement, financial benefits, and certifications, while external factors are government regulations and legislations, customers, competition, suppliers, and social factors (Sajjad et al., 2015; Diabat et al., 2014; Ageron et al., 2012; Giunipero et al., 2012; Walker and Jones, 2012; Walker et al., 2008). However, several barriers exist hindering organizations from implementing sustainable practices within supply chain functions. Barriers might be related to organizations' internal environment known as internal barriers or forces arising from the organizations' external environment known as external barriers, yet internal barriers tend to have a higher impact than external barriers (Sajjad et al., 2015; Ageron et al. 2012; Walker et al 2008).

This study aims to identify drivers and barriers to SSCM implementation in Egyptian industries and provide recommendation for organizations to deal with these barriers. The choice of Egypt was due the lack of previous research on such topic, and the increasing importance of sustainable development issues. This research study starts with a literature review including background about SSCM, drivers, barriers, and how to overcome barriers, then research gap followed by research methodology, results and discussion, and finally the conclusion, research limitations and recommendations for future.

LITERATURE REVIEW

Sustainable Supply Chain Management (SSCM)

The term sustainability first appeared in the literature about 20 years ago and, over the years, academics and practitioners has proposed many ways of defining sustainability (Winter and Knemeyer, 2013). The most commonly used definition of sustainability was suggested by Brundtland Report in 1987, "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (Ashby et al., 2012). The inclusion of sustainability in supply chain management is based on the triple bottom line approach (3BL) combining environmental, social, and economic aspects rather than the single focused focusing only on environmental dimension (Touboulic and Walker, 2015; Beske and Seuring, 2014). SSCM can be defined as managing materials, information and flow of capital in order to improve organizations economic, environmental, and social performance taking into consideration all stakeholder's expectations (Kannan et al., 2013).

Drivers for SSCM

Organizations as well as their supply chain partners are facing multiple pressures to engage in SSCM activities, such pressures can be seen as drivers for SSCM implementation (Varsei et al., 2014). Those drivers arise as a consequence of internal and external influences affecting the organization. Internal factors are normally linked to circumstances inside the firm while external factors are beyond the firms' borders (Sajjad et al., 2015; Diabat et al., 2014). Table 1 shows a summary of drivers of SSCM implementation based on previous literature.

Internal Drivers for SSCM Implementation

Top management support: top management commitment and ethical values of top management.	Esen and Elbarky, 2017; Sajjad et al., 2015; Beske and Seuring, 2014; Ageron et al., 2012; Walker and Jones, 2012
Financial benefits: cost reduction, and better financial performance.	Esen and Elbarky, 2017; Sajjad et al., 2015; Deepak et al., 2014
Certification: ISO 14001 certification, and other rules (WEEE and RoHS).	Esen and Elbarky, 2017; Elbarky and Elzarka, 2014; Deepak et al., 2014
Competitive advantage: environmentally related competitive advantage.	Esen and Elbarky, 2017; Sajjad et al., 2015; Walker and Jones, 2012
External Drivers for SSCM Implementation	
Government regulations: provide guidance for organizations' sustainable practices.	Esen and Elbarky, 2017; Deepak et al., 2014; Mathiyazhagan et al., 2013
Customers: customers' awareness and opportunity to access new customers.	Sajjad et al., 2015; Diabat et al., 2014; Deepak et al., 2014
Competition: competition extended to be between supply chains.	Esen and Elbarky, 2017; Sajjad et al., 2015; Varsei et al., 2014
Suppliers: catalyst for the implementation of SSCM in organizations.	Esen and Elbarky, 2017; Ghadge et al., 2017; Walker and Jones, 2012
Social factors: such as non-governmental organizations, labor unions, media, and Civil society groups	Esen and Elbarky, 2017; Sajjad et al., 2015; Varsei et al., 2014; Elbarkouky and Abdelazeem, 2013

Table 28: Drivers for SSCM implementation

Barriers to SSCM

Despite the benefits of implementing SSCM, organizations are still reluctant to adopt sustainable practices due to internal and external barriers (Esen and Elbarky, 2017). In review of literature about SSCM, it was reported that fewer studies have been discussing the barriers of SSCM (Sajjad et al., 2015). The reason behind that can be explained as researchers sometimes prefer reporting positives rather than negatives or due to social desirability bias where organizations participating in such studies highlight drivers (Walker et al., 2008). Table 2 shows a summary of barriers to SSCM implementation based on previous literature.

Internal Barriers to SSCM Implementation	
Financial constraints: high initial costs, non-availability of loans supporting sustainability programs, high capital investment with lower return and high implementation costs.	Mangla et al., 2017; Esen and Elbarky, 2017; Ghadge et al., 2017; Elbarky and Elzarka, 2015; Sajjad et al., 2015; Elbarkouky and Abdelazeem, 2013
Lack of top management support: lack of interest by top and middles managers or lack of commitment of responsible actors.	Esen and Elbarky, 2017; Sajjad et al., 2015; Elbarkouky and Abdelazeem, 2013; Mathiyazhagan et al., 2013
Lack of SSCM Awareness: lack of knowledge about sustainability benefits.	Esen and Elbarky, 2017; Mathiyazhagan et al., 2013; Ageron et al., 2012
Lack of organizational encouragement: lack of training courses and workshops and poor employees' commitment.	Esen and Elbarky, 2017; Elbarky and Elzarka, 2015; Mathiyazhagan et al., 2013; Elbarkouky and Abdelazeem, 2013
Poor quality of human resources: higher costs/ lack of access to trained expertise.	Mangla et al., 2017; Esen and Elbarky, 2017; Mathiyazhagan et al., 2013

Table 29: Barriers to SSCM implementation

Overcoming SSCM Barriers

Although adopting sustainable or green supply chain management practices is complex and challenging (Deepak et al., 2014). Relatively little number of articles have focused on ways to overcome SSCM barriers (Rauer and Kaufmann, 2015). Since organizations might face difficulty in attempting to eliminate all barriers simultaneously, it is recommended to first critically analyze all barriers, prioritize them, and work on the most influential and important barrier then another (Ghadge et al., 2017; Deepak et al., 2014).

Operationalization of sustainability: complexity of sustainability measurement systems and lack of effective tangible metrics.	Mangla et al., 2017; Touboulic and Walker, 2015; Sajjad et al. 2015; Mathiyazhagan et al., 2013; Elbarkouky and Abdelazeem, 2013
Resistance to change: Fear of change of traditional practices and resistance to technology advancement adoption.	Esen and Elbarky, 2017; Elbarkouky and Abdelazeem, 2013; Ageron et al., 2012; Abbasi and Nilsson, 2012
External Barriers to SSCM Implementation	
Lack of government support: Poor legislations and regulations or lower emphasis on environmental aspects or inadequate incentives to support SSCM implementation.	Mangla et al., 2017; Esen and Elbarky, 2017; Ghadge et al., 2017; Sajjad et al., 2015; Elbarkouky and Abdelazeem, 2013; Walker and Jones, 2012; Walker et al., 2008
Poor suppliers' commitment: lack of suppliers' awareness, lack of collaboration with suppliers, and difficulty in monitoring suppliers.	Mangla et al., 2017; Ghadge et al., 2017; Elbarkouky and Abdelazeem, 2013; Mathiyazhagan et al., 2013
Unawareness of Customers: lack of customers' pressures concerning green practices, and unwillingness to pay more.	Mangla et al., 2017; Sajjad et al., 2015; Elbarkouky and Abdelazeem, 2013; Mathiyazhagan et al., 2013
Other Barriers: Culture difference, and industry specific barriers	Esen and Elbarky, 2017; Sajjad et al. 2015; Giunipero et al. 2012; Walker et al., 2008

Table 30, Continued: Barriers to SSCM implementation

RESEARCH GAP

By reviewing previous literature about sustainability and supply chain management, it was found that the majority of research conducted on barriers and motives for SSCM is theoretical in nature (Seuring and Gold, 2013). Thus there is a great emphasis on analyzing empirical data collected from companies (Ageron et al., 2012). Furthermore Seuring and Gold (2013) had recommended having additional studies for low income countries as supply chain managers are facing more challenges due to limited distribution or communication infrastructure that may hinder the ability of organizations to have a SSCM. Additionally Esen and Elbarky (2017) mentioned that although a well-developed literature about barriers and consequences of SSCM exists, yet the research of such field in Egypt is limited.

Accordingly, the research gap this study aims to fulfill is identifying drivers and barriers to SSCM implementation in Egyptian industries and providing recommendations to overcome such barriers. The choice of Egypt was due the lack of previous research of similar topics, and the increasing importance of sustainable development issues in Egypt. Consequently, the research questions for this study are; RQ1: What are the drivers for SSCM implementation in Egypt? RQ2: What are the barriers to SSCM implementation in Egypt? And RQ3: How can companies overcome barriers to SSCM implementation in Egypt?

RESEARCH METHODOLOGY

To decide for the methodology, the researcher had reviewed multiple previous studies finding that the field of SSCM is mostly encouraging the use of empirical data with a great emphasis on qualitative empirical data (Seuring and Gold, 2013). In order to find an answer to the previously mentioned research questions, this study adopts a descriptive research approach using a qualitative methodology through individual semi-structured interviews to discover the drivers, barriers, and ways of overcoming barriers of SSCM implementation in Egypt. The primary instrument used for data collection was semi-structured interviews with an interview protocol developed on the basis of previous literature to enhance reliability of such instrument. Interview questions were developed using questions from Walker and Jones (2012), Walker et al. (2008), and Rauer and Kaufmann (2015) in addition to some questions the researcher developed in accordance to literature review.

Focusing on industrial and manufacturing sector is known to be a historical trend in studying SSCM as the evolution of this concept relies heavily on the recent evolution of environmental regulations (Hassini et al., 2012). The research population was all industrial companies operating inside Egypt. As not only quantitative research requires sampling but qualitative research as well, qualitative sampling issues deal with the selection of whom and how many would be included (Ghauri and Grønhaug, 2002). Qualitative sampling usually begins with determining the target population, then using a non-probability technique to decide on sample to be included (Sekaran and Bougie, 2013). This research used a non-probability -purposive judgment- sampling technique which suggests selecting sample according to a certain criteria set by the researcher serving the research objective. And this criteria was that organizations; represent multiple industries, have direct and observable impact on external environment (environmentally, socially, and economically), relatively similar size companies, and had implemented or planning to implement SSCM practices. Deciding on a sample size for qualitative research is preferred to be based on theoretical saturation, as researchers might not be able to determine the sample size prior to data collection, they usually continue to sample until they are not getting any new insights or new information (Sekaran and Bougie, 2013). So, the final sample included 14 organizations representing four different industries with 22 experts engaged in sustainability implementation within supply chain functions being interviewed.

Qualitative data analysis is traditionally performed according to three steps represented; data reduction, data display, and drawing conclusions (Sekaran & Bougie, 2013; Ghauri and Grønhaug, 2002). Data reduction was done through deductive coding process where codes are generated from previous literature, and data coding was performed using N-Vivo qualitative data analysis computer software. Followed by data display, conclusions were drawn about barriers and drivers and how organizations could overcome such barriers which answer the three research questions addressed in this study.

Qualitative research, validity and reliability concerns are usually challenging to handle (Ghauri and Grønhaug, 2002). To enhance this research reliability, the researcher performed data analysis more than once to ensure similar interpretations were reached every time kept records of all interviews scripts for validation. Additionally, to improve theoretical validity, the researcher was working on understanding the topic, planning for sampling procedures to ensure sample representativeness of population through including multiple industries. While to enhance external validity, the researcher ensured the concept of saturation is achieved to mark the completeness of data collection phase, as replication logic enhances generalizability. Finally, to deal with the main challenge of qualitative research which is researcher bias, the researcher had provided a specific in-depth explanation of research project giving chance to other researchers to conduct similar research and compare results. Also, the researcher was keen on not using personal knowledge and experience to expect results.

FINDINGS AND ANALYSIS

SSCM Activities

It was found that organizations operating in Egypt have been implementing sustainability within supply chain differently with the majority (79%) working on three aspects of sustainability; economic, environmental, and social while only 21% are focusing on environmental and social aspects and not giving attention to economic aspect. Previous studies were focusing solely on environmental aspect of sustainability which is the environmental aspect and a very limited number of exceptional studies had integrated multiple dimensions (Winter and Knemeyer, 2013). Accordingly, this research's findings are different from previous studies as it was conducted on organizations implementing either the three aspects of sustainability or two at least.

Although organizations have reported implementing social and economic SSCM activities, organizations have put higher emphasis on environmental aspect related to SSCM activities as 57% of the sample have ranked environmental aspects within supply chain functions to be of a higher importance while 43% stated that all sustainability aspects are equally important. Hence it is concluded that organizations are implementing multiple economic and social SSCM activities, yet with limited variety. Meanwhile, the environmental dimension of sustainability is given higher emphasis as organizations are trying to enhance the "green" side of their supply chain. Confirming previous conclusions suggested by Ashby et al. (2012) suggesting that environmental dimension of sustainability is the most frequently integrated aspect within SSCM activities.

Barriers and Drivers for SSCM Implementation

Findings showed that multiple internal and external factors might act as either drivers or barriers. Moreover, findings suggest that some factors might act as drivers and the lack of such factors would be considered a barrier. Table 3 shows a summary of internal and external drivers and barriers to SSCM implementation in Egyptian industries.

Findings suggested multiple similarities between drivers and barriers to SSCM implementation identified in previous literature and barriers and drivers for SSCM implementation in Egyptian industries, however some differences might exist on how important these drivers or barriers are for organizations in Egypt.

For instance, results showed that regardless of the financial benefits, the majority (92%) have reported financial constraints to be among major barriers to SSCM implementation in Egypt. Matching with previous literature, as the most frequently highlighted challenge in implementing SSCM was the increased cost through creating a dilemma between reducing environmental impact and increasing financial cost (Esen and Elbarky, 2017; Ghadge et al., 2017). Findings confirmed that top management support and commitment is a powerful factor driving SSCM implementation in Egypt. Obviously, lack of support and commitment of both top management and middle management teams would be considered as a barrier. Hence confirming Esen and Elbarky (2017) that top management have a significance influential role in the success of SSCM implementation. Moreover findings reported slightly different insights concerning certification; although majority of organizations (71%) consider certifications as among drivers. Organizations considered certifications as drivers of lower importance or a facilitating factor enhancing SSCM implementation. Contradicting with a research by Deepak et al. (2014), certifications -ISO 14001- were ranked amongst the most important drivers for SSCM implementation.

A previous study by Elbarkouky and Abdelazeem (2013) for the challenges to SSCM in Egypt reported that the government does not support SSCM activities by any incentives or tax reduction. Findings confirmed that governmental regulations and policies are among the main factors influencing the implementation of SSCM in Egypt. Some aspects are still considered as barriers that need to be improved such as lack of monetary support for organizations in terms of incentives or tax reductions. Mangla et al. (2017) reported that there is a lack of awareness among customers about environmentally friendly products or services in developing countries. Customers in Egypt are not so much aware of sustainability or sustainable practices of organizations which acted as a barrier to SSCM implementation in Egypt. Yet there is a recent increase in awareness among international customers and organizations need to enter more international markets thus increased awareness among international customers is considered among drivers for SSCM implementation. Finally, low awareness about sustainability activities among local Egyptian suppliers was reported to be a major barrier to SSCM implementation in Egypt as sometimes those suppliers might resist implementing sustainability strategies. This agrees with Elbarkouky and Abdelazeem (2013) research about SSCM challenges in Egypt, reporting that unavailability of green suppliers as well as poor coordination between supply chain partners is a major barrier for implementing SSCM in developing countries.

Additionally, results have confirmed that some barriers and drivers do exist similar to previous literature such as resistance to change, lack of employees' experience, lack of sustainability awareness among employees, and lack of availability of standardized performance measurement. However, results have reported some differences with previous literature. For instance social factors are preferably considered as a facilitator for SSCM implementation in Egypt, rather than a driver as suggested by Sajjad et al. (2015), Elbarkouky and Abdelazeem (2013), and Walker and Jones (2012). Furthermore the majority of the research sample does consider cultural differences neither a barrier nor a driver for SSCM implementation in Egypt as managers believe that sustainability strategies can be understood by partners from different cultures, yet it might require some time and effort. This contradicts previous study by Sajjad et al. (2015) who reported that cultural differences are among barriers of SSCM implementation.

	Drivers	Barriers
Internal	• Financial benefits. • Top management vision and support. • Organizational encouragement. • Certifications.	• Financial constraints. • Lack of interest/ commitment of top management. • Lack of organizational encouragement. • Employees' resistance to change. • Lack of employees' experience. • Lack of awareness about sustainability among employees. • Lack of availability of standardized sustainable performance measurement systems.
External	• Governmental regulations. • Increased awareness about sustainability among international customers. • Competition.	• Lack of government support. • Lack of sustainability awareness among Egyptian customers. • Lack of sustainability awareness among suppliers (poor suppliers' sustainable performance).

Table 31: Drivers and Barriers to SSCM implementation in Egyptian Industries

Overcoming Barriers to SSCM

Organizations might face difficulty in attempting to eliminate all barriers simultaneously and it is recommended to first critically analyze all barriers, prioritize them, and work on the most influential and important barrier first (Ghadge et al., 2017; Deepak et al., 2014). Therefore, it is recommended that organizations focus on barriers according to their importance to organizations, so that managing these barriers would enhance sustainability implementation. It was suggested that for a better implementation of SSM strategies in Egypt, there is a need for a platform to synchronize efforts of various businesses, civil society, and the government. Such platform would help in providing support for organizations about sustainability mechanisms and allow for communication between government and private sector thus identifying potential areas of needs and help in solving those issues.

Internally, for better implementation of SSCM, organizations should have; supportive top management, encourage and inspire employees to commit to sustainability strategies through training courses and programs about sustainability, formal and informal communication between managers and employees and teams across different departments or different countries, and allowing for employees' participation in setting directions for organizations toward SSCM. Furthermore, organizations should consider achieving certifications related to social or environmental sustainability such as ISO 14001 for instance would provide helpful guidelines for organizations. Lastly organizations are required to carefully analyze financial issues related to sustainability projects implementation to be able to identify trade-off between financial benefits and financial constraints for sustainability practices.

Externally, organizations should think of interactive methods to enhance sustainability awareness among customers within operations or supply chain side. And since suppliers are among key success factors for SSCM implementation, organizations should work on enhancing suppliers' sustainable performance and increasing their commitment to sustainability objectives through; suppliers' development programs, initiatives to enhance the communication between supply chain partners to improve their overall sustainable performance, inclusion of sustainability performance measurements within criteria for suppliers' selection and evaluation, and conducting regular sustainability audits on suppliers to ensure compliance with international sustainability standards.

CONCLUSION

This study aimed to identify drivers and barriers to SSCM implementation in Egypt in addition to trying to solve these barriers based on data collected from organizations successfully managing these barriers. Findings have reported slightly different drivers and barriers other than drivers and barriers found in previous literature. This research study is considered among very few studies discussing SSCM issues in developing countries as Egypt, addressing both drivers and barriers equally with no focus on benefits only and ignoring challenges like multiple previous researches. Moreover it includes multiple organizations of different sizes and from various industries thus results can be more representative and generalizable on organizations operating in Egypt. Results provide practical contributions too, as it clearly identifies drivers and barriers for SSCM implementation in Egypt and valuable suggestions and recommendations for managers on how to deal with these barriers. Findings would inspire future research on barriers of SSCM implementation to enhance the integration of sustainability concept within supply chain management functions.

Finally, some limitations occur. First limitation is lack of availability of reliable sources of data which limit the sample size in multiple industries. Hence, future research should dig deeper into collecting data specific to each industry to offer better solutions specific to these industries. Second limitation is self-reported data which can be considered as potential sources of bias as it cannot be verified. It is recommended to integrate multiple sources of data in future research with a focus on more quantitative research approaches for this topic. Finally, as this study focus on large organizations, results might not be applicable for small and medium size enterprises. Therefore, research focusing on SSCM implementation among small and medium size enterprises in Egypt is highly recommended.

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