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(ISL 2022)

The Journey to Sustainable Supply Chains

10-13th July 2022

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26TH International Symposium on Logistics, 10th - 13th July 2021

INTRODUCTION

We are delighted to welcome our friends and colleagues, both old and new to the 26th International Symposium on Logistics. This year provides a unique opportunity to have debates on one of the most salient issues facing humanity, given the urgency of climate change. We are glad to have a hybrid event this year, which enables us to meet and network with colleagues from different parts of the world as in times past. The COVID-19 pandemic and other environmental forces have continued to challenge our strategies in hosting ISL due to disruptions to international travel.

The organising committee debated and agonised over the last 12-15 months or so on how to host this year's event, especially considering the sustainability theme of the conference. After extensive consultations, discussions and deliberations it was decided to hold a hybrid event with in-person meetings in the beautiful city of Cork, Ireland and online with Microsoft teams.

Bearing this in mind, two categories of paper submissions were invited. The first type was so called 'Full Papers' - that is up to 8 pages in length along with a one-page structured abstract. These types of papers were subject to a peer review process. These papers, if accepted, are included in the part 2 of the Proceedings of the Conference with an ISBN number. The second category of papers that were invited were labelled as 'Working Papers'. These may be considered as developmental, representing early-stage research ideas or initial findings. Only the abstract was required for the initial submission, which underwent the review process. If accepted, the authors were requested to submit an expanded (between 4-6 pages) version of the abstract. These Working Papers were made available on the ISL ConfTool portal for a limited period so that the registered delegates could access these during the event. However, only the abstracts of the working papers appear in this set of proceedings in part 1. It is expected that the submitted Working Papers would be significantly changed for any subsequent journal publication. Both types of paper submissions – working papers and full papers – were considered for publication in the special issue of the International Journal of Logistics Management or Computers and Industrial Engineering. The duration of the in-person presentations was 20 minutes, whilst the online presentations were for 10 minutes during the two-day event.

Considering the current context in terms of the environment (climate change), Covid-19 pandemic and disruptions to global supply chains, this year's theme was chosen as '*The Journey to Sustainable Supply Chains*'. This 26th 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 of proceedings represent the latest in academic thinking, as well as case examples of successful implementations. The 26th ISL also presents an opportunity to engage in various discussions and debates during the course of the event, exploring 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, we have been able transfer learnings associated with using online platforms from last year and combine it with expertise generated over the years in hosting physical events to deliver an excellent experience for delegates. We are delighted with the success in terms of number of submissions resulting in 68 paper presentations

representing authors from 28 countries. In addition to this, we were fortunate to have three excellent keynote speakers namely Prof Christopher Tang, UCLA, USA; Janice Scully, PEPSICO, Ireland and Joerg Buchwald, SIEMENS, Germany. We were also pleased to host a workshop on Circular Supply Chain Systems in the food and automobile industries with our colleagues in Cork University Business School, Ireland and Technische Hoschule Nuremberg, Germany.

On the whole the event proved to be highly successful considering the variety of activities ranging from keynotes, paper presentations, workshops, debates etc. These were further supported by a user-friendly online virtual group discussions and debates between delegates. All these activities enabled the ISL community to maintain its tradition as an informal yet productive and knowledge intensive event – all in all culminating in another memorable experience and successful event, despite travel restrictions and general concerns with the pandemic.

As mentioned above, like 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 in 2 parts according to the following categories:

Part I: Abstracts

- Sustainability in Logistics and Supply Chains
- Supply Chain Analytics
- Smart/Digital Logistics and Supply Chains
- Building Resilience for Supply Chains
- Humanitarian Logistics
- Transportation and Distribution
- Logistics Network Design and Management

Part II: Full Papers

- Digital Supply Chain Management
- Resilient Supply Chains
- Humanitarian Logistics

To date ISL has been held in Europe, Africa, Australia and Asia (see full list below), and the last event was held online. 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, partner journals - International Journal of Logistics Management (IJLM) and Computers and Industrial Engineering (CAIE) for their valuable support and contributions. Finally, our special thanks go to Dr Jasper Donelan in Nottingham University in UCC, Senan Ensko and Zita Philpott in the Executive Education Development Centre, Dr Christopher McElligott from the Digital Advisory Centre and Cork University Business School postgraduate students Marie Merlo, Chris Moran & Amanda Sithole for their advice and unwavering support before and during the event making sure the technology worked to perfection.

Professor Andrew Potter, Professor Kulwant S Pawar, Dr. Seamus O'Reilly and Ajeseun Jimo – July 2022.

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Sustainability in Logistics and Supply Chains

Simulating organizational learning from returns: simulation of closed loop supply chains in Military Cases

Ilkka Johannes Ritola1, Harold Krikke1, Marjolein CJ Caniels1, Quan Zhu2
1: Open University Netherlands, Netherlands, The; 2: Zuyd University of Applied Sciences

Purpose of this paper:
Advances in new technologies and in management of complex supply networks have given firms the opportunity to make their supply chains more flexible, responsive, and efficient. Organizational learning, improved IT capabilities, and new manufacturing technologies are among the drivers of these supply chain improvements. The purpose of this study is to investigate the effectiveness of organizational learning and emerging technologies in the context of a closed loop supply chain (CLSC) management.

Design/methodology/approach:
We apply simulation methodology to a case of military CLSC involving line replaceable units (LRU). Priority is put on minimizing downtime in the equipment caused by LRU failures. Additionally, we consider costs and environmental footprint. We incorporate learning into the simulation in two ways. Firstly, every instance of an LRU failure is a learning opportunity. Secondly, every instance of downtime is considered a failure in the supply chain and thus a learning opportunity.

Findings:
This study presents a set of quantitative assessments on the effectiveness of several learning and technology-based interventions in a military CLSC. The different interventions are compared in their effectiveness based on cost savings and their effect on minimizing equipment downtime.

Value:
The value of organizational learning in the context of CLSC has been studied before. This study contributes to the current research on CLSC value creation by quantifying the concrete implications of specific interventions in a CLSC using realistic data in a military CLCS.

Research limitations/implications:
This research studies the effectiveness of specific learning and technology-based interventions in a CLSC, therefore contributing to the growing literature on CLSC value creation in general, and in CLSC informational value research more specifically. However, this study focuses on a specific intervention, representing only few ways in which value can be created in a CLSC.

Practical implications:
By providing managers quantitative results regarding various CLSC interventions, this research can aid managers in making better decisions regarding which ways to invest in their CLSC improvements. Moreover, managers can benefit from the introduced simulation approach to simulate various other interventions important for their specific organisational needs.

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Reduction of Post-Harvest Losses in agricultural supply chains: A field study in Ghana

Atanu Chaudhuri[1], Kiran Fernandes[1], George van Dyck[2], Robert Bell[3], Andrew Bird[4], Adowarim Lugu- Zuri[5]

1: Durham University Business School, United Kingdom; 2: Regional Maritime University, Accra, Ghana; 3: Graydon Lloyd Ltd; 4: Spencer Bird Ltd; 5: Independent

Purpose of this paper: Post-Harvest Loss (PHL) is defined as a loss in edible parts of food products originally intended for human consumption but not consumed due to alterations in their physical-chemical or organoleptic characteristics. Reducing post-harvest losses would not only boost agricultural output but also "save" land which is particularly important considering limited arable land available in various countries (Claes et al., 2021). The purpose of this research are as follows: 1. Identify relevant crops in Ghana to reduce PHL 2. Analyse the extent of PHL for the specific crops 3. Identify supply chain related interventions to reduce PHL for the above crops 4. Develop an integrated framework considering people-process-technology to reduce PHL in Ghana

Methodology: Secondary research was conducted to collect data on annual yield and PHL in various vegetables in Ghana. This was followed by interviews with local agricultural entrepreneurs and experts to identify the relevant crops for the purpose of this research. A detailed process mapping and baseline assessment of PHL for the supply chains are currently in progress. Reasons of PHL for the specific crops will be identified based on the field studies and interviews. Some relevant interventions related to post harvest storage, packaging and transportation, use of sensors and tracking devices and online marketplace connecting buyers and sellers have been identified from the literature. An integrated framework and capabilities needed to reduce PHL for the specific crops will be created with potential applicability for other crops with similar perishability and supply chain characteristics.

Findings: The secondary analysis followed by expert interviews helped us in identifying tomatoes, onion and okra as the three vegetables with high potential to reduce PHL. Farmer reported PHL is 27% for tomatoes (Suggri, et al., 2021). The highest loss is in transportation, accounting for 37.8% and harvesting accounting for 18.5% of the total PHL for tomatoes. For onions, PHL is estimated to be 27.3% PHL (Suggri, et al., 2021) and according to farmers, maximum PHL is during storage, accounting to 79% of the total loss. Okra is a particularly relevant crop as it is a native African vegetable and is vital in Ghanaian diets. The stage-wise PHL show that the losses are concentrated at the harvesting stage accounting to 77% of the total loss according to farmer perceptions (Ridolfi et al., 2018). This happens because fresh okra pods bruise easily, blackening within a few hours. Thus, there is potential to reduce PHL by focusing on transportation and harvesting for tomatoes, storage for onions and on harvesting for okras.

Value: The paper in its final form is expected to identify specific supply chain interventions which can reduce PHL for the three studied crops in Ghana and report about their deployments and potential challenges. Such detailed study of agricultural supply chains particularly in the context of sub-Saharan Africa is scarce.

Research limitations: The study is limited to 3 crops and is based on the research teams' access to stakeholders in the studied supply chains.

Practical implications: The study will help players in the food supply chain to adopt the appropriate practices to reduce PHL in Ghana.

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CIRCULAR SUPPLY CHAIN VALORISATION: EXPLORING TRANSITION CHALLENGES AND OPPORTUNITIES IN THE USED CLOTHING SECTOR

Rudrajeet Pal[1], Erik Sandberg[2]
1: University of Borås, Sweden; 2: Linköping University, Sweden

Purpose of this paper: Amidst growing climate concerns, operationalizing an effective circular supply chain (CSC) has gained prominence in several sectors, and textiles is one of them (Pal et al., 2019). Textile circular economy adoption has led to European Union (EU)-wide planning for separate collection of post-consumer textiles by 2025, and aiming for higher value recovery as per waste hierarchy (EEA 2019). For enabling such transitions in textiles, of essence is creating systematic knowhow of used clothing CSCs (Zhuravleva & Aminoff, 2021), through mapping of not only the *status quo* of post-consumer textile flows and embedded values therein for different actors involved, but also in exploring how to improve the valorisation potential. The purpose of this paper is to investigate how used clothing CSCs can be made more effective to capture higher valorisation potential.

Design/methodology/approach: An embedded case study approach is adopted via semi-structured interviews with several used clothing CSC actors, such as non-profit charity organizations, municipalities, for-profit retailers, sorters and recyclers. Each case (sub-unit) is represented by the used clothes CSC tiers that constitute the value recovery steps of collection, grading, and recycling of post-consumer textiles. All the used clothing CSCs originate at Swedish collectors, and end at large sorters and recyclers at other EU countries, such as Netherlands, Germany and Poland. Sweden serves as an interesting starting point amidst ongoing development of national circular textile strategy, and emergence of diverse innovative actors. The semi-structured interviews uses a thematic guide to understand: current supply chain and business models, values and perceived challenges and solutions to future transition.

Findings: Preliminary findings reveal a complex net of actors, and flows, in the used clothing CSCs. While on one hand this is crucial to create multi-dimensional values (economic, environmental, information) in current CSCs, challenges also arise due to current ways of operation, such as due to decentralized processes, low volume efficiency and competition between different actors. As the future landscape unfolds with policy nudges, some of the actors, such as commercial sorters and recyclers are perceived to be in more favourable position compared to the others, such as non-profit charity organizations.

Value: The study identifies the challenges to value creation and capture stemming out from the current ways of operating in used clothing CSCs, and identify key solutions to improve opportunities for valorisation.

Research limitations/implications: Future research requires inserting a dynamic capability perspective as a means to extend knowledge on how to improve current valorisation in used clothing CSCs. Other geographical contexts within Europe could be explored. Finally, used clothing CSCs span Global North-South and such glocal perspective in future studies could be enriching.

Practical implications: This study contributes to the used clothing CSC actors by presenting a systematic approach towards valorisation opportunities and challenges that hinder it.

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European Environment Agency (2019), Textiles in Europe's circular economy, https://www.eea.europa.eu/publications/textiles-in-europes-circular-economy

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Closed loop supply chain as a complex system: a different angle to understand the hurdles in implementation

Harold Krikke
Open University of the Netherlands, Faculty of Management Sciences and Technology
P.O. box 2960, NL-6401 DL Heerlen, the Netherlands, Tel: (+31) 45 576 2724
E-mail: Harold.Krikke@ou.nl

Purpose of this paper:

Closing the loop has taken various shapes and forms over the last decades. Apart from closed loop supply chains, approaches were presented called life cycle management, cradle-to-cradle, product stewardship, total cost of ownership and lately circular economy. Although content wise progress has been made, practical implementations are lagging behind. Much literature is available on (the dynamics of) vicious cycles (e.g. Schenkel et al., 2015) yet we fail to understand precisely what is holding up large scale applications. This research deals with closed loop supply chains.

Design/methodology/approach:

To complement on earlier research, e.g. using system dynamics models, complexity provides a new angle to analyse closed loop systems. Complex systems are characterized by distinct properties, such as nonlinearity, many subparts in a hierarchical structure, cascade failures, adaptation (sometime by chance, sometime on purpose), and feedback/learning loops. Closed loops are typically non-linear (namely circular), add processes, actors and relationships, experience higher level of uncertainty, are subject to gaming, have many regulations and multiple triple P objectives.

Findings:

By describing typical CLSC characteristics as a complex system we hope to enhance implementation. We will present a framework based on systematic literature review. Also we present two case studies to validate the framework and discuss if this is sufficient for publication or whether we need more field research. Cases were/are to be conducted in medical devices for hospitals, large power transformers (energy sector), railway infrastructure (public transport) and Defense industry.

Value:

The research aims to further deepen insights on how success factors and constraints interact through a complexity lens (such as e.g. Geels, 2004). This should give us handles to turn around vicious cycles into virtuous cycles. The main aim of this paper is to develop a new theoretical framework based on existing (complexity) theory and cases.

Research limitations/implications (if applicable):

The research is primarily qualitative. Initially we aimed for a mixed method approach but the case companies were not able to provide many numbers or KPIs.

Practical implications (if applicable):

World Economic Forum in Davos recently presented 'Circularity Gap Report 2021 showing that circularity dropped worldwide from 9,1% in 2019 to 8,6% in 2020 and 2021. In the meantime problems are mounting up so this needs to be changed urgently.

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Determinants for the uptake of alternatively fuelled HGVs: Towards a maturity framework

Nikolaos Valantasis Kanellos, Xu Zhang

Technological University Dublin, Ireland

Purpose of this paper: Alternatively fuelled vehicles (AFVs) have received increasing attention from policy makers and industry practitioners because they are perceived as a silver bullet for decarbonising freight transport (Mohammed et al., 2020; ITF 2021). However, the uptake rate of AFVs by heavy goods vehicle (HGV) freight operators in Europe remains low. With 97.8% of all trucks in the EU running on diesel, only 0.04% of trucks are zero-emission vehicles (ACEA, 2021). Price, technology maturity, infrastructure, and government policy support are factors examined by freight transport operators who consider the switch to AFVs as a low-carbon option (Mohammed et al., 2020). Research studies have identified enablers and barriers for adopting AFVs. Practical guidance and tools for decision making from freight transport operators' perspectives are still limited. This research study explores what factors influence the adoption of AFVs and proposes a framework to assess the maturity level of HGV freight transport operators for the uptake of AFVs.

Design/methodology/approach: Initially, determinants for decision making on adopting AFVs were identified from academic literature. Secondly, content analysis of secondary sources (e.g., media reports from AFVs freight operators in Europe who already have adopted or are willing to adopt AFVs) was carried out to examine how these factors can affect decision making. Finally, the proposed framework was tested on an HGV operator based in Dublin, Ireland.

Findings: A conceptual maturity assessment framework, which is based on the technology adoption lifecycle, is proposed to enable HGV freight operators to assess their readiness and feasibility for uptake AFVs in their fleet. The maturity framework consists of four distinct phases of AFVs uptake, namely: avoid, aware, accept, adopt, and apply. Relevant aspects and indicators in each phase were also presented.

Value: The determinants for AFVs uptake that were identified provide valuable insights for policy makers to develop interventions with effective measures to facilitate the uptake of cleaner fuels in the road haulage industry.

Practical implications: Tools like the maturity model help logistics and transport managers to systematically evaluate the readiness and feasibility of their company to uptake AFVs.

Research limitations/implications: This study considered AFVs as an alternative option in contrast to conventional fossil fuel vehicles, no specific types of AFVs were considered. Future research could further explore a specific type of AFVs.

Keywords: Alternatively fuelled vehicles (AFVs), Heavy goods vehicles (HGVs), freight transport, maturity assessment, decision making, green logistics, Ireland

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Food Recycling Platform in the Food Supply Chain

Shuang Tian, Lin Wu, Kulwant S. Pawar
Nottingham University Business School, United Kingdom

Purpose

Food waste is generally seen as a significant challenge because of its negative impact on the economy, environment, and society. Given the fact that one million inhabitants are suffering from hunger and malnutrition, the edible food waste can be redistributed to new consumers to solve food waste and food poverty. Driven by the digital revolution, food recovery platforms focus on establishing connections between suppliers and demanders, promoting food waste recycling while reducing the negative impact of waste (Michelini et al., 2018). Theoretically, food recycling platforms establish channels between suppliers and demanders to promote the food waste flow. However, in reality, recycling performance is restricted by many factors, which hinders the redistribution of food waste. Since food recycling platforms have emerged only recently, related research focuses on platforms' economic model, dissemination, and classification. There is still a lack of research on the platform's performance in solving food waste and the factors that practically hinder recycling performance. This research establishes ideal-reality gap models to uncover recycling performance by focusing on the food redistribution process. Based on the four gap models, this research explores recycling efficiency and relevant impact indicators at different stages of food waste redistribution and builds an evaluation framework for food recycling platforms.

Methodology

This research conducts a mixed method to establish gap models and investigate the influence indicators of food recycling performance. The ideal-reality gaps are built on the existing literature on E-service quality, perceived value, food accessibility, and suboptimal food. These gaps summarize the possible inefficiencies and describe the difference between expected performance and the reality of food redistribution. The data collection includes questionnaires, semi-structured interviews, and secondary data obtained from OLIO- a food recycling mobile application.

Findings

The gap models based on four stages have been completed in this research, and data collection is currently in progress. The expected findings will provide efficiency evaluation and key impact indicators analysis for food recycling platforms. In addition, based on gaps analysis, a comprehensive evaluation system of the platform's food recycling performance will be built.

Value

This research examines the sustainable performance and crucial indicators of food recycling platforms in the food supply chain. This research adds an early empirical insight into the platform-based circular supply chain models, which contribute to improving the food recycling process. In addition, the result provides a new perspective for platform-related research through ideal-reality gap models. **Besides, this research** responds to the growing interest in the circular economy by providing empirical evidence about the food circular supply chain.

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AN ANALYTICAL FRAMEWORK FOR SUPPLIER RELATIONSHIPS IN THE CIRCULAR ECONOMY

Matthias Kalverkamp
Wiesbaden Business School, RheinMain University of Applied Sciences, Germany

Purpose of this paper: The circular economy paradigm changes business models and hence supply chains. To close resource and material loops, new buyer-supplier relations emerge (e.g., buyers can become suppliers). The procurement of used products is often identified as the bottleneck of the supply chain, because companies struggle with managing supplier relationships and the implementation of a comprehensive procurement marketing process. A lack of suitable supplier relationship management tools and underlying procurement marketing concepts on the one hand and lacking operational knowledge on the other hand, may explain this challenge. Eliminating this bottleneck can improve the productivity and competitiveness of businesses and stimulate the economic potentials of circular business models.

Design/methodology/approach: The study develops and tests an analytical framework to assess supplier relationships in circular supply chains. The framework builds upon new institutional economics. Case studies from the automotive domain are used to test the framework. Eventually, the framework is aimed to support supplier relationship strategies and respective process development for supply chains in the circular economy.

Findings: The study supports the notion that the procurement of used products remains one of the main bottlenecks for increased circularity in the automotive value chain. Although actors and their specific role differ significantly, most challenges arise from uncertainty regarding transactions and planning. Specificity can be of relevance as well. To overcome challenges, supply chain actors need to understand their specific position and role in the supply chain and towards (potential) suppliers.

Value: The paper adds to the body of knowledge on supplier relationships in the automotive circular economy. The framework can help to identify relationship management strategies and tools, specific to SC role and position, to overcome bottlenecks for circularity. In addition, the approach may help to identify potential new collaborators for procurement in circular supply chains.

Research limitations/implications: The derived findings are limited and need to be tested with further cases and in business practice to improve structure, applicability, and practicability of the framework. Findings indicate that the potential of strategic supplier relationship management may be underrated.

Practical implications: A further reduction of information and transaction costs is crucial to establish lasting supply chains in the circular economy. At this stage, the findings highlight the value of strategic supplier relationship management for successful circular economy business models.

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On challenges of industrial green transition – AHP approach on the supply chain value creation

Jyri Vilko, Oskari Lähdeaho

Kouvola Unit, Lappeenranta University of Technology, Finland

Purpose of this paper: Sustainability and green transition are changing the way service and manufacturing businesses and supply chains operate. The global change of technological innovations and obsoletion of old technologies is crucially impacting the value production of organisations. 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 changes of green transition include emission restrictions and renewable energy sources have experienced increasing pressure in the pace in which those are implemented due to the turbulence in the operational environment. This paper illustrates the challenges in value creation caused by the green transition in an industrial supply chains.

Design/methodology/approach: This study aims to explore the challenges in value creation an industrial supply chains facing green transition, namely emission restrictions and changing to renewable energy sources, using both supply chain sustainability and value network theories. The empirical part of the research is based on qualitative research design with cross industry expert group utilised as main informants. The explorative research approach includes three step data collection and analysis steps, including identification of the most relevant challenges in the green transition, Analytic Hierarchy Process as prioritization of the results as well as closer descriptive analysis of the meaning of those changes to the businesses. The expert group included 12 persons from different industries representing different roles in their supply chain. Numerous sources found from the literature are used to gain a holistic understanding of the attributes and impact of emission restrictions and renewable energy adoption to the value creation.

Findings: This study provides an important, yet sparsely addressed viewpoint to the supply chain management literature by illustrating the challenges related to implementing green transition related changes in the supply chain. The findings of the paper suggest that there is a lot of uncertainty in how different people view the changes. As the most important factors energy efficient products, increasing pace of product development cycles as well as alternative manufacturing methods were identified. While sustainability is viewed overall as a positive change, the challenges it causes to the manufacturing and service industries are substantial.

Value: This paper contributes to both supply chain sustainability management and value management literature with insights into how networked manufacturing industries are facing the challenge in the green transition, more precisely emission restrictions and renewable energy solutions. Analysing the most relevant factors with a systematic and explorative research process seemed to work well in building a holistic picture about the relevancy of different attributes in the industrial supply chain.

Research implications: The study helps to understand the nature and dynamics of value in the supply chain and how green transition impacts machining industry. The presented view offers insights for implementing the changes for emission restrictions and renewable energy in the supply chain.

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Managing Supply Chain disturbances: insights from the perishable food sector following the Covid Pandemic

Christos Braziotis[1], Helen Rogers[2], Haihan Li[1]
1: Nottingham University Business School
2.Technische Hoschule Nuremberg

Purpose of this paper: Supply Chain (SC) disturbances, namely risks and uncertainties, have been a long-standing topical issue for research (e.g. Jüttner *et al*., 2003); recent events such as the Covid pandemic, Brexit, and the war in Ukraine have further reignited interest due to the major breakdowns and product shortages. One of the industries majorly affected by such disturbances is the food SC, and more importantly the one for perishable food. With the projected increase in the human population globally, there is much research suggesting we may be faced with some major food Supply Chain sourcing and distribution challenges by 2050 (e.g. Van Dijk et al., 2021). The purpose of our study was to explore and review the disturbances that have impacted the perishable food SC during the Covid pandemic of 2020-2022. We aim to better understand these disturbances, and their impact on key stakeholders including wholesalers, retailers and caterers in the perishable food SC, and investigate their responses in managing those risks and uncertainties to mitigate their impacts. Perishable food was selected as the unit of analysis owing to its particularly short shelf life, quick turnaround and in some cases complex, cross border SCs (e.g. Gokam and Kuthambalayan, 2019).

Design/methodology/approach: Our study was qualitative in nature, and considered both secondary data (reports, news, academic and practitioner articles) as well as primary data (interviews with key food SC stakeholders). The in-depth semi-structured interviews were conducted in companies in the fresh food industries in both the UK and China.

Findings: Our study proposes a conceptual framework relevant to the perishable food SC in times of a major breakdown, namely the Covid pandemic of 2020-2022. The framework identifies the operational nature of the disturbances and the methods employed by companies along the SC, as well as policy makers to manage them and be better prepared for any such future events.

Value: The study aims to contribute to the SC risk management and resilience literature by providing new insights to the disturbances that the perishable food SC faces and the impacts of major international disturbances and breakdowns, such as pandemics.

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Supply Chain Analytics

Simulating food supply chain operations to drive sustainable consumers choices

Riccardo Accorsi, Emilio Ferrari, Beatrice Guidani, Riccardo Manzini, Michele Ronzoni
[1]Alma Mater Studiorum – University of Bologna
Department of Industrial Engineering
Viale Risorgimento, 2, 40136, Bologna, Italy
E-mail corresponding author*: riccardo.accorsi2@unibo.it

Purpose of this paper:
Whilst the environmental sustainability of agriculture, food industry, and food supply chains should be a leading principle of innovation, it is not obvious which actors among policymakers, growers, practitioners are responsible for that, and how to lead such transition. In this paper, the role of consumers in pulling the change of food supply chains processes and operations toward more sustainable, less polluting, and energy-effective systems is explored.

Design/methodology/approach:
In this paper, a simulation supply chain digital twin aids the quantitative assessment of food operations impacts and externalities with the aim to label food products with such impacts, thereby driving more aware decisions by consumers. The digital twin platform consists of an Objected-Oriented (OO) programming language interface with an embedded GIS for network and transportation evaluation and a SQL database to collect parameters from the simulated supply chain environment. Agricultural, production, packaging, storage and distribution stages are modelled in this platform.

Findings:
It emerges that local and less-processed food items have a lower environmental impact, but also the crop yield and the storage stage contribute to the footprint of products. The geographic distribution of the supply chain, likewise the presence of intermediate storage facilities, should be visible to the consumers through the proper quantification of the related impacts.

Value:
The proposed system builds upon the popular eco indicators that provide a rough idea of the impact behind the production and distribution of food items. Digital twin platforms support the punctual quantification of such impacts, lot by lot, with the purpose to increase the visibility and the awareness of the supply chain complexity and weaknesses, conveying more sustainable choices by the consumer.

Practical implications:
The proposed digital twin could support eco-labelling of food items to be used by retailers to educate consumers to more sustainable food habits.

Keywords: Supply Chain Digital twin, Food supply chain, Operations control, Impact assessment, Food labels

THE ROLE OF POWER IN SUPPLY CHAIN MANAGEMENT: A SYSTEMATIC LITERATURE REVIEW

Xingru Li, Min Zhang
Queen's University Belfast, United Kingdom

Purpose of this paper:
Power is one of the most long-standing and salient research topics continuously within supply chain management (SCM). This study aims to explore the role of power in SCM by facilitating the synthesis of fragments from a range of literature. We address two research questions. First, what are the impacts of power in SCM? Second, how does power affect the performance outcomes?

Design/methodology/approach:
We conduct a systematic literature review using the Web of Science database. After data cleaning, we have selected 88 articles between 1991 and 2020. We employ network analysis and content analysis to analyze the literature. VOSviewer visualization tool is used to conduct the network analysis. We also use the context-intervention-mechanism-outcomes (CIMO) logic in the content analysis to synthesize the studies and develop a framework for future research.

Findings:
We have created a co-occurrence network map based on the keywords in the power literature. The results show that research trends shift from focusing on the impacts of power on supply chain relationships and integration to how power affects sustainability and innovation. Based on the CIMO, we find that power has been explored in the context of dependence, uncertainty and partner history/characters in accordance with relational, business environments and features of partners. We also find that the use of power influences performance outcomes in terms of supply chain relationships (SCRs), supply chain performance (SCP) and supply chain capabilities (SCCs). The study further identifies the mechanisms through which power/interplay interventions affect the SCRs, SCP and SCCs. Based on the findings using the CIMO logic, we develop a contingent framework to synthesize the role of power in SCM which provides insights on how to apply appropriate power interventions to invoke the generative mechanisms to achieve expected outcomes in specific contexts.

Value:
This study contributes to the literature in three ways. First, it provides empirical evidence on the evolution of research of power in SCM. Second, the findings provide insight into the role of power in SCM by clarifying the performance outcomes of power. Third, the study also sheds light on the mechanisms through which companies can use power to influence SCM. Moreover, we develop a framework and identify future research directions on the role of power in SCM.

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Integrating supply chain aspects into factory planning – a simulation approach

Tobias Wild[1], Stefan Galka[1], Mona Wappler[2], Xing Lu[2]
1: OTH Regensburg, Germany; 2: HS Rhein-Waal, Germany

Purpose of this paper: One major goal of greenfield factory planning is to decide on space requirements in the plant [1, p. 93]. In this phase, detailed information on the supply chain network (e. g. which suppliers deliver which parts) is often not available. Nevertheless, typical decisions in supply chain management, like the definition of replenishment processes and quantities, or make-or-buy decisions have an impact on space requirements in the factory and should therefore be considered in the design phase [2, p. 403], [3, p. 206]. For example, depending on the depth of manufacturing, production steps must be integrated into the factory. Otherwise alternatively warehouse capacity of parts that are sourced externally have to be considered in the planning process. Due to the complex interrelationships between supply chain and production design as well as the dynamic changes in the framework conditions, this research article propose a model to integrate both aspects in close coordination. The impact of supply chain aspects on factory space requirements by applying simulation studies are evaluated.

Design/methodology/approach: A simplified final production process of a water electrolysis stack is used to analyze the impact of changes in the supply chain on space consumption in factory. In this process, four subprocesses, cutting steel pipes, welding, assembly of a rack as well as stacking of cells, are needed. Four different scenarios, which essentially differ in their depth of production, are defined to simulate buffers, delivery capability and the above-mentioned working steps. In addition to these various scenarios, stochastic disruptive influences, such as machine failures, are included in the model. Besides, changes in demand and variability in suppliers' performance in terms of delivery time and quality are also integrated into the simulation study.

Findings: The inventory level and the associated area for goods vary depending on the selected manufacturing and supply chain scenario and parameters. Exemplary questions which can be answered are: how does the space requirements change when the depth of manufacturing is increased or decreased? How does the variability in suppliers' performance and production processes impact the delivery performance and lead time of the final products?

Value: The working paper presents the description of a case study and the simulation model, including the selected stochastic disruptive influences as well as initial results. Furthermore, it addresses the lack of literature study integration material flow simulation in greenfield factory planning [4] and tools dealing with uncertain data in this context [5].

Research limitations/implications: In this initial model the focus lies on the evaluation of space requirements. Therefore, costs haven't been integrated into the model. In future work, a cost analysis should be integrated into the approach.
Practical implications: The simulation approach can support factory planners in decision making at an early stage of factory planning by enabling the analysis of the interrelationships between supply chain and the production processes in combination with stochastic influences.

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The influence of production priority policies on the operational performance of closed-loop supply chain

Shupeng Huang[1], Andrew Potter[2], Daniel Eyers[2], Qinyun Li[2]
1: College of Management Science, Chengdu University of Technology, People's Republic of China; 2: Cardiff Business School, Cardiff University, UK

Purpose of this paper: The urgent need for sustainability drives more and more companies to adopt closed-loop supply chain (CLSC) management practices. With CLSC, the returned products are reprocessed after consumption, with those products that are remanufactured going on to be sold as substitutes for new products, which not only increases the value of the product in its whole life cycle, but also reduces overall pollution and carbon emission. However, although CLSC is often beneficial to both companies and society, how CLSC can be effectively operated under capacity constraints is not clear. Currently, due to the various causes, such as disasters or pandemic, it is highly likely for CLSC to lose some, if not all, of its capacity in producing new or remanufactured products. Therefore, it is imperative to study how CLSC can achieve high performance under limited capacity.

Design/methodology/approach: In this paper we assume CLSC works under a limited capacity in producing new and remanufactured products, and the capacity can be shared within these two operations. To explore how CLSC can obtain high performance under capacity limitation, we compared two production policies, namely manufacturing priority policy and remanufacturing priority policy. The first policy results that the CLSC will always apply its limited capacity to prioritise manufacturing new products, whilst the latter means the CLSC will use the capacity to remanufacture customer returns first. Using the bullwhip effect as a performance measure of CLSC, we developed a system dynamics simulation to investigate which policy will lead to lower bullwhip of CLSC.

Findings: We show that in most cases CLSC should prioritise remanufacturing as it will lead to a lower bullwhip effect, although it may result in slightly higher bullwhip in remanufacturing operations if demand standard deviation is relatively low.

Value: This study extends research on the CLSC bullwhip by considering capacity sharing. To the best of our knowledge, there are only three papers that have previously examined the CLSC bullwhip under the capacity constraints, and none of them consider the case that manufacturing and remanufacturing can share capacity. Therefore, our study enriches the existing literature and provides new mathematical models for future studies.

Research limitations/implications (if applicable): In this study we assumed that the capacity consumed in one unit of new product is the same as in one unit of remanufactured product, which is not always the case in the reality. Therefore, future research can relax this assumption and explore the influence of capacity on bullwhip of CLSC.

Practical implications (if applicable): The study can inform the practitioners that to achieve a high CLSC performance, it can be necessary to redesign the production process to prioritise the remanufacturing.

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Supply Chain Integration Failure and Attentional Responses: An Exploratory Study

ALEX BOATENG[1], DOMINIC ESSUMAN[2], LISTOWEL OWUSU APPIAH[3]

1: KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, Ghana; 2: KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, Ghana; 3: KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, Ghana

Purpose of this paper: Supply chain integration (SCI) "...is easier to talk about than to do" (Knemeyer and Fawcett, 2015, p. 304). Despite this, and the recognition that some firms are unable to realize the performance aspirations associated with SCI investment (i.e., SCI failure) (Wiengarten et al., 2019; Fawcett et al., 2015), knowledge is lacking on the organizational responses activated following SCI failure. This research explores how firms respond to SCI failure and its associated economic and relational costs.

Design/Methodology/Approach: Given the underdeveloped literature on SCI failure and its outcomes, a theoretically-driven exploratory study is considered in this research. Specifically, we integrate attention-based view of the firm (ABV) and conservation of resources theory, and ABV and problemistic search theory, to identify SCI effort and learning from SCI failure, respectively, as two important attentional responses to SCI failure. We explore the study propositions using survey data from 123 medium and large manufacturing firms in Ghana. The data is analyzed using exploratory factor analysis, regression analysis, and Hayes' PROCESS.

Findings: Results suggest that the magnitude and direction of association between SCI failure and SCI effort are conditional upon *level* and *type* of failure costs (relational versus economic) as well as the portion of the supply chain where the failure occurs (upstream or downstream). For example, overall SCI failure has stronger positive effects on customer integration effort and supplier integration effort under low conditions of relational and economic costs, respectively. Again, customer integration failure has positive and negative associations with customer integration effort and supplier integration effort, respectively; the reverse effects hold in the case of supplier integration failure. Lastly, the study finds that learning from SCI failure has positive effects on both customer and supplier integration efforts.

Value: This research departs from the dominant SCI-performance research by exploring how and when performance shortfall instead determines SCI. In so doing, we identify three important but previously ignored determinants of SCI: SCI failure, SCI failure costs, and learning from SCI failure. Our research additionally broadens the conceptual scope of the strategy failure research from the perspective of SCI.

Research limitations/implication: This study offers initial analysis and evidence on the learning and SCI consequences of SCI failure. Our findings require further validation using large-scale and or longitudinal survey data from similar or different empirical settings.

Practical implications: SCI is crucial but its associated performance aspiration may not always be realized. This negative discrepancy and its costs are stressful issues that need to be managed tactfully to promote SCI. SCI failure can be outside the control of supply chain managers; therefore, it should be anticipated while pursuing SCI. Supply chain managers should appreciate and analyze the nature of SCI failure and its costs at a decomposed level and act accordingly.

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Improving Picking Efficiency of a Cold Warehouse to Shorten Exposure Time under Unfavorable Temperature

Marco Fabio Benaglia[1], Mei-hui Chen[2], Shih-Han Hung[3], Shih-Hao Lu[4], Kune-muh Tsai[5], *

[1, 4]National Taiwan University of Science and Technology, Taipei, Taiwan 10633
[2]Chia Nan University of Pharmacy and Science, Taiwan 71710
[3 ,5] National Kaohsiung University of Science and Technology, Kaohsiung, Taiwan 81164
corresponding: e-mail: kmtsai@nkust.edu.tw

Purpose of the paper:
This study investigates how to plan the optimal storage allocation strategy based on Apriori association rules, in order to effectively reduce the picking time and distance in low-temperature logistics centers, where a truck load is a combination of many orders picked individually. Furthermore, as a consequence, the length of time spent by picked items in the loading area can also be reduced, thus lowering the risk of exposing temperature-sensitive goods to unfavorable conditions for long periods.

Methodology
We first identified the main characteristics of the yearly average orders of a large cold logistics company. Using VBA, we generated four sets of yearly historical data and three sets of yearly test data matching this profile, and we performed the ABC classification of item order times and order amounts based on the historical data; then, we wrote a program in Python to calculate shipment correlation coefficients to use as relevance values of refrigerated food items following Apriori association rules. Finally, eight storage allocation strategies were devised after discussing with the case company and considering the physical layout of their warehouses; these eight strategies were tested on the three sets of test data as simulated future orders to compare the picking distance, the picking time and the waiting time in the loading area.

Findings
The experimental results found that the eight storage allocation strategies proposed in this study can reduce picking time and distance. Of the eight storage allocation strategies, the strategy called "Random placement in ABC classification - Dispersed" (R-ABC-D) performs best in terms of the shortest waiting time of picked items in the loading area.

Originality
Previous research on optimal storage allocation strategies did not consider association rules based on item sales correlation coefficients. This research combines association rules with several storage allocation strategies and warehouse layouts, then evaluates their performances compared to random assignment as the baseline strategy, to find the combination that minimizes picking time, picking distance, and order waiting time in the loading area.

Keywords: cold warehouse, low temperature, association rules, picking, storage allocation strategy, item placement

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Initial approach for data mining in logistics – software supported prognosis exemplified by delivery damage probabilities

Jens Eschenbächer[1], Linus Kühl[2], Jost Wiethölter[3]

1: Hochschule Bremen, City University of Applied Sciences, Germany; 2: Hochschule Osnabrück; 3: Mars GmbH

Purpose of this paper: The usage of big data analytics has become increasingly important in the business world throughout the last years because of the high potentials such as improving profit and customer satisfaction (Raman e.a. 2018). However, in the logistics industry this topic is not yet as widespread as it is in other sectors such as banking or retail (Lamba and Singh 2017). Thus, the field big data analytics represents a possible differentiation criterion compared to other logistics companies for instance in terms of generating insights on utilization, empty runs or damage rates. The biggest challenge here is not to collect the data but to use and analyze it systematically while also creating know how and providing adequate IT-tools for usage within the own company (Muntzke 2016). In this paper the authors present a standardized data mining approach on how data mining can potentially be used and applied in the logistics sector to face the mentioned challenge.

Design/ methodology/ approach: This paper uses the quantitative analysis of reference data (German cargo market) to assess the possibilities in tool assisted data mining. By applying CRISP-DM (Standard for Data Mining), the raw data is processed with a systematic approach. The preparation of the raw data is carried out by using Power BI to enable scalability for data sets with varying quality levels. In the next step, the homogenized and processed data is used in RapidMiner to create forecast models for determining the probability of damage based on different factors. This process is retrospectively analyzed for applicability to other scenarios and an assessment of the possibilities in the corporate context is made.

Findings: This work shows that the tool-based data mining approach delivers very good results in the use case of predicting shipping damages. By applying transferable queries and steps for data processing, the models and processes can also be used for other data sets. In the process, the difficult-to-capture, non-homogenized source data could be made usable for further operational control processes.

Value: The application of data mining to logistical processes with the aim of creating a target group oriented basis for decision-making for operational units is main innovation in this paper. The use of current utilities and tools in interaction with each other shows the possibilities that arise for logistics companies, which are often deficient in this area. The major added value of this paper is for decision-makers in logistics companies, as it offers an opportunity to review the status quo of their organization's utilization of data.

Research implications: By extending the research to other targets, the stability of the process can be further tested. Furthermore, the added value of the generated information for day-to-day business has to be examined. By implementing the findings in the business processes and optimizing them through double-loop learning, the feasibility can be tested and optimized.

Practical implications: Through the preemptive data evaluation and analysis via a centrally developed process, the existing data can be used in a cost-effective approach. The standardized procedure ensures that an extension to other data sets is possible and only very little knowledge in data processing is required here. Large amounts of data already available in a company can consequently be used for day-to-day decision-making.

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The role of data analytics in supporting the enablement of strategic decision making in S&OP

Alan Jerry Shanahan, Seamus O'Reilly, Frederic Adam

University College Cork

Purpose: This paper explores strategic decision making in the Sales & Operations Planning (S&OP) process and in particular when and how data analytics capabilities can be leveraged to support the enablement of such decisions.

Design: Building on existing research on the importance of strategic decision making in S&OP, a critical analysis of the literature is conducted on the role that data analytics has in enabling strategic decision making in the S&OP process. Analysis of empirical data obtained through an expert Delphi study in the field identifies current and potential future developments in this area and provides the basis for a critique of ex-ante literature.

Findings: The review of the literature points to the role of data analytics in supporting strategic decision making in the S&OP process (Schlegal et al., 2021, Davenport, 2013). The Delphi study findings highlight the need to build the right capabilities to utilise data analytics (as defined by Power, 2014) appropriately to enable strategic decision making in S&OP. The level of trust and transparency in the data emerges as a key factor for the decision makers in the process. In addition the empirical data from the field challenges some of the published literature which advocates for advanced software capabilities to be in place to reach mature S&OP levels, which it turn support strategic decision making.

Value: The paper defines the role of data analytics in S&OP in support of enabling strategic decision making. The broad considerations that influence value from data analytics are defined, highlighting the importance of building the right capabilities in terms of systems, processes, skills and culture.

Research Implications: The paper builds on a long standing call for action on strategic alignment in S&OP (Kristensen & Jonsson, 2018). It contributes to an emerging literature on the role of data analytics when it comes to strategic decision making enablement.

Practical Implications*:* The findings from the Delphi study combined with the synthesis of the academic research provide guidelines for practitioners on the conditions for deploying data analytics to support the enablement of strategic decision making.

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Multicriteria inventory classification reliability
Frank Michael Theunissen, Paul Childerhouse, Carel Bezuidenhout

Massey University, New Zealand

Purpose of this paper:

Practitioners rely on quality research to solve contemporary management challenges. In support, researchers ensure the reliability of data supporting an empirical claim or used to develop and verify a computational model (Arstein & Poesio,2008). This ensures an effective flow of information between researchers and practitioners. However, the research-practice gap points to a weakness in this relationship (Roux et al. 2008). One of the contributing factors is the production of research with little practical utility (Fraser et al. 2018). From a multicriteria inventory classification perspective, the proliferation of complex mathematical/theoretical models challenge practitioners from a skills perspective, (Roda et al. 2014; Lenard & Roy, 1995). Part of this complexity relates to the evaluation of MCIC models that require practitioners to appraise the results of alternative models in the literature. However, no process is presented to do this, therefore, this paper aims to: i. estimate the reliability of the results of verification models reported across multiple MCIC studies, ii. Identify gaps in the application of reliability coefficients to MCIC research and practice.

Design/methodology/approach:

Krippendorff's a was used to estimate agreement between the reported results of selected MCIC models applied for model verification across multiple studies. The analysis was limited to 33 studies applying the Flores et al. (1992) and Ng (2007) adaptations of Reid's (1987) standardised 47 item dataset. The Flores et al. (1992) adaption consists of four criteria; i) annual dollar usage ii) average unit cost iii) criticality and iv) lead time whilst Ng's three criteria version excludes criticality. Discrete analysis of both versions of these datasets is done for comparability.

Findings:

18 verification models presented in 33 MCIC studies for model verification purposes were considered. Disagreement was found in the reported results of models used in studies applying both versions of the dataset. In studies using the four criteria dataset, four models yield a values below 1 (Reid, 1987; Flores et al., 1992; Ramanathan, 2006; Ng, 2007) and in studies using the three criteria version of the dataset seven models yield a values below 1 (Reid, 1987; Flores et al, 1992; Ramanathan, 2006; Ng, 2007; Hadi-Vencheh, 2010; Mohammaditabar et al., 2012; Ladhari et al., 2016). Consequently, the reported results of four well-known models from the MCIC literature exhibit the lowest levels of agreement across both dataset versions.

Value:

The main contribution of this work is the application of Krippendorff's a reliability coefficient in the context of MCIC studies to estimate the reliability of results reported in the literature. The results inform practitioners considering the application of the models evaluated in this paper, to consider the reliability of the reported results before model selection.

Research limitations/implications:

Several limitations affect the integration of this method into accepted MCIC procedure. The findings represent a minor subset of MCIC literature, and the method is yet to be applied for the estimation of agreement across results reported in studies using heterogeneous datasets. Additionally, the classic reliability measurement literature lacks a suitable method for the interpretation of a in the context of MCIC research. Concerningly, the cause of the low a values could not be determined, thereby diminishing the practical value of MCIC contributions to date.

Practical implications:

The results inform practitioners considering the application of the methods evaluated in this paper to consider the reliability of the reported results before model selection and implementation.

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Smart/Digital Logistics and Supply Chains

OBSTACLES, INCENTIVES AND IMPACTS OF INDUSTRY 4.0 IN PHARMACEUTICAL SUPPLY CHAINS

Marianthi Omiriadou[1], Dimitra Kalaitzi[2]

1: School of Business Administration, European University Cyprus; 2: Department of Engineering Systems & Supply Chain Management College of Engineering and Physical Sciences Aston University

Purpose of this paper:

The purpose of this paper is to investigate the technological evolution offered by the industry 4.0 in the supply chains of the pharmaceutical industries, but, also, to recognise all the obstacles that can delay the pharmaceutical companies in their conversion to "smart factories". This paper will also present the significant benefits offered by the new Industrial revolution and the incentives that eventually, perhaps, will force the pharmaceutical companies to become totally integrated into the industry 4.0.

Design/methodology/approach:

A qualitative approach was followed. More specifically face to face semi-structured interviews with 5 executives and managers from one pharmaceutical company in Greece were conducted. Moreover, secondary data from several sources were also used to triangulate our data. Thematic analysis was used to process the data.

Findings:

This research concluded that the most important barrier to the use of new technologies is the economic one, which has been exacerbated by the economic crisis and the COVID-19 pandemic in Greece. Lack of expertise, difficulty in coordinating actions, and the lack of international standards and protocols for the implementation of the new technologies were also identified as important obstacles. The most critical motivation for the implementation of Industry 4.0 is the increase in productivity and flexibility. Other important incentives are cost reduction, revenue increase and customer satisfaction. The interviewees highlighted that there was a huge difference in production time (reduction), traceability, as well as minimization of human error, which is a very important advantage especially in pharmaceutical industry.

Value:

To the best of authors knowledge there is no study that explores the obstacles, incentives and impacts of implementation of Industry 4.0 in pharmaceutical companies. The paper analyses the relationship between these dimensions that may be used as a test base for further research.

Research limitations/implications:

This study suggests that managers in the pharmaceutical industry need to rethink the current processes and the integration with the upstream supply chain by identifying the competencies required for future competitiveness and implementation of Industry 4.0 technologies.

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Pay Per Use Business Models as a Driver for 3DP Adoption: Implications for Supply Chains

Anisha Prashad, Helen Rogers, Daria Fixel
Nuremberg Institute of Technology, Germany

Purpose of this paper –
A key pathway to successful commercialization of 3D printing technology in both the industrial and consumer markets is through 3D Printing Service Providers (3DPSP). Increasing importance is given to creating customer access using industrial partner service networks and by offering diverse financing options. The buyers in the industry are looking for state-of the art product quality but do not want to pay high prices for the 3DP machines and technology (Costabile et al., 2017). These buyers range from industrial organizations to private consumers, as well as prosumers who want to be involved in the product development and manufacturing cycle. With that, 3DPSPs have become invaluable stakeholders in the supply chain for conducting businesses and creating a common platform for open exchange between consumers and additive manufacturing service providers. Their aim is to orient customers to use 3D printing technology at its optimum capacity (Rogers et. al., 2016). With that, they attempt to disrupt the business models by providing dynamic financing and contracting options. 3DPSP fashionably use performance-based contracting options such as renting, leasing, subscription, pay-as-you-go, pay-per-use, etc. to attract the buyer market (Machado et al., 2019). These rapid movements of financing create dynamic supply chains, leading to uncertainty that may be limiting industry-wide adoption of additive manufacturing (Thomas, 2016).

In this study, we perform an exploratory analysis of the pay-per-use (PPU) business models in the 3DPSP marketplace. In view of these finding, we examine the synergies offered by PPU and its implication on the 3DPSP supply chains. Hence, the goals of this paper will lay the foundation of the -

- Literature review on the evolution of 3DP service industry and its financing activities.
- Sustainability analysis of the PPU business model in terms of cost and flexible adoption, as compared to other performance-based financing and contracting methods in the 3DPSPs marketplace.
- Exploratory analysis on supply chain of the PPU model comprising both the buy and sell side implications of buyers and 3DPSPs, respectively.

Design/methodology/approach: We investigate the capabilities of the PPU model in reducing various design-, process-, and system-level cost from the perspective of buyers-market and 3DPSPs. The exploration of the main hypothesis formulated in this study presents the efficiency analysis of the PPU business model on three criteria - (i) mapping the quality and cost advantages of the PPU model in the supply chain management process, (ii) synergies offered by the PPU model in supply chain innovation in terms of real-time analysis & predictive maintenance, (iii) value proposition of using PPU to streamline supply chain complexities. In this way we review the related studies to cover (i) the marketplace paradigm of 3DSP, (ii) financing methodology of PPU model (iii) adoption rate of the PPU model in the 3DSP marketplace.

Findings: Additive manufacturing promotes sustainability and using the PPU model further accelerates adoption rates of 3DP technology, by minimizing the investment risk. Subsequently, various cost intervals are eliminated using the PPU model that were earlier reasons of supply chain disruptions. We observed significant reduced inventory & transportation cost and cost of over-processing at the buyer's location. In our initial observations, we found that 3DPSPs were able to flexibly provide services and position the 3DP technology at various intervals of the manufacturing process at the right time using the PPU model.

Value: This study will contribute in performing a sustainability analysis on the PPU based financing platform in commercializing 3DP technology in the buyers-market and its supply chain implications. Subsequently, we will develop strategies to use PPU for increased accessibility and quality 3D service provisions. Thereby, accelerating new product development, reduced logistic procedures and sustainability for both additive manufactures and buyers.

Research Limitations/implications: As the research is still at the early stages and the modelling PPU options adopted by 3DPSP is complex, these initial findings are tentative.

Practical Implications: As the research is ongoing, this paper provides initial insights into the status of 3DFP marketplace. In particular, it offers an overview of financing options available to make 3DP technology assessable to buyers. It also provides a sustainability analysis of the PPU business model and its supply chain implications in comparison to more conventional financing methods.

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Exploring sustainable food supply chains enabled by digitalization

Orsolya Diófási-Kovács, Elizabeth Lengyel

Corvinus University of Budapest, Hungary

Purpose of this paper: The population of our planet is expected to increase up to nearly 10 billion by mid-century. Growth is projected not only in numbers but also in affluence, leading to higher levels of consumption of food products, which have serious impact on environmental, social and economic sustainability. Food production contributes for example to GHG emissions, deforestation, loss of biodiversity and additionally, there is lots of waste in the production, processing, distribution, and consumption stages of the food supply chain. Furthermore, today's food supply chains create economic inequalities by concentrating food production, processing, and distribution in the hands of a few large organizations, on one hand decreasing prices, but on the other hand eliminating jobs and distorting the prices of food products by not including the environmental and social costs of their production. Finally, there are consequences for public health, both in terms of the climbing rates of obesity in both developed as well as developing nations, as well as the lack of access to fresh, nutritious food.Food supply chains are currently experiencing a change, due to the pandemic, the rise of e-commerce and changing consumer expectations supported by policy level expectations, like the EU Farm2Fork Strategy.The purpose of our paper is to explore different business models and distribution channels supported by digitalization solutions, that connect farmers with consumers.

Design/methodology/approach: As a first step in our research we analyse European best practices of shortening and optimizing food supply chains. As a second step we examine distribution channels of Hungarian food producers and focus the research on digitalization as an enabler of building networks between actors in short food chains.

Findings: Preliminary results show supply can be optimized with the help of digital technologies by exactly knowing customer demand. The customer demand can be projected for different timeframes varying between short and long term (e.g. ordering food online for next day delivery or renting land for a year and buying the goods produced on it) Additionally transportation can also be optimized based on demand, thus avoiding unnecessary emissions.

Value: More and more innovative digitalization solutions are used to connect farmers with the end consumers with the aim of reducing negative impacts of food production and distribution, providing benefits for consumers and farmers as well. This has indirect relevance in public procurement (e.g. school food systems), and direct impacts on the business sector (e.g. hotels, restaurants) and private consumers (households).

Research limitations/implications: Our empirical research focuses on Hungarian food producers, we collect best practices from other European countries.

Practical implications: The description and analyses of the different business models and distribution channels supported by digitalization can be a useful source of information for organizations within the food industry and NGOs supporting farmers in building up their farm2fork networks.

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A demonstrative framework for blockchain-based decentralized traceability in textile supply chain

Vijay Kumar, Rudrajeet Pal
University of Borås, Sweden

Purpose of this paper: Textile supply chains are complex due to their globally dispersed, multi-tiered structure, which contributes largely to the lack of sustainability and visibility (Garcia-Torres et al., 2021). In this context, traceability plays a major problem-solving role, but is difficult to implement uniformly across the entire supply chain by a single actor or a central authority (Kumar et al., 2017); however blockchain-based traceability system could be prospective (Agrawal et al., 2021). This paper aims at developing and testing a decentralized framework for blockchain-based traceability for the textile supply chain that requires no central authority, and the interaction is governed by smart contracts in a digital environment.

Design/methodology/approach: A multistage approach is followed to develop a blockchain-based traceability framework. In the first stage, smart contracts – that govern the interactions of the supply chain actors while keeping the material traceability through mass balancing concept – for decentralized interactions were designed. The second stage implements the developed smart contracts on an Ethereum virtual environment where the interaction of the supply chain stakeholders and the supply chain transaction were recorded on a distributed register, or blockchain. Finally, the implemented system is tested using a discrete event simulation which demonstrates the implication of the framework for the textile supply chain.

Findings: The blockchain system is managed by multiple actors (also known as nodes) which are incentivized for implementing or registering the transactions on the blockchain. In this work, the smart contracts that govern the interactions of the supply chain stakeholders were linked to the material flow and mass balancing on each transaction. However, keeping the lot or batch information on each production stage increased transaction data which has subsequently resulted in a higher cost for registering a transaction on the Ethereum blockchain. Furthermore, the analysis reveals the role of certification authority when mass balancing cannot be carried out.

Value: The paper proposes a framework for implementing blockchain-based traceability and then testing by using discrete event simulation. Therefore, the study not only makes theoretical contributions by proposing a new traceability framework but also tests it in a computer-simulated environment to understand its practical implication.

Research limitations/implications: The discrete event simulation considers the role of sellers and buyers while not accounting for the operations of intermediate stakeholders such as transporters. Therefore, the role of these stakeholders needs further to explore to establish the full impact of the proposed framework.

Practical implications: The paper provides an insight into peer-to-peer interactions of supply chain actors in blockchain and cost analysis of registering transactions on a distributed ledger that create a pathway for decentralized traceability system in the textile industry.

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Establishment of a digital transformation scale and food supply chain resilience: A case study of European food manufacturing firms

I-Hsuan Su, Lin Wu, Kim Hua Tan, Jimmy Huang
Nottingham University Business School, United Kingdom

Purpose of this paper:
During COVID-19 pandemic, there are many disruptions that European manufacturing firms has faced. For example, supermarket started to have the phenomenon of panic buying (Hobbs 2020). On the other hand, many restaurants in the UK were forced to close because of the lockdown measures imposed by government, which has caused food waste for the reason that they could not sell their food out (Hills 2020). These disruptions indicate that food supply chain is still not resilient. Therefore, to achieve a more resilient food supply chain, digital transformation plays an important role.The pandemic speed up the reliance on digital technologies (Hobbs 2021). However, not many studies explore the relationship between food supply chain resilience and digital transformation. In addition, there is no complete scale for measuring digital transformation; Most studies pointed out that digital transformation is about technology adoption (Hartley and Sawaya 2019, Faruquee, Paulraj, and Irawan 2021). Others indicated that digital transformation is related to organisational support (Sousa and Rocha 2019). Therefore, the purpose of the study is to build a comprehensive scale for digital transformation as well as realise how food supply chain resilience can be improved by digital technologies in European manufacturing industries.

Design/methodology/approach:
Mix method is adopted in this study. This study aims to build a scale of measuring digital transformation in food supply chain resilience through organising the current literature, conducting interviews to purify the items, and a survey to construct the scale.

Findings:
The expected outcomes will establish a measurement scale of digital transformation in food supply chain resilience. In addition, it will also indicate that how the food manufacturing firms in Europe face and deal with the disruptions by adopting digital technologies.

Value:
The contribution of the study is that we will establish a measurement scale of digital transformation in food supply chain resilience. In addition, few research explores about the relationship between digital transformation and food supply chain resilience as well as focusing on the target of food manufacturing firms in Europe.

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AN COMPARATIVE MARKETSTUDY OF CLOUD SOLUTIONS SUPPORTING VISIBILITY IN PRODUCTION LOGISTICS SCENARIO

Jannicke Baalsrud Hauge[1,2], Masoud Zafarzadeh[2], Wajid A. Khilji[2]
1: BIBA, Germany; 2: KTH Sweden

Purpose

Improved visibility across the supply chain is expected to support the transition towards greener supply chains and logistics. A prerequisite for a seamless data flow is to have an infrastructure facilitating constant, flexible, secure, and sustainable access to data for all stakeholders [1]. Such data-driven concepts are expected to be required for achieving improved visibility. A technical solution that enables the transition toward data-driven smart in-house logistics is IoT based cloud solution. Despite the noticeable progress in the associated technologies, there is limited access to empirical studies regarding the contribution of in-house logistics and how to select the right cloud solution. This paper compares different cloud solutions already available in the market and matches these with a set of criteria to meet for different purposes.

Design/Methodology/Approach

 To clarify the specification of IoT based cloud infrastructures, we first screened the literature to define suitable criteria for evaluating cloud-based solutions. This was followed by a market desk search on available IoT based cloud infrastructure systems. We used an action-based research methodology. For this purpose, we used both information from the providers as well as reports found online. In a final step, we evaluated the IoT based cloud infrastructure to the criteria.

Findings

"Cloud computing is a model of service delivery and access where dynamically scalable and virtualized resources are provided as a service with high reliability, scalability and availability over the Internet." [2] p5. As a result, several services have evolved as the services provided by cloud computing. A core capability is a virtualization [3]. According to [2] cloud computing fulfils a set of characteristics. The first results of the current market service showed the following fulfilment of these characteristics. The table below shows the first results of how different market solutions fulfil the characteristics established by [2]

Table 1: INITIAL OVERVIEW OF IOT BASED CLOUD PLATFORMS' CHARACTERISTICS FULFILLMENT

Criteria	IoT based cloud platforms						
	Microsoft Azure	*GCP IoT*	*IBM Watson IoT*	*AWS IoT*	*Oracle IoT*	*Siemens Mindsphere*	*Bosh IoT suite*
Security & Privacy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Scalability Performance	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interoperability/ Integrations & API Access	Partial	Partial	No	Partial	No	Partial	Partial
Support	Full	Full	Community	Full	Full	Full	Full
Role Based Access/ User management	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geographical coverage & Performance	Global	Global	Global	Global	Global	Global	Global
Availability	99%	99.9%	98%	99.9%	99%	99%	99.9%
Usability/ Visualization	GUI	Partial GUI	Partial GUI	Partial GUI	Partial GUI	GUI	GUI
Data Management & Analysis	Yes	Yes	Yes	Yes	Yes	Yes	Yes

As seen in this table, the main differences seem to be in the very important aspects of supply chain visibility concerning interoperability and graphical user interface (affecting the usability)

Value/Originality

This paper discusses the limitation and the advantages of IoT based cloud solutions specifically for SMEs operating in supply chains.

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NON-IMMERSIVE NFC-BASED SMART WEARABLE FOR PICKER-TO-PARTS ORDER PICKING

Peik Bremer, Hani Alyones, Yannic Henz, Anna-Lena Hoch, Manuel Mauer, Abdelrahman Nassar, Matthias Tafel
University of Applied Sciences Würzburg-Schweinfurt, Germany

Purpose of this paper:
Surveys have shown that most companies still use paper-based lists or RF handhelds to support picker-to-parts order picking. More modern approaches like Pick-by-Voice or Pick-by-Vision are gaining ground but have raised concerns about cognitive ergonomics. More recently, smart wearables for order picking with integrated or wirelessly connected barcode scanners have arrived on the market. The purpose of this paper is to discuss details of a smart wearable that uses Near-Field Communication (NFC) which allows confirming storage bins and order bins without any input from the order picker.

Design/methodology/approach:
Starting from a Business Process Model and Notation (BPMN) concept of the order picking process and informed by both an analysis of existing smart wearables and a literature review of design guidelines for user interfaces on smart wearables, a smart wearable was designed from scratch. The technical design, which focuses on order pickers' productivity, features (1) a novel approach to using NFC for order picking support, (2) a streamlined user interface, and (3) a fast middleware connecting the smart wearable to a Warehouse Management System (WMS).

Findings:
Industrial smartwatches often come with an NFC reader integrated into the display, requiring non-ergonomic movements of arm and hand when reading NFC tags on storage bins. Antenna extenders directly connected to the integrated NFC reader can be placed arbitrarily in more ergonomic positions (e.g., in a glove) but at the cost of reducing the reading distance substantially. An additional, separate active NFC reader, however, can smoothly identify storage bins while moving the hand at the usual arm operation speed of 2 m/s and retains the option of using antenna extenders. Careful design of the user interface is key to smooth and fast picking; the small screen size is a neglectable restriction.

Value:
This paper contributes to the still relatively small body of literature on smart wearables in order picking by discussing design features in detail – technical ones (such as the integration of an NFC reader) as well as the user interface.

Research limitations/implications:
The NFC-based smart wearable is a prototype and has not been tested in industrial applications yet.

Practical implications:
This paper increases the technical options available for supporting picker-to-parts order picking.

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Scaling-up 5G adoption in seaports: barriers and enablers
Andrew Potter, Yingli Wang, Mohamed Naim

Cardiff University, United Kingdom

Purpose of this paper:

As the 5th generation of mobile communication technology, 5G is predicted to be a significant focus for investment by the logistics industry in the next three years. One area where it is expected to have a significant impact is seaports, enabling further digitization and the development of Smart Ports. However, seaports often struggle with innovation (Acciaro et al. 2018) and many applications of 5G in ports are still at the early stages of deployment. The purpose of this paper is to investigate the barriers and enablers to 5G adoption, focusing on the UK seaport industry.

Design/methodology/approach:

Data has been collected from nine senior representatives from the UK port sectors (ports, port groups, trade bodies), through a focus group (n=6) and interviews (n=3). Combined, the participants represented organisations with operations in around 1/3 of all UK major ports. Additionally, interviews with two technology providers were also conducted for data triangulation . Using thematic coding, barriers and enablers to the use of 5G have been identified, with comparisons made to existing literature on digitization within the ports sector.

Findings:

Several potential barriers and enablers have been identified, including building a business case with appropriate use cases, the trade off between legacy systems and 5G capability, technology maturity, investment requirements, skill development within the workforce and the role of government in supporting innovation.

Value:

Research of 5G applications in logistics currently focuses more on the technological applications rather than the business implications from adoption. This work provides insights into the challenges when introducing 5G within the seaport environment.

Research limitations/implications:

The research is focused on UK seaport operations, where adoption of 5G technologies is relatively new. While this provides consistency, allowing comparisons between interviewees, it may not fully reflect the operating context for seaports in other countries

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A simulation-based approach for measuring the performance of human-AI collaborative decisions

Ganesh Sankaran[1,2], Marco Palomino[1], Martin Knahl[2], Guido Siestrup[2]

1: University of Plymouth, United Kingdom; 2: Furtwangen University for Applied Sciences, Germany

Purpose of this paper:
Despite the widespread adoption of artificial intelligence and machine learning for decision-making in organizations, a wealth of research shows that situations that involve open-ended decisions (novel contexts without predefined rules) will continue to require humans in the loop. However, such collaboration that blends formal machine and bounded human rationality also amplify the risk of what is known as local rationality, which is when rational decisions in a local setting lead to globally dysfunctional behavior. Therefore, it becomes crucial, especially in a data-abundant environment that characterizes algorithmic decision-making, to devise means to assess performance holistically, not just for decision fragments. There is currently a lack of quantitative models that address this issue.

Design/methodology/approach:
To this end, this paper proposes a simulation-based model that combines system dynamics and data science methods to measure process performance in decision-making contexts that involve a mix of formal and bounded rationality. The model is validated using a simulated dataset set in a closed-loop supply chain to assess the inclusion of machine learning methods to improve returns forecast.

Findings:
The toy example reveals that a myopic assessment—of the forecasting process in isolation—overstates improvement potential and obscures problems that only a broader framing reveals. Broadening the process scope to include production and order fulfillment aspects surfaces performance issues that have to do with algorithms and human judgments working at cross-purposes.

Value/originality:
The presented simulation framework allows a more holistic problem framing through its ability to mix machine learning methods and simple heuristics that model human judgments. Such an approach to surface issues involving the complex interplay between human and algorithmic decisions can precede deployment to avoid costly errors.

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Exploring the potentials of using Eye Tracking in logistics: a systematic literature review and concept

Ting Zheng[1], Eric Grosse[2], Christoph Glock[1]

1: Institute of Production and Supply Chain Management, Technische Universität Darmstadt, Darmstadt, Germany; 2: Juniorprofessorship of Digital Transformation in Operations Management, Saarland University, Saarbrücken, Germany

Purpose of this paper: Logistics is an essential determinant of the success of companies, as it is a major source of cost and an important contributor to customer service. Its main objective is to deliver the right products at the right time and to the right place (Fawcett and Clinton, 1997). Although automation solutions have recently been introduced in logistics, a large share of logistics activities is still performed manually (Sgarbossa *et al.*, 2020). To ensure that workplaces and processes in logistics match the requirements of workers, it is necessary to analyse how workers interact with their work environment. One technology that can potentially support such an analysis is Eye Tracking (ET). ET is a non-intrusive technology for measuring human eye movements that has started to attract attention in manufacturing, as it has some interesting use cases in assembly (Borgianni *et al.*, 2018) and quality inspection (Duchowski, 2002). Its usage potentials in logistics have, however, not received much attention yet. The aim of this paper therefore is to explore the potentialities of ET in logistics.

Design/methodology/approach: This study adopts a systematic literature review approach to synthesise the knowledge about how ET can be used in logistics. Two scientific databases are used to search the literature, namely Scopus and Web of Science. Two clusters of keywords are identified and combined by using Boolean operator "AND" to identify the literature. The first keyword cluster refers to ET and the second keyword cluster refers to logistics by using terms including logistics, warehouse, distribution, delivery, order picking, material handling, and packaging. After searching keywords in scientific databases, a screening process is conducted to include papers that are relevant to fulfil the research objective. In this regard, papers that 1) investigate ET, and 2) with applications in a logistics context are considered relevant. A "snowball" search is then applied by examining the reference lists of relevant papers to identify further works of interest. The results of the literature review are used to develop a concept that illustrates the benefits of using ET in logistics.

Findings: Our preliminary results show that papers that discuss ET in logistics have received less attention than works investigating ET in manufacturing, however, there are some interesting applications of ET in logistics. For example, ET was used to evaluate couriers' interaction frequency with navigation devices and couriers' distraction during last mile delivery. ET was also used to estimate forklift drivers' mental workload during material handling and transportation. ET was further adopted to investigate how autonomous forklift robots can perceive human intention and communicate their navigation intent in a warehouse setting. Given that some activities in retailing are similar to processes that occur in logistics, we also transfer some insights of ET applications from retailing to logistics. We argue, for example, that ET may help understand different order picking strategies adopted by experts and novices, and that ET could be used to develop training programs that match order pickers' needs. Moreover, ET can also capture worker's visual behaviour and help identify optimal lighting conditions in warehouses.

Value/originality: This paper is the first to investigate the potential applications of ET in logistics by adopting a systematic literature review approach. The developed concept synthesises how ET can be used in logistics and use insights obtained in retailing to develop further opportunities for using ET in logistics. Our study gives insights into how ET can be employed to understand the interaction between humans and technology in warehouses and during delivery activities, as well as to evaluate workers' mental workload during logistics tasks in an objective and non-intrusive way.

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Evaluation of Industry 4.0 on Sustainable Supply Chain of manufacturing companies: A Thematic Literature Review.

Akin A Davies1,*, Mouhamad Shaker Ali Agha1, Tariq Masood2
1Department of Management Science, Strathclyde Business School, University of Strathclyde, Glasgow, UK
2Department of Design, Manufacturing and Engineering Management, Faculty of Engineering, University of Strathclyde, Glasgow, UK
Email*: akinbolarinwa.awoyinfa-davies@strath.ac.uk

Abstract - The transition from the previous industrial period to the technology era known as Industry 4.0 has increased demand for horizontal, vertical, and end-to-end digital integration. Adoption of Industry 4.0 has been shown to have a significant impact on supply chain network sustainability in previous research. However, there has been little research on using Industry 4.0 technologies to manage supply chain network sustainability. The goal of this article is to provide a thematic review of existing literature focusing on the evaluation of Industry 4.0 with respect to supply chain sustainability in the manufacturing sector.

Using distinct keywords related to the research topic, the various themes emerging from existing literature were identified and discussed with the aim of providing a deeper understanding of such themes and any gap in literature in order to pinpoint areas for further research. For the review of the literature, a combination of keywords associated with the topic were used to search for appropriate literature that will be relevant for the review. After a thorough screening process, peer-reviewed journal publications were chosen from the following databases: ProQuest, Science Direct, IEEE Explore, Scopus, Wiley Online Library (WOL) Google Scholar and Web of Science. The screening process involved the use of inclusion and exclusion criteria, removal of duplicate articles, assessment of journal abstracts and titles and the reading of full texts. This process resulted in a total of 63 journal articles deemed relevant and appropriate for the review of existing literature.
Key Words- Industry 4.0, Supply Chain, Sustainability, Sustainable Supply Chain, Supply Chain Sustainability, Manufacturing.

The Perceived Impact of Blockchain Technology on Information Flow within Supply Chain

Esraa Osama Zayed, Ehab Ahmed Yaseen

German University in Cairo, Egypt

Purpose of this paper: This paper aims at investigating the perceived impact of blockchain technology implementation on flow of information within the supply chain; through three measures; degree of information sharing, data security, and quality of information being shared.

Design/methodology/approach: This paper adopts an inductive exploratory approach. Using a Delphi approach, integrating online surveys with semi-structured in-depth experts' interviews. Delphi method is considered a mixed method capturing both qualitative and quantitative data through multiple rounds of panels with professionals in the field of blockchain technology and supply chain management in organizations operating in Egypt. Analysis was conducted qualitatively through content analysis and quantitively through descriptive analysis.

Findings: Findings of this paper suggest that blockchain technology is expected to enhance information flow within the supply chain, which is matching with previous literature. Blockchain technology is expected to increase the degree of information sharing across the supply chain, improve security as well as the quality of information shared.

Value: Blockchain is offering multiple benefits for supply chain management practices. It was found that little attention has been given to link the impact of blockchain technology on supply chain flows, especially information flow. Hence, this paper is considered among the very first few studies addressing such impact, thus enriching the knowledge in this area and suggesting researchable propositions for future researchers for further analysis.

Research limitations: It is worth mentioning that no respondents included in the sample of this study had implemented any blockchain technology in their supply chain management practices yet, however they have some basic knowledge about the topic based on non-technical sources. Thus, further future analysis of data from blockchain-based supply chains is required to confirm the proposed impact.

Practical implications: Findings from this paper are expected to encourage decision makers to think precisely about the actual implementation of blockchain technology in supply chain management practices. This is because findings suggest multiple benefits for information flow, which in return will improve the overall supply chain performance.

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An empirical analysis of the determinants of Blockchain implementation in food supply chain

Nam Vu[1], Abhijeet Ghadge[2], Michael Bourlakis[3]

1: Centre for Logistics and Supply Chain Management, Cranfield University, United Kingdom; 2: Centre for Logistics and Supply Chain Management, Cranfield University, United Kingdom; 3: Centre for Logistics and Supply Chain Management, Cranfield University, United Kingdom

Purpose: In recent years, Blockchain has gained strong momentum in the food supply chain (FSC) area. Considering this trend, scholars have also called for empirical studies investigating the adoption of Blockchain within supply chains (van Hoek, 2019; Wamba and Queiroz, 2020). This study aims to examine Blockchain's integration at the organizational level, to understand better the impact of different determinants to each stage of the implementation process within FSC.

Design/methodology/approach: A conceptual model of the Blockchain implementation process previously developed by authors (Vu et al., 2021) is utilized to propose sixteen hypotheses. 159 responses collected using a questionnaire survey are statistically analysed. Partial Least Square Structural Equation Modelling (PLS-SEM) was used to test the hypothesis and draw valuable inferences.

Findings: Drawing from the prominent theories and concepts of Innovation Adoption (IA) literature, along with the findings from our previous work (Vu et al., 2021), an integrative model for Blockchain implementation is developed, as seen in Figure 1. Three main stages of implementation and four main categories of determinants are featured in the model. It is found that a three-staged model is sufficient to capture the implementation process of Blockchain. The resources of the adopting firm are found to have a positive relationship to the initiation phase. Furthermore, relative advantage and complexity are found to have significant impacts on the second phase, with positive and negative correlations, respectively. Finally, for the implementation phase, compatibility of Blockchain is found to have the most relevant impact.
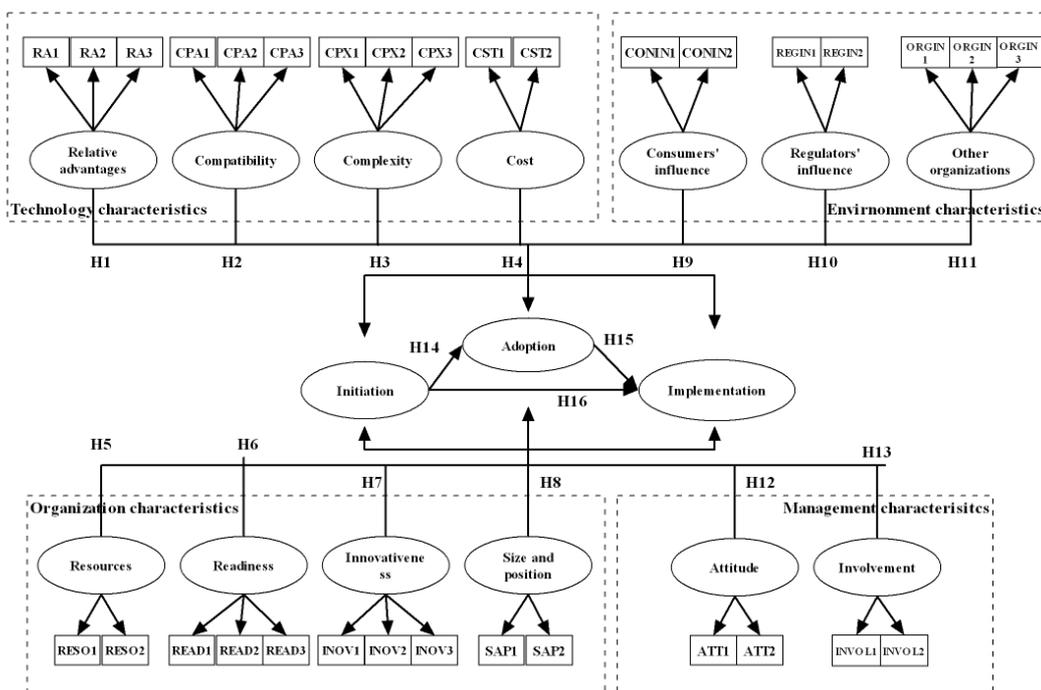
Figure 1. A model for Blockchain implementation in the food industry.
(RA1, RA2, RA3,… are indicators for measuring the main constructs in the model)

Originality: The study proposes a process perspective for examining the adoption of Blockchain, which is currently lacking in the extant literature. Thirteen determinants of Blockchain implementation based on technology, organization, environment and management characteristics within the food industry are established.

Research limitations/implications: Due to the emerging nature of Blockchain technology with FSC, few survey respondents may have limited views and understanding of the technology.

Practical implications: The 'determinant-driven' model is helpful for FSC practitioners to develop their roadmap for successful blockchain implementation.

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SC 5.0 - Digital Supply Chain and Supply Chain Management Education Challenge

Kamila Walters, Peter Mccullen
University of Brighton, United Kingdom

Purpose – The purpose of this paper is to examine the current curriculum design of logistics and supply chain management (L&SCM) postgraduate courses, which are offered by a selection of higher education (HE) institutions worldwide. Further, to assess them, in the light of ongoing changes of the skills requirement within the field due to the rapidly progressing digitalisation of the supply chain (Deloitte, 2020).

Design/methodology/approach – The paper is composed of two sections. The first part is a structured literature review, related to the new digital environment and its implications for the skills required in the future of the Supply Chain; also, the challenges in relation to teaching methods for equipping students for work within the digital supply chain. The second part of the paper focuses on desk-based research, involving content analysis of postgraduate L&SCM courses from selected institutions and work advertisements (e.g., LinkedIn).

Findings – With talent shortages not only 'the numbers' concern today's businesses. Supply Chain Management has evolved through new methodologies, developed to improve efficiency and to meet customers' expectations. As supply chains become more dynamic and complex - shaped by technology, society, politics and economics - the knowledge and skills needed to manage them has also changed (Accenture, 2021).
A structured literature review allows the relative importance of professional and general management knowledge versus specific L&SCM subject knowledge to be established; also, the necessary changes in the skills portfolio requirement, due to the rise in disruptive technologies and the progressing supply chain digitalisation (Agrawal, P. *et al.*, 2020, Agrawal, P. and Narain, R., 2021). Finally, it is possible to address the role of higher education in delivering new talent to cover this talent shortage.

Value – The initial findings suggest the growing importance of "human-factor" in the digitalisation of supply chains; however, they also highlight the widening gap between the available skills and the industry requirements. A McKinsey Global Survey of more than 900 C-level executives found that talent shortages top the list of challenges companies face in meeting their strategic digital aspirations (McKinsey, 2017).
This paper provides new insights into the L&SCM employers' requirements and indicates the current optimal skills portfolio of curriculum design for L&SCM graduates. In response to this need, this article presents a collaboration model, that serves as a guide for development of collaborative projects between academia and industry; this is achieved by developing and reinforcing a set of redefined supply chain competences in the participants.
In order to achieve and maintain currency and relevance within L&SCM programmes/courses, the Authors also propose a framework for the regular implementation of curriculum changes - despite the rapidly changing industry skillset. The Authors endeavour to develop a simple, adaptable, and flexible model, designed to embed employability effectively within the curriculum - in order to help to: improve graduate outcomes, build student confidence and address the skills gap.

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Building Resilience for Supply Chains

Supply Chain Resilience: Strategies and Impact on Sustainable Operations Among Ghanaian Manufacturers

Joshua Ofori-Amanfo[1], Juliet Ohenewa Siaw[2], Prosper Konlan[3], Florence Adwoa Newman[4]

1: University Of Ghana, Ghana; 2: University of Ghana, Ghana; 3: University of Ghana, Ghana; 4: University of Ghana, Ghana

Purpose of this paper: The purpose of this study was to examine the supply chain resilience strategies predominant among Ghanaian manufacturers and further determine the extent to which the prevalent supply chain resilience strategies impact on the sustainable operations of manufacturers in Ghana.

Design/methodology/approach: The study employed a quantitative research approach with data collected from 186 manufacturing firms in Ghana through the use of a questionnaire. The questionnaires were self-administered to respondents who were purposively sampled from the participating firms. The Statistical Package for Social Sciences (SPSS) and Partial Least Square- Structural Equation Modelling (PLS-SEM) was used to analyse the structural relationships between the research variables.

Findings: The study measured supply chain strategies using agility, information sharing, collaboration, and redundancy. Sustainable operations were measured using the dimensions of raw material consumption, employee well-being, and financial performance. Agility and redundancy were discovered as the dominant supply chain resilience strategies adopted by Ghanaian manufacturers to enhance their supply chain performance. Out of the twelve hypothesised relationships between resilience strategies and dimensions of sustainable operations, six were supported. The relationship between agility and financial performance, collaboration and raw material consumption, information sharing and financial performance, redundancy and employee wellbeing, redundancy and financial performance, and redundancy and raw material consumption were all statistically confirmed.

Value: The study contributes to the operations and supply chain literature by enhancing understanding of the relationship between supply chain resilience strategies and sustainability as an operations performance dimension. Thus, the study may be among the first to establish the influence of supply chain resilience strategies on sustainable operations in the context of manufacturing. The findings from this study informs manufacturing firms on how supply chain resilience strategies can be used to pursue sustainability objectives.

Research limitations/implications (if applicable): The study investigated only four supply chain resilience strategies. Future studies may explore other resilience strategies relative to the same dimensions of sustainable operations. Further, the study was only limited to manufacturing operations in Ghana hence, the generalisation of the results to other contexts should be done with caution.

Practical implications (if applicable): The paper has significant practical implication. The discoveries emerging from the relationship between supply resilience strategies and sustainable operations may inform manufacturing firms with intentions to pursue sustainable operations on what resilience strategies are relevant. In additions, the findings may inform manufacturers that they can pursue resilience strategies which can at the same time enhance the sustainability of their operations.

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National cultures' role in supply chain disruptions
saita Abdulaziz Al sadoon

Aston university, United Kingdom

The supply chain's massive globalisation has increased its vulnerability to risks and disruptions over recent decades. Many risks threaten the supply chain's flow of products and goods, from the uncertainty of surrounding environmental systems, such as hurricanes and earthquakes, to terrorist attacks. The enormous expansion of the supply chain across many countries and cultures suggests that national culture can be a critical factor that could significantly affect firms' responses to disruptions. However, the influence of national culture has rarely been introduced in the frameworks and strategies presented to manage and respond to such disruptions. Therefore, this research aims to investigate the role of national culture in supply chain disruptions by focusing on the effect of national culture on supplier relationships and supply chain disruption orientation. The research questions for this study involve asking what and to what extent the national culture disrupts the supply chain through its impact on the suppliers' relations and the supply chain disruption orientation.

Considering the nature of this research and its questions, the researcher selected the mixed method approach given its suitability in terms of the research approach and scope. The research begins with an exploratory inquiry, followed by confirmatory inquiry. According to the investigative nature of this research, data collection in this study followed the exploratory sequential mixed method model. The exploratory sequential method fits the current study better as indicated in the literature that the national culture topics in the supply chain in general and in supply chain disruptions specifically require further clarification; therefore, additional investigation is required, and the sequential exploratory design is a suggested model for such unclear issues. The sequential exploratory design suggested that when the problem under investigation is ambiguous and the variables are unknown; therefore, to study and explore the phenomenon in-depth and expand the occurrence of its dimensions, the researcher needed to discover the main variables.

Thus, the researcher started with qualitative research to explore the participants' perspectives after analysing qualitative data and indicating the primary constructs and diminutions. The information will be applied to assist in the second stage of the research, the quantitative method stage. Accordingly Semi-structured interviews were conducted with supply chain managers from the oil and petrochemical sector to gather their insights about current processes in crisis management and the main aspects affecting their responses. Despite the effectiveness of disruption and risk management frameworks, the interviews revealed many factors affecting the firm's response to disruptions that are influenced by national cultures, such as trust and commitment. The information received from the first phase, the qualitative phase, has been utilized to develop the questionnaire, the second stage of this research. The constructs and variables deduced from the collected qualitative data are the foundation on which the researcher built the quantitative instrument—considering that the analysis results of the interviews data narrowed down and concentrated on some constructs that are more related to the aim of the study investigation.

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CAN LOGISTICS AND SUPPLY CHAIN RESILIENCE STRATEGIES MINIMIZE THE IMPACTS OF DISRUPTION ON FIRM PERFORMANCE? EVIDENCE FROM THE IMPACTS OF THE COVID-19 PANDEMIC ON JAPANESE COMPANIES.

Rajali Maharjan[1], Kato Hironori[2]

1: Japan Transport and Tourism Research Instiute, Japan; 2: The University of Tokyo

Purpose of the paper

The resilience of logistics and supply chains has been receiving heightened attention in recent years and even more so with the widespread impacts of the COVID-19 pandemic. The resilience capabilities in the supply chain operations are critical to the firm's competitive advantage in a coronavirus scenario (Zhang et al., 2021). However, during the COVID-19 pandemic, it became evident that supply chains were not as resilient as they should be (Kiers et al., 2022). To cope with future disruptions, supply chain resilience should be improved based on lessons learned from the impacts of the COVID-19 pandemic (Kiers et al., 2022). While implementation of resilience strategies is desirable and indeed critical to withstand disruptions, resilience enhancement often requires investment, but it is difficult to monetize payback (Pettit et al., 2019). To encourage firms to implement resilience strategies, it is indeed important to illustrate the benefits associated with the implementation of resilience strategies. With this background in mind, this study aims to firstly identify the status of implementation of logistics and supply chain resilience strategies in Japanese companies and the impacts of the COVID-19 pandemic on firm performance to determine if the existing logistics and supply chain resilience strategies helped to minimize the impacts of disruptions caused by the COVID-19 pandemic. The goal is to identify logistics and supply chain resilience strategy best practices in Japanese companies.

Design/methodology/approach

A combination of semi-structured interviews and questionnaire surveys is used to gather necessary data mainly focusing on companies in the manufacturing sector in Japan. A combination of qualitative and quantitative analysis is used to analyze and interpret the data.

Findings

Preliminary findings show that the implementation of logistics and supply chain resilience strategies varies by organization size and the industry sector. While firms in some industry sectors observed benefits from the resilience strategies implemented prior to the COVID-19 pandemic some did not.

Value/Originality

To the best of our knowledge, this is the first study attempting to identify if the existing logistics and supply chain resilience strategies helped minimize the impacts of disruptions caused by the COVID-19 pandemic.

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Option contracts for products with seasonal disruption
Joong Y. Son

MacEwan University, Canada

Purpose of this paper: This paper studies the effectiveness of implementing option contracts for the procurement of seasonal products, subject to short selling season, demand uncertainty, and supply-side disruption. The research intends to show how profitability and product availability can be enhanced both locally and globally by combining different supply contracts such as fixed price contracts and option contracts. In particular, the paper aims to identify business settings with respect to disruption parameters, demand uncertainties, and option contract pricing under which the supply contract could improve the overall supply chain performance.

Design/methodology/approach: The normative model for the paper is built on the newsvendor model to analyse the characteristics of the option contract for products with short shelf life (seasonal goods, high-fashion items, COVID-19 vaccines, etc.) in which the buyer (retailer) works with two types of suppliers: Supplier 1 can be characterized as low-cost and offshore, whereas supplier 2 is deemed expensive and local. The buyer can sign multiple contracts with different suppliers to procure items before the selling season for future demand by combining the fixed price contract and the option contract that enable risk hedging as well as profit improvement. Using the traditional fixed-price contract as the base case, this research conducts numerical experiments to assess the effectiveness of implementing option contracts when both the demand uncertainties and the supply disruptions are in place.

Findings: The analytical model and the initial results of the numerical experiments indicate that, compared to the base case, the option contract provides a better risk hedging protection and profitability for both the retailer and the overall system when the supply-side disruption prevails.

Value: Most existing research on procurement management using option contracts is primarily based on the demand uncertainty setting. The main contribution of this research is that it incorporates the impact of the supply-side disruption in addition to the demand-side uncertainty in evaluating supply contracts.

Research limitations/implications: While this paper provides insights on the effectiveness of option contracts for the procurement of products with short shelf life under supply disruptions, its structure of single retailer – two suppliers setting can be considered a limitation. A future research extension can include the study of portfolio contract by adding spot market purchase as a possible option in a multi-retailer setting.

Practical implications: The study of the procurement management of products subject to seasonal disruption can be readily applied to numerous business situations where supply-side disruption could lead to a devastating impact such as the insufficient or untimely supply of COVID 19 vaccines which also show limited shelf life.

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Humanitarian Logistics

OPTIMAL COVID-19 VACCINE WAREHOUSE LOCATIONS WITH MULTIPLE FACILITY LOCATION PROBLEMS

Soomin Hong[1], Su-Han Woo[2], Tae-Young Kim[2]

1: Graduate School, Chung-Ang University, Korea, Republic of (South Korea); 2: Department of International Logistics, Chung-Ang University, Korea, Republic

Purpose of this paper:
This study aims at applying different facility location problems to a real data of metropolitan city in Korea to find out optimal sets of locations for humanitarian COVID-19 vaccine warehouses.

Design/methodology/approach:
Considering the vaccine warehouse as a pre-positioning humanitarian facility, this study uses the classical discrete-deterministic facility location problems as a tool for decision making under different constraints. Three different facility location problems with different objectives are applied to the same existing geographical data set.

Findings:
Comparing the total distance of each case, MCLP-1 provides the most adequate result for the optimum warehouse location.

Value:
Finding the optimum place through employing one model connected to cost could be straightforward and rather simple. However it would be comparatively incomplete unless it contains the reference to the characteristics of disaster. It is, therefore, suggested that multiple location problems are employed and their results are compared to find out the most desirable place which is adequate for the purpose.

Developing innovative supply chains through digital technologies: the mediating role of supply chain dynamic capability

Shuang Tian[1], <u>Lin Wu</u>[1], Kulwant Pawar[1], Aijing Song[2]
1: University of Nottingham, United Kingdom; 2: Yunnan Normal University, China

Purpose

In the background of the Covid-19 pandemic and Industry 4.0, this study aims to empirically investigate how the use of modern digital technologies by the focal firm, including Artificial Intelligence (AI) and Internet of Things (IoT), can help develop a sustainable supply chain through nurturing supply chain dynamic capabilities of supply chain resilience (SCRes), supply chain robustness (SCRob) and supply chain agility (SCAgi). Based on the Dynamic Capabilities Theory (Teece, 2007; Teece et al., 1997), this study extends the dynamic capabilities of sensing, seizing and reconfiguring to the wider context of the supply chain, which is more meaningful in the current highly globalised world where companies are tightly interconnected. Moreover, this study also investigates the moderating role of supply chain disruption caused by the Covid-19 pandemic.

Design/methodology/approach

This study takes a quantitative approach and validates the proposed model through data collected from a large-scale survey among Chinese manufacturers. Since the purpose of this study is to extend an existing study and validate the extension, Partial Least Squares Structural Equation Modelling (PLS-SEM) is used for data analysis (Hair et al., 2019).

Findings

Results have confirmed our model and hypothesized relationships. Specifically, the use of IoT and AI has been found to directly contribute to sustainable supply chain performance measured by supply chain performance and supply chain innovation capability. The direct links between digital technologies and supply chain performance is fully mediated by supply chain dynamic capabilities. Supply chain disruption caused by the Covid-19 pandemic is found to play a positive moderating role in the digital technology-performance link.

Value

Against the background of globalisation, this study extends the well-established theory of Dynamic Capabilities beyond the organisational boundary to the context of supply chain. Based on the micro-foundations of dynamic capabilities, namely, sensing, seizing and reconfiguring, our study is among the first attempts to propose SCRes, SCRob and SCAgi as supply chain dynamic capabilities. Our study also integrates the IT literature and the supply chain management literature by empirically investigating the role of modern digital technologies in supporting the sustainable development of the supply chain. Our study is also a timely attempt to address the challenges caused to the global supply chain by the ongoing Covid-19 pandemic and propose practical insights on operations in the post-Covid era.

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Transportation and Distribution

Last-Mile Delivery in an Urban B2B Context: A Blockchain Technology-based Solution Implementation Challenges

Meysam Shaverdi, Shams Rahman, Kamrul Ahsan
RMIT University, Australia

Purpose of this paper: Last-mile delivery (LMD) is considered the most expensive, most pollutant, and least efficient phase of a supply chain that requires radical advancement. Recently, blockchain as an evolutionary technology has emerged as a solution for the enhancement of LMD performances. Considering the evolving challenges of LMD, this study develops a blockchain-based LMD deployment model and assesses the deployment challenges in an urban business to business (B2B) context.

Design/methodology/approach: Underlined by the technology, organisational, and external environment (TOE) framework, a conceptual model with four challenge categories and twenty-two challenges is developed. Since the blockchain-based LMD is a new research domain and so far very little is known in the literature, we adopt a case study approach in this research, and critical case sampling is applied to identify stakeholder groups which include blockchain technologists, policymakers, logistics managers, and retail managers for interviews. A total of 20 semi-structured interviews were conducted with these four groups of experts/stakeholders. A criticality–effort matrix analysis is performed to group challenges and to suggest ways for implementation.

Findings: The four groups of experts that were interviewed considered the applicability of blockchain in LMD and its challenges in different ways. Logistics and retail managers who work directly in the logistics and retail section are more concerned about organisational challenges such as employee resistance to change, financial constraints, and level of knowledge and expertise. Whereas the main concerns for blockchain technologists are related to inter-organisational challenges and organisational challenges, they are more anxious in resolving the technology barriers such as security and complexity issues of blockchain in LMD services. On the other hand, policymakers are more concerned about the external-environmental challenges such as governmental policies, carbon emissions issues, and urban policy.

Value: This study is one of the first studies that consider blockchain technology deployment in LMD services and provides insights and knowledge of the applicability of blockchain-based LMD services in an urban B2B context. The results of this study would assist a wide range of stakeholders including logistics and retail managers, blockchain technologists, and policymakers.

Research limitations/implications: This research has two main limitations. First, blockchain application in LMD is in the early stages, hence all issues and concerns may not still be apparent. Second, this research is conducted in an Australian urban context, where industrial, market, political, and cultural norms could be different compared to other geographical and political regions which may impact the generalisation of the findings of this study.

Practical implications: Theoretically, this study contributes to the digital transformation literature and provides extended insights and knowledge of the applicability of blockchain-based LMD services in an urban B2B context. In terms of managerial implications, this research provides practical guidelines for policymakers, blockchain technologists, logistics, and retail managers to apprehend the challenges that organisations may face during the implementation of blockchain-based LMD services and formulate strategies overcoming these challenges.

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The effect of discount incentives on customers' willingness to accept 'no-rush' delivery

Yi Liu, Vaggelis Giannikas, Fotios Petropoulos
School of Management, University of Bath, United Kingdom

Purpose of this paper: The paper aims to examine how discounts on purchased products (DPP) can be used to influence online customers to accept alternative delivery methods. Particularly, it investigates customers' willingness to accept a slower delivery, also known as "no-rush" delivery under different delivery times, retail prices and product categories.

Design/methodology/approach: This study used experiments based on the Gabor-Granger method to ask 1,500 UK participants to accept or reject different discounts in return for slower delivery times in hypothetical scenarios. We analysed the effect of DPP and segmented customers to explore the relationship between customer characteristics and their willingness to accept DPP.

Findings: We find that most UK online customers are willing to consider a slower delivery within a given range of DPP. On average, the minimum acceptable discount increases with the length of delivery time, while the 10–15% discount range sees the most variation of willingness to accept the DPP under different delivery times. Additionally, delivery time, retail price and product category show a significant impact on customers' willingness to accept a slower delivery.

Value: This paper examines the discount on the product value rather than conventional delivery charge to largely incentivise customers considering a slower delivery service. This new pricing –and delivery– method has the potential to create win-win situations while enabling sustainable delivery and retaining customer satisfaction. This paper contributes to relevant literature by assessing the value of speed in last-mile delivery, one of the most important factors in online shopping deliveries.

Research limitations/implications: The study can be further extended to estimate how a slower delivery can improve the delivery efficiency and the ecosystem. Industrial case studies can evaluate if companies can improve their delivery management and reduce congestion and emissions by adopting longer delivery times. One limitation lies that we only consider a few factors that may affect customers' acceptance of a slower delivery. Future studies can examine more factors to generalize the model into a broader context.

Practical implications: This new method is especially useful for retailers experiencing a surging demand for online orders within short periods due to events such as Black Friday. In fact, retailers such as Amazon and Look Fantastic have already experimented with this initiative at a small scale. This study systematically examines the effect of the method and provides insights for more retailers to consider on their cases.

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POTENTIAL OF BIODIESEL AS CLEAN ENERGY FOR SUSTAINABLE MARITIME TRANSPORT

Jasmine Siu Lee Lam[1], Wei Juan LIM[2]
1: Nanyang Technological University, Singapore; 2: Nanyang Technological University, Singapore
E-mail: sllam@ntu.edu.sg

Purpose of this paper: This study aims to assess the potential of biodiesel as a clean energy source to enhance the sustainability of maritime transport.

Design/methodology/approach: The assessment is based on four aspects: economic, social, environmental, and technical. After a thorough review of literature, interviews with industry professionals were conducted to collect first-hand information and views.

Findings: The high potential of biodiesel for shipping is due to the feature that it can be added to conventional fuel as a drop-in-fuel. Infrastructure is not required to be modified. Adoption of biodiesel is relatively more straightforward as compared to other clean energies. However, biodiesel production, supply, and cost are obstacles to its large-scale adoption.

Value: The International Maritime Organization (IMO) Greenhouse Gas (GHG) Strategy aims at a reduction in carbon intensity of international shipping by at least 40% by 2030. Among the various ways to help achieving this goal, adopting cleaner alternative energy sources is a promising option.

Practical implications: The research findings offer practical insights into the potential of biodiesel as a solution towards sustainable shipping till 2030. Stakeholders may take reference for applications in the industry.

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IMPACT OF COVID-19 PANDEMIC ON SHIPPING CONNECTIVITY OF SINGAPORE

Wei Yim Yap, Yan Weng Tan

School of Business, Singapore University of Social Sciences, Singapore

Purpose of this paper: Global trade and logistics are severely impacted by the Covid-19 pandemic. The impact includes the extensive disruption of port and shipping operations. This study aims to analyse the changes in shipping connectivity of the port of Singapore brought by Covid-19 and offer insights for shipping logistics.

Design/methodology/approach: The research approach involves data analysis of liner shipping services in the key Asia-Europe trade route before and during the Covid-19 pandemic for a comparative assessment. Data of liner shipping services include shipping volume, number of shipping services, number of ships, and shipping operators.

Findings: The onset of Covid-19 saw number of liner shipping services in the Asia-Europe trade route fell from 33 in December 2019 to 31 by June 2020, having a corresponding reduction of shipping volume by 4.6%. In contrast, liner shipping services which called at Singapore in the same period rose from 25 in December 2019 to 26 in June 2020. However, by December 2020, the Asia-Europe trade route bounced back rapidly with an additional three services added, bringing the total number to 34. Shipping volume from December 2019 to December 2020 increased by 9.7%. At the same time, the number of liner shipping services calling at Singapore also rose to 29. This cemented the port's role as a dominant shipping hub in Southeast Asia.

Value: Analysis of shipping connectivity in relation to the Covid-19 pandemic remains a knowledge gap. The port of Singapore is among the busiest in the world in terms of shipping traffic. The study is a good reference for other ports and those who are interested in Asia-Europe liner shipping services.

Practical implications: Due to lockdowns in many countries, shipping companies in general substantially reduced shipping capacity to lower cost. Counter-intuitive research findings show that Singapore's shipping connectivity continued to increase, as reflected by liner shipping services linking Singapore with trade regions in Asia and Europe. The performance of Singapore as a "catch-up" port to enable shipping operators to remain service reliability shows that the port well facilitates shipping logistics and trade during the pandemic.

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A STEP-BY-STEP GUIDELINE TO OVERCOME CHALLENGES MODELLING URBAN LOGISTICS SCENARIOS USING SUMO

Jannicke Baalsrud Hauge[1,2], Yongkuk Jeong[1]

1: BIBA, Germany; 2: KTH, Sweden

Purpose of the paper

According to Eurostat [1] only 20.1% of the population lived in rural areas in 2018, while 70,9% lived in cities, towns, or suburbs. Pollution and greenhouse gas (GHG) emissions generated by the traffic have therefore a considerable impact on the quality of life [2], and consequently, during the last decades cities worldwide have implemented strategies improving the quality of life of their citizen. A typically instrument for European cities are the Sustainable Urban Mobility Plans (SUMPs) [3], which aims at efficiently solving urban transport related problems. SUMP covers all forms and modes of transport and is thus dealing with very complex problems from a policy perspective [3]. A second trend in the last years have seen a change, and cities tries to attract local production [4,5]. Previous research has stated that the different needs and the different objectives of all stakeholders being involved in developing urban transport and mobility solutions are cause of conflicts [6] often quite challenging to solve.

In order to improve the understanding on how all the different factors and decisions at different decisions level would support a realization of a specific SUMP, a generic simulation modelling using Simulation of Urban MObility (SUMO) [7,8] was developed. The goal was to provide a multi actor-based SUMP scenario model as the main output for urban and peri-urban areas. Target groups are the authorities, infrastructure providers and operators in and around the city [9].

We envisaged that this combination would contribute to a better understanding improve stakeholder awareness and involvement, and thus contribute to assessing the impact of policy regulations at different level [10]. However, discussion with the practitioners revealed that the developed approach for implementing new or transfer existing simulation scenarios was considered as too difficult. To support the take-up as well to ensure that the project results are transferable to other cities, we developed a step-by-step guideline and evaluated the usability with students with similar skills as many of the potential users.

Design/Methodology/Approach

We used an action-based research methodology. The conceptual design of the guidelines was based on analysis of the stakeholder involved in developing a set of simulation scenarios. Furthermore, in order to evaluate the developed guidelines, we ran an experiment with students in a course in Master's program who used the guideline as a part of a lab exercise. After the exercise, we collected their answers on five questions related to this part of the lab.

Findings

11 students submitted the evaluation feedback sheet (anonymously). We had five questions related to the usage of the guidelines. On the direct question on how good the guidelines explaining how to change the model the majority were not satisfied (i.e., 6 negative, 1 neutral and 4 positive). Following up on this, we asked if it was easy to understand why something should be done. Also, this question indicated that the current state of the guidelines is insufficient in details, since again the majority voted negative (64%). An important aspect of changing the model is that the user understand how the changes impacts on the simulation model. Here we see a more equal distribution, with a trend to more positive compared to negative. The evaluation showed that we need to improve the guidelines, but on the question related to the learning, the students clearly state that the exercise helped the students to understand the intended learning outcome, asl well as to deepen their knowledge.

Value/Originality

This paper shows the relevance of developing step-by-step guidelines fitting the knowledge level of the intended users.

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Capturing Sustainability Goals in City Logistics: A Delphi Approach to Develop Sustainability Indicators

Xu Zhang[1], Eoin Plant[2], Nikolaos Valantasis Kanellos[1]
1: Technological University Dublin; 2: Edinburgh Napier University

Purpose of this paper: 'Sustainability' as a phenomenon is difficult to define and sense (Meadows, 1998). Sustainable city logistics is a concept with many subjective interpretations by different actors in the urban freight transport ecosystem (Behrends *et al*., 2008). Developing useful metrics to measure sustainability performance and impact in city logistics is challenging as there are many uncertainties and multiple stakeholders' interests to consider. Selecting the indicators is also a complicated task because of the numerous variables used in literature and the variety of KPIs reported by logistics companies in their sustainability reports.

Extant research studies have proposed different frameworks and indicators to assess sustainability in city logistics. However, the quality, practicality and applicability of the indicator vary. This is due to the absence of a holistic approach that engages both public and private stakeholders who can define sustainability goals for city logistics and develop the sustainability indicators accordingly.

Following the design thinking approach, this study aims to capture the sustainability goals in city logistics with consideration of both public and private stakeholders, and propose indicators to measure the sustainability performance of city logistics activities.

Design/methodology/approach: The Delphi method was chosen in this study based on its two distinct features: soliciting experts' opinions through an anonymous and geographically dispersed panel and seeking consensus through multiple rounds of the moderated survey process. A heterogeneous Delphi expert panel was formed with 50 city logistics experts in Europe. The participants included academic experts, local authorities, and logistics service providers identified from city logistics-related research projects in Europe, such as Horizon 2020, Interreg and CIVITAS projects. Using three rounds of Delphi survey questionnaires, qualitative and quantitative data were collected. A niche form of the "policy Delphi" was also incorporated in the questionnaire design, not only for gauging the consensus but also for eliciting the diverse views among the panel experts (Rayens and Hahn, 2000).

Findings: The definition of 'sustainable city logistics' and different sustainability goals perceived by public and private stakeholders were captured. A list of 42 provisional indicators developed from literature, sustainability reports and experts' evaluation was presented using a Global Reporting Initiative (GRI)-augmented framework.

Value: This study extends the empirical observations of key city logistics stakeholders in various European countries to explore the priority of different sustainability objectives, and subsequently to assess the relevance and applicability of indicators for sustainable city logistics. The empirical findings were further triangulated with established studies to provide a timely update to the city logistics knowledge in the context of sustainability.

Research limitations/implications: Radical and innovative ideas identified among experts during the three-round Delphi surveys help to gain a holistic understanding of sustainable city logistics from a multi-stakeholder perspective.

Practical implications: The proposed sustainable city logistics indicators were developed by engaging experts from different cities with different expertise backgrounds. These indicators could provide policymakers and practitioners with a list of prioritised metrics, which they could apply to their policy or business objectives. Adapting the GRI sustainability reporting framework to the city logistics context, the proposed indicator framework could bridge the public and private key stakeholders

contributing to the understanding of this widespread sustainability phenomenon, and therefore, foster communication and collaboration on this shared agenda.

Keywords: city logistics, sustainability, indicator, policy Delphi method, triple bottom line (TBL), Global Reporting Initiative (GRI), stakeholder, Europe

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EFFECTS OF TIME WINDOW POLICIES ON ELECTRIC FREIGHT VEHICLE POPULARIZATION AND TRAFFIC CONGESTION IN CHINESE CITIES: A SBM-DEA APPROACH

Haoyang Li, Yongling Gao

School of Business, Central University of Finance and Economics

Purpose of this paper

In recent years, a number of Chinese cities have implemented different time windows for electric freight vehicles (EFVs) and internal combustion engine powered freight vehicles (ICVs). The purpose of this paper is to study the impact of such time window differences on EFV popularization and traffic congestion in Chinese cities.

Design/methodology/approach

This paper proposes a method to calculate differences between time windows for EFVs and ICVs based on their time and spatial characteristics. Then the paper uses these differences as inputs and EFVs sales and traffic congestion indices as outputs to measure the efficiency of time window policies. Our study employs the slacks-based data envelopment analysis (SBM-DEA) model with unexpected output and Malmquist Productivity Index to compare the policy effects in 20 Chinese cities and analyzes the policy implications based on EFV sales and traffic congestion indices.

Findings

The method applied can distinguish the efficiency of traffic incentive policy of different cities. The results show major disparities in policy efficiency between different cities. The *Green Freight Distribution Demonstration Project* implemented by a number of Chinese cities has a positive effect on the efficiency of time window policies.

Value

This paper is one of the first works to study the efficiency of traffic window policies capturing their chronologic and spatial characteristics. We propose a method to measure difference between time window policies for EFVs and ICVs. By applying the method, our study can evaluate the performance of time window policies for EFVs and ICVs in 20 Chinese cities, which could help provide policy recommendations.

Key Words

Electric Freight Vehicles; Time Window Policy; City Logistics; Data Envelopment Analysis; Policy Effects

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The Common Resource Development Conundrum – A Case Study of the Developmental Path of Dubai port

Shiva Madani, Booi Kam

RMIT University, Australia

Purpose of this paper: Studies on seaport competitiveness over the last two decades indicate that the leading determinants of competitive advantages largely fall into six main groups: seaport location; productivity and efficiency; price of services; connectivity of seaport and hinterland access; port organization, and infrastructural facilities. Among the six groups of factors, four — productivity and efficiency, price of services and connectivity of seaport, and infrastructural facilities — require development of resources. This implies that the fundamental factors determining seaport competitiveness in the last five decades have largely been resource-based in characteristics. Thus, there is little surprise to find that seaports around the world typically have comparable resources. In fact, not only global seaports have comparable resources, they also have relatively similar operational routines to facilitate the intermodal or multimodal transport process. Yet, the Resource-based View (RBV) argues that firms must possess rare, valuable, inimitable and hard-to-substitute resources to gain competitive advantages. The phenomenon of seaport competition seems to challenge the basic tenets of RBV. This study explores the necessary and sufficient conditions of resource development, bundling, and deployment in seaport operations from a multi-theoretic perspective – RBV, dynamic capability and contingency – to unravel the conundrum of how seaports achieve competitive advantages using common resources and apparently similar operations processes.

Design/methodology/approach: We address our research question through a case study of the development path of the port of Dubai, the largest seaport in the Middle East region, from its initial development to the mid-2010s. Drawing exclusively from secondary data sources, we examine the infrastructural investments and capability building programs of Dubai port across five decades to develop resource-based constructs.

Findings: Our analysis reveals that while Dubai seaport's evolvement predominantly featured ongoing large-scale infrastructure (resource) building programs, Dubai Port Authority has been highly strategic in organizing, bundling and re-deploying its resources to meet the evolving geopolitical dynamics of the Middle East region that underpin its import-export trade. We developed six dynamic resource-based capabilities - resource agglomeration, resource connectivity, resource complementarity, resource fortification, resource alignment, and resource adaptation – to explain the developmental path of Dubai port as it built its competitive position.

Value: This study contributes to theory building by offering a resource structuring management framework to explain how seaports achieve their competitive strengths through resource development, bundling, and deployment. The framework also provides as a blueprint for strategic seaport development.

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Indigenous Crowd Sourcing in Last Mile Delivery in a Developing Economy

Kola Ewedairo[1], Prem Chhetri[1], Samuel Babatunde Adedotun[2]
1: RMIT University, Australia; 2: Osun State University, Osogbo, Nigeria

Customer-suppliers relationship in developing economy informal sector is different from the traditional dyad supply chain networks. The collaborative relationship between the customer and the supplier is also different.

Purpose: The purpose of this paper is to examine and streamline the collaborative relationship between customer and supplier in a developing economy towards sustainable last mile delivery. The paper aims at examining the informal collaborative relationship between stakeholders to improve last mile delivery (LMD) process, trust and efficiency in a developing economy. The paper thus evaluates and proffer techniques to improve the use of informal crowd sourcing process through vehicle motor parks and commercial vehicles in LMD

Design/Methodology/Approach: Challenges associated with LMD are ongoing in relation to sending and receiving goods, particularly in a developing economy where there are larging 3PL providers. Iproved technology has allowed the increased use of crowd sourcing (CS) in last mile delivery, indigenous idea of B2B, B2C and C2C has been on the increase through motor parks and commercial transport providers in developing economy like Nigeria.

The research utilised mixed methods using questionnaires and interviews to understand the current involvement of informal sector in last mile delivery and proposed a process of improving its use in LMD.

Findings: The research found out that goods are not limited to physical objects but includes cash and that the price for goods is based on the transport cost of one person physically travelling on the vehicle. In addition, goods moves from one location to any part of Nigeria and the efficiency and effectiveness depend on the personality of drivers.

Value: Extant literature has enumerated the importance of different relationship in LMD in developed economy. However, the operational process and the contribution of this informal sector has not been studied, hence, the contribution has been greatly unnoticed, hence the potential has not been fully harnessed. This paper is therefore the first attempt in examining the operation of this informal crowd sourcing approach in LMD, particularly in a developing economy.

Research Implications: The findings of this research will assist stakeholders in formalising the process, improve trust and efficiency of the indigenous use of commercial vehicles in LMD.

Research Limitation: The dearth of data regarding the weight, size and value of goods sent limit the rigour of analysis that can be carried out. A formalise arrangement as proposed by this research will provide appropriate data and ability to for comparison of the type of crowd sourcing identified in the research.

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Estimating ship carbon emissions in ports: A mixed approach for obtaining missing ship technical data

Ruikai Sun, Wessam M.T. Abouarghoub, Bahman Rostami-Tabar, Emrah Demir

Cardiff Business School, Cardiff University, United Kingdom

Purpose of this paper: In recent years ship emissions have become a major source of global air pollution and greenhouse gas emissions. Annual emissions of carbon dioxide account for 2.9% of global emissions. And 70% of ship emissions are generated in offshore areas. Unlike airports, ports are mostly built near city centres and emissions in port areas can have a significant negative impact on the environment of urban and the health of the citizens who live around the port. If the carbon emissions from ships in ports can be accurately estimated, it will be possible to reduce the amount of CO_2 produced in the port area more effectively.

Design/methodology/approach: In this paper, we propose a combination of Big Data and a Fuel-based Bottom-up method. The technical data of individual ships and the historical activity trajectory of the Automatic Identification System (AIS) are obtained by Refinitiv, and the specific fuel consumption curves of ships' engines are used to calculate the fuel consumption under different activity patterns. Based on these fuel consumptions the ship emissions from the port can also be precisely estimated.

Findings: The new model is able to reduce the overestimation of CO_2 emissions from the Energy-based method for ships' main engines operating at high loads. It also compensates for the under-estimation of CO_2 emissions from the Energy-based method at low loads on the ship's main engines. This results in more reasonable emission estimates for ships in port.

Value: There are currently two main types of methods for measuring emissions from ships in ports: the Top-down and Bottom-up methods. The recent research suggests that the Bottom-up method is more accurate due to the improvement of AIS. In addition, most Bottom-up methods use the Energy-based approach, but for some emissions, which are based on a fixed amount of fuel consumption, such as CO_2, the Fuel-based method is more precise. Finally, most of the current port emission studies are focused on large international ports and use local port databases, which are not generalisable. The new method balances the difficulty of collecting data with the accuracy of the estimation results. As the data is sourced from Refinitiv, it has data on ships from almost all over the world. The new method is therefore not only suitable for large ports, but also for the rest of the small and medium-sized ports. By adjusting the different emission parameters, it is also possible to simulate the impact of various policies on port emissions, providing powerful data to support port managers in their future green port plans.

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Logistics Network Design and Management

EFFECTS OF TRAFFIC AND GEOMETRICAL ENVIRONMENT CONDITIONS ON BUSINESS FLEETS BY USING GPS RECORDS

Takeo Takeno[1], Masayuki Inoue[1], Masaaki Ohba[2]
1: Graduated School of Iwate Prefectural University, Japan; 2: Nippon university, Japan

Purpose of this paper: Business fleets, which might consist of lorries and other vehicles, play very important roles in freight transportation. In fact, they conveyed more than 90% of freight tons and 50% of freight ton kilometres inside Japan in 2018 (MLIT 2019). Condition of each vehicle depends on not only time duration in service but also environment in service, e.g. weather including temperature and road conditions such as altitude. The aim of this research is to clarify effects of environment condition on business fleets. As the first step of our research project, we present relationship among fuel consumption and road conditions such as altitude, velocity, road category, etc.

Design/methodology/approach: We have conducted collaborated research project with truck manufacture. We have obtained GPS trajectory records of several trucks in service through the project. First we develop Map-Matching system which estimates accurate position of the vehicle on road network from latitude and longitude obtained from GPS records. We use a digital road network in which whole roads and intersections are represented in edges and vertexes. With the system, we identify the edges where the truck actually runs and derive information of the edge such as altitude or width of the road. Second, we conduct regression analyses to present relationship between condition of the vehicle and environment in service. As the first step of this research, we set fuel consumption as the outcome variable. For explanatory variables, followings are employed that are altitude of intersection, road category such as highway or general road, and velocity of the vehicle.

Findings: Correctness of Map-Matching varies from about 50% to 90%. Here we count number of correct edges from the start point to the end point of single trip of truck. High accuracy is obtained if the truck runs on Highway. On the other hand, it gets worse if the truck runs community roads. We have conducted a regression analysis. As an example, we have found that very weak relationship has been observed among fuel consumption, altitude and inclination of the road. Further analyses will be conducted for another explanatory variable.

Value: Analyses of running vehicles has been conducted in convention. However, these analyses couldn't identify exact position of the vehicle was. Therefore, outcome of analyses may be ambiguous. On the other hand, our approach provides exact behaviour of a vehicle. Further analyses will be able to employed.

Research limitations/implications: Currently we are developing and aiming to establish analysing methodology. Therefore, several vehicles are selected to analyse. And trip area is also limited.
Practical implications: Outcome derived from our research will provide to estimate fuel consumption according to planned trip route. It will contribute transportation industry. Furthermore, our estimation will contribute future parts failure and to increase availability ratio of business fleets. With accumulation progressed, insight obtained from these analyses will contribute development activity in a vehicle maker.

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A two-stage stochastic programming model for humanitarian logistics network design considering uncertain data

Chung-Cheng Lu[1,*], Yu-Shyun Chien[1], Da-Cheng Hong[1]
Kuo-Hao Chang[2], Wen-Jui Su[2], Chih-Chang Chang[2]

1: Department of Transportation and Logistics Management, National Yang Ming Chiao Tung University, Hsinchu, Taiwan 2: National Science and Technology Center for Disaster Reduction, New Taipei City, Taiwan
*: Corresponding author, Email: jasoncclu@nycu.edu.tw

Purpose of this paper: This study addresses a network design problem for the humanitarian logistics in the aftermath of earthquakes. The urgent relief distribution network consists of three levels, namely relief suppliers, relief distribution centers (RDCs), and relief stations in affected areas. The problem involves the following decisions: (i) the location and capacity of the RDCs, (ii) the allocations of the relief suppliers and relief stations to the selected RDCs, and (iii) the paths for sending reliefs from the selected RDCs to the reliefs.

Design/methodology/approach: The uncertainties in link travel times and breakdown probabilities and in relief demand are described using a set of scenarios with given probabilities. This study formulates the problem as a two-stage stochastic programming model in which the location decisions are considered in the first stage and the allocation and path selection decisions in different scenarios are made in the second stage. The underlying model combines the features of both the vertex p-center model and the p-median model such that not only the maximum distances between the RDCs and the relief suppliers and stations but also the expected total distance between the facilities are minimized.

Findings: To evaluate the performance of the stochastic optimization model, we selected New Taipei City, Taiwan as the case study and generated the test instances using real-world data from the city government. The test instances of the proposed model were solved using Gurobi. The numerical results show that the model is effective and efficient in designing the urgent relief distribution network considering the data uncertainties. Additionally, sensitivity analyses were also conducted to examine the impact of the different parameters on the solution results.

Value: This study contributes to the existing literature by proposing an optimization model that integrates the supply side and the demand side in the humanitarian logistics (or relief distribution) network design problem. The proposed two-stage stochastic optimization model addresses a number of important decisions in designing the relief distribution network and considers uncertain travel time, link breakdown, and relief demand. The proposed approach could assist the decision-making of urgent relief distributions in the aftermath of earthquakes.

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A debate on Current Trends that shape the Future of Supply Chain Systems

Nicoleta Tipi[1], Sara Elgazzar[2]

1: The Open University, United Kingdom; 2: College of International Transport and Logistics, Arab Academy for Science, Technology and Maritime Transport, Egypt

Purpose of this paper:

Over the last two decades, global supply chains have faced significant transformations where approaches that emphasised the benefits of leanness, agility, risk, sustainability, resilience, and digital technologies have dominated research agendas.

The scope of this paper is to delve into a discussion that not only characterises current trends but also provides a critique to potential impact these may have on future supply chains.

Design/methodology/approach:

Supply chains have been assessed in terms of their leanness, responsiveness, agility and leagility (Fadaki et al. 2020), sustainability (Brandenburg et al., 2014), risk and resilience (Ivanov and Dolgui, 2020), the use of technology (Frederico et al., 2019), the application of business analytics and modelling (Tipi, 2021; Tipi and Elgazzar, 2021).

The approach adopted in this research is to take a critical view on evaluating current trends that have shaped supply chain systems by reviewing current literature and reporting on key findings.

Findings:

Based on findings from the literature, over the years various trends have created opportunities as well as challenges for organisations, with the expectation to observe increase flexibility, quality, productivity where with the introduction of new technologies, we see new societal challenges and the impact these have on users' interactions and the way optimisation and decision-making is being approached. The impact global pandemic has had on supply chain and the new approaches adopted during this period give a new angle on understanding the way supply chain design and structures are changing.

Value:

This work will capture key challenges and benefits offered by new trends in the use of technology, sustainability and resiliency in the supply chains. Supply chain management trends (supply chain integration and visibility, digital twins, sustainability powered by technology, self-thinking supply chains, sustainable and resilient supply chain, viable supply chains, and others) have been evaluated to help us explain how they will reshape the industry and contribute to the current research agenda in this field.

Research implications:

The structure of supply chain is expected to change in the future, therefore practitioners as well as academics must engage in extensive research and implement new approaches and new technologies to ensure compliance with changing strategies and processes, allowing supply chain members to operate more effectively and efficiently across the board. This work brings theoretical contributions to the field of supply chain management by drafting a research agenda for future supply chains and by raising awareness among practitioners on how these trends may changes and impact their business.

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FULL PAPERS

Sustainability in Logistics and Supply Chains

AN EMPIRICAL ANALYSIS OF SUPPLY CHAIN POLICIES AND AMBIDEXTROUS GREEN INNOVATION: THE PERSPECTIVE FROM CHINA

Wenhao Yang, Zhaokun Guo, Xiaohong Liu
Central University of Finance and Economics, China, People's Republic of
Business School, Central University of Finance and Economics, Beijing, China
E-mail: xliu@cufe.edu.cn

ABSTRACT
This study develops a research framework concerning supply chain policies and a firm's ambidextrous green innovation. The investigation was taken in China, in which the first policy as to the innovation and development of supply chain management（SCM） issued in 2017 was utilized for examination. The method of Propensity Score Matching-Difference in Differences (PSM-DID) was employed to measure the effect of this policy. The results reveal that the first policy of SCM is associated with a firm's exploitative and exploratory green innovation. Consequently, the implications derived from empirical results are made for researchers and SCM practitioners as well.

INTRODUCTION
It is recognised that government policies play an important role in innovation in green firms. For example, Frondel et al. (2008) found that environmental innovation activities are closely correlated with the stringency of environmental policy, by exploring the case of German manufacturers. Furthermore, Chen et al. (2018) argued that government environmental policies and regulations can put coercive pressures on firms, driving them to engage in green innovation activities. Hu et al. (2021) examined the green subsidy, a well-designed environmental policy, highlighting its positive impact on green innovation behaviours.

Yet a close examination of the extant literature reveals that most studies focus on the effect of governmental policies on corporate green innovation at the aggregate level; a detailed analysis of a firm's ambidextrous green innovation, i.e. exploitative green innovation and explorative green innovation (Wang et al., 2020), is still lacking. In particular, it is unclear what the effect is when the policy is specific to supply chain management (SCM) in a particular context, such as China. In China, SCM is inextricably intertwined with the Chinese economy and society, having developed rapidly in recent years (Liu and McKinnon, 2016). The critical role played by SCM in the nation has received considerable attention in both the academic and business worlds. In October 2017, the General Office of the State Council of China issued its 'Guidance on Promoting Supply Chain Innovation and Application', proposing that the supply chain has become a new organisational form of industry and economy, and that it is important to promote the development of supply chain innovation. From this starting point, the purpose of this study is to investigate the extent to which this policy implemented by the Chinese government at a certain time has an impact on a firm's ambidextrous green innovation.

The remainder of this paper is organised as follows. Section 2 discusses the relevant literature. Section 3 introduces the theoretical background and develops the hypotheses. In Section 4, the methodology and data used in this paper are presented. The empirical results are described in Section 5. Finally, a general conclusion and discussion of the limitations of this study and suggestions for future research are provided in the last section.

LITERATURE REVIEW
Ambidextrous green innovation
The theory of organisational ambidexterity suggests that firms need to balance the needs of the present and the future in their business operations, requiring them to manage existing operations efficiently while adapting to future changes; for this, the ability to both exploit and explore is essential (Duncan,1976). March(1991) proposed that exploration and exploitation represent the core of organisational ambidexterity, with exploration being related to behaviours such as innovation, discovery, and search, and exploitation being related to behaviours such as improvement, implementation, and execution; and pointed out that firms need to combine both capabilities in order to adapt to

environmental changes and achieve sustainable development. It is widely recognised that balancing exploration and exploitation of business opportunities is essential for the long-term sustainability of an organisation (Tushman and O'Reilly,1996), and that ambidextrous innovation is necessary for firms to balance short-term performance with long-term sustainability (Raisch and Birkinshaw,2008).

Based on the perspective of organisational ambidexterity theory, O'Reilly and Tushman (2008) suggest that green innovation can be similarly divided into two forms, explorative and exploitative, which cycle back within the firm and together drive green development. In this context, exploitative green innovation refers to activities that follow existing resource and capability pathways, use existing technology, and improve current green products, processes and services, while explorative green governance innovation refers to exploring new knowledge and capability pathways, involving the development of new technologies (March,1991; Raisch et al.,2009; He and Wong,2004). Both types of green innovation practices can not only help firms develop environmentally friendly products and processes, but can also play an important role in operating in a socially responsible way and deterring imitation by competitors (Chang,2018).

The role of policy in a firm's green innovation

Since green innovation behaviour has "double externalities" arising from "spillover effects" and "external environmental costs", it is not sufficient to study it from the perspective of general innovation management theory alone (Bansal and Roth, 2000). Therefore, scholars generally recognise the important role of policy for green innovation in firm. Some scholars believe the policy will have a positive effect. Porter and Van der Linde (1995) proposed the Porter hypothesis, which argues that environmental protection cannot be discussed simply in opposition to economic development, and that appropriate environmental regulation will promote more green innovation activities. Jaffe and Palmer (1997) classify and analyse policy instruments, suggesting that appropriate environmental regulations may stimulate green innovation. Lanoie et al. (2011) argue that government regulation will have a positive impact on firm green innovation by promoting green process innovation. Some other points of view are at opposite poles. Yet Horbach (2008) argues that in order to respond to the government's environmental regulations, firms need to invest resources into purchasing relevant equipment and technology and paying for labour and technology, which forces them to reduce their green innovation activities.

A review of previous studies shows that many scholars have examined the impact of policies on green innovation, but there is still a lack of research on ambidextrous green innovation. Moreover, the different policies are heterogeneous in terms of the green innovation activities of firms, and the diversity of policy instruments will lead to complex outcomes (Goulder and Watkins, 2008). There is also a lack of research on supply chain policy and green innovation. Thus, this paper aims to explore the role of government supply chain innovation policies in influencing firms' ambidextrous green innovation in the context of China.

THEORETICAL BACKGROUND AND HYPOTHESIS DEVELOPMENT

The Supply Chain Innovation Policy implemented in China in 2017 calls for improving integrated innovation capabilities and establishing a green industrial system covering all aspects of design, production, distribution, consumption, and recycling. Highlights include: promoting green management of the entire product life cycle, exploring the establishment of a standard system for unified green products, carrying out green manufacturing management demonstrations in pilot firms, encouraging the innovation and promotion of energy-saving technologies, and supporting the establishment of a reverse logistics system.

We argue that the above-mentioned supply chain innovation policy has clarified the important development objectives of green innovation for pilot enterprises, proposed reasonable and effective means of supervision and management, therefore promote ambidextrous green innovation in pilot firms. First, for enterprises, undertaking green innovation reflects their concern and consideration for the ecological environment, requiring the pursuit of economic performance while acting in an environmentally responsible way (De Medeiros et al., 2014), which requires the investment of more

corporate resources and increased costs while also facing greater risks of uncertainty (Zailani et al., 2014). Relevant policies aim to create a good policy environment for supply chain innovation and application; build an innovation service platform; provide inspection and certification, market development and other services to mitigate the potential risks posed by green innovation; and encourage the establishment of specific investment funds and research centres to provide financing support and technical support for firms to carry out innovation activities. By reducing costs and controlling risks, enterprises will be more motivated to participate in ambidextrous green innovation activities. Based on the theory of market failure and government intervention, Mamunesa and Nadiri (1996) suggest that there is a spillover effect of green technological innovation that leads to insufficient investment in technological innovation by firms; policy support serves to correct the effect and helps to promote green innovation behaviour. Finally, for firms, the application of environmental management implies the development and application of different green technologies that extend beyond the traditional scope of business operations and research. In addition, environmental programmes involve all parts of an organisation's management system, as well as the entire supply chain, including suppliers, retailers, customers, and other non-traditional stakeholders. Technical barriers and complex environmental planning relationships are major impediments to green innovation activities by firms. The policy proposes to encourage the promotion of collaborative green innovation in the supply chain and the construction of a reverse logistics system, among other measures, to promote ambidextrous green innovation activities. Therefore, this paper puts forward the following hypotheses:

H1: The supply chain policy in China promotes exploitative green innovation in pilot firms
H2: The supply chain policy in China promotes explorative green innovation in pilot firms

RESEARCH METHODOLOGY
Data collection
In order to ensure data availability and obtain relatively balanced panel data, we selected listed companies as the study sample for the treatment group, a total of 63 pilot firms, drawn from the list of pilot firms publicised by the policy. The time span selected was from 2013 to 2019 to avoid any impact of the Covid-19 pandemic on the experimental results. To minimise industry heterogeneity, 63 manufacturing firms that were not affected by the policy were selected as the control group. The data were obtained from the RESET Database, Chinese Research Data Services (CNRDS), Chinese Corporate Social Responsibilities Database (CCSR), and the Green Patent Research Database (GPRD).

Research variables
According to Wang et al. (2020), exploitative green innovation refers to innovation behaviour that follows the existing green technology track, which is expressed as the improvement and perfection of existing green knowledge and technology. By contrast, explorative green innovation is defined as innovation behaviour that breaks through the existing green technology track, accompanied by the generation of new green products and technologies. Therefore, we selected the four dimensions of product strategy emission reduction strategy, recycling strategy, and energy strategy to measure exploitative green innovation, and used the logarithm of number of green R&D patents to measure explorative green innovation. Subsequently, we selected a series of control variables related to green innovation capability: Return on Assets (ROA), Current Ratio (CR), Debt Asset ratio (Lev), and Assets turnover (ATO).

Research modelling
In order to identify the relationship between supply chain innovation policy and the ambidextrous green innovation of firms, we used a difference-in-difference (DID) method to construct the model.

$$\text{US} = \alpha_0 + \alpha_1 Treat + \alpha_2 Treat * After + \alpha_3 After + \alpha X + \varepsilon \qquad (1)$$
$$\text{ES} = \alpha_0 + \alpha_1 Treat + \alpha_2 Treat * After + \alpha_3 After + \alpha X + \varepsilon \qquad (2)$$

Where US and ES are the explanatory variables, denoting firms' ambidextrous green innovation. denotes the experimental variable in the difference-in-difference method, where the collated pilot firms are defined as the treatment group (set as 1), and the remaining firms are the control group (set as 0). denotes a time dummy variable in the difference-in-difference method to measure exogenous policy shocks, with the policy being initiated in 2017; thus, it has a value of 0 before 2017 and 1 for 2017 and beyond denotes a series of control variables in this study, and is a random disturbance term.

Considering that the pilot firms selected for the policy may not be randomised, and to avoid the ensuing endogeneity problem, before conducting the double difference regression analysis, we applied propensity score matching (PSM) for the control group to ensure that the intervention effect estimates were based on different outcomes between comparable individuals (Heckman et al., 1997), using the PSM method with the control variable as a covariate in matching, and choosing Logit regression to achieve it.

EMPIRICAL RESULTS
Descriptive statistics
Due to there being some missing values, this is an unbalanced panel. Among the explanatory variables, the mean value of exploitative green innovation is 0.934, the mean value of exploratory green innovation is 0.394, the minimum value is 0, and the maximum value is 4.575, which indicates that there are large differences between firms at the level of green patent R&D. As for the control variables, the current ratio and asset turnover ratio differ significantly, which reflects the importance of conducting propensity score matching.

The results of PSM
Subsequently, we adopt a caliper matching approach and select all control variables as covariates, and the results after regression using the Logit model are shown in Table 1.

It can be seen that the deviation between the experimental group and the control group before matching is large, as can be seen by the p-values all being 0. After matching, the standard deviation is well controlled and the error reduction is obvious.

Variable	Unmatched Matched	Mean Treated Control		%bias	%reduct bias	t-test t p>t		V(T)/ V(C)
Lev	U	0.558	0.396	94.5		13.72	0.000	0.89
	M	0.558	0.566	-4.8	94.9	-0.69	0.490	0.80*
CR	U	1.461	2.187	-54.6		-8.02	0.000	0.28*
	M	1.462	1.366	7.2	86.8	1.44	0.150	0.67*
ROA	U	0.045	0.089	-61.7		-9.05	0.000	0.34*
	M	0.045	0.043	3.4	94.4	0.53	0.597	0.38*
ATO	U	1.062	0.812	37.3		5.38	0.000	1.81*
	M	1.052	0.946	15.7	57.9	2.00	0.046	0.78*

Table 1: Results of PSM

Results of hypothesis tests
After removing the 37 observations that failed to match successfully, a difference-in-difference test was performed. The results are shown in Table 2. It can be seen that exploitative green innovation and explorative green innovation are positively correlated with the DID regression results, both significant at the 95% level, and the regression results are consistent with expectations, supporting the research hypothesis that the implementation of the supply chain innovation policy has promoted ambidextrous green innovation activities in the pilot firms.

	(H1) US	(H2) ES
After	-0.155	0.140
	(-1.13)	(0.13)

Treat	0.534***	3.016**
	(4.11)	(2.99)
Treat*After	0.337*	2.473*
	(1.78)	(1.68)
Lev	-0.743	6.847*
	(-1.74)	(2.06)
CR	-0.142**	-0.184
	(-2.80)	(-0.47)
ROA	-1.100	-1.038
	(-1.48)	(-0.18)
ATO	-0.344***	-1.857**
	(-4.64)	(-3.22)
_cons	1.694***	-0.520
	(5.78)	(-0.23)
N	843	843

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Regression results for H1 and H2

CONCLUSION AND LIMITATIONS

The empirical evidence reveals that the first SCM policy published by the Chinese government in 2017 is associated with both exploitative and exploratory green innovation within firms. This finding derived from the empirical results has implications for both researchers and SCM practitioners.

To the best of our knowledge, this study is the first to examines the effect of supply chain policies on a firm's ambidextrous green innovation by considering the case of the first SCM policy implemented in China. The findings of this study contribute to SCM and innovation literature and the results can help supply chain managers to better understand the SCM policies and ambidextrous green innovation.

However, this paper has some limitations. First, we chose to measure corporate ambidextrous green innovation from the perspective of four dimensions, and green patent R&D, which may ignore other important influencing factors. There is still a lack of research and analysis on the specific process, mechanism of action, and path of policy influence, and future research could introduce more influence mechanisms to explore the relationship between policy and ambidextrous green innovation in more depth.

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DO BUYER POWER AND BUYER-MANUFACTURER RELATIONAL TIE AFFECT MANUFACTURERS' SUPPLIER QUALITY ASSURANCE?

Manh Khang Lai[1], Booi H. Kam[2]

1: PhD Candidate, School of Accounting, Information Systems and Supply Chain, RMIT University, GPO Box 2476, Melbourne VIC 3001, Australia; 2: School of Accounting, Information Systems and Supply Chain, RMIT University, GPO Box 2476, Melbourne VIC 3001, Australia

1. Introduction

In an open buyer-manufacturer-supplier triad, where the buyer has little or no contact with the supplier, the buyer's concern on supplier's compliance with its requirements is largely channelled through the manufacturers (Villena & Gioia, 2018). Recent studies on achieving supply chain sustainability practices (e.g., Marshall et al., 2019; Meqdadi et al., 2018) have shown that buyers could use various power sources associated with their customer status to induce manufacturers (or tier-one suppliers) to manage lower-tier suppliers accordingly.

In developing countries, reported sustainability practices have largely been found to be "suspect" (Alamgir & Baneriee, 2018; LeBaron et al., 2017), which throws into questions the effectiveness of buyer's power in realizing sustainability practices on their upstream supply chains. Noteworthily, empirical evidence has shown that quality management is a precursor to the development of sustainability practices, such as environmental management (Jabbour et al., 2014) and corporate social responsibility (Abbas, 2020), within organizations.

On account of the empirical link between quality management and sustainability practices, this study examines the effect of buyers' use of power to engender their manufacturers to take specific actions to manage their suppliers' quality practices in open buyer-manufacturer-supplier triads. We explore the effects of buyer's use of five power sources — coercive, reward, legitimate, expert, and referent power — on three manufacturer's supplier quality assurance mechanisms – supplier quality monitoring (SQM), manufacturer-supplier supportive norms (MSSNs), and supplier quality collaboration (SQC) – within the context of Vietnam's manufacturing sector, where companies have been building up their quality management systems to gain a competitive edge (Phan et al., 2019). Further, given the proven interactions between power use and relationship attributes, such as trust and commitment, existing between the power user and power recipient (e.g., Horak & Long, 2018; Jain et al., 2014), we also assess how these relationships are moderated by the relational tie (manifested through trust and commitment) between buyer and manufacturer using hierarchical regression analysis.

This study extends current knowledge on buyers' use of power to prompt manufacturers' management of upstream suppliers' sustainability practices through an understanding of these effects on quality management within open triads. It also provides an understanding of the moderating role of buyer-manufacturer relational tie on those effects, contributing to both theory and practice.

2. Theoretical Background and Hypothesis Development

2.1 Use of Power in Supply Chain Management

French and Raven's (1959) seminal work distinguishes five power sources: coercive, reward, legitimate, expert, and referent power. Coercive power refers to the power user's threat to the power recipient should the latter fails to comply with its requests. Reward power denotes the power user's offer of incentives to encourage the power recipient to comply with its requests. Legitimate power is derived from the power recipient's recognition of the power user's rights to remind it of its obligations. Expert power stems from the power recipient's belief that it could benefit from the power user's knowledge and

expertise. Referent power nests on the power user's reputation, which the power recipient values and desires to be associated with.

Extant literature has found that each power source invites distinctive responses from power recipients. When coercive power is used, power recipients would generally respond negatively, ranging from reluctance to accept unfavorable deals (Clauss & Boucken, 2019) to outright refusal (Nyaga et al., 2013), contingent upon the dependency relationship between the user and recipient. In contrast, reward power and referent power tend to generate positive engagement from power recipients (Meqdadi et al., 2018; Clauss & Boucken, 2019). The effects of legitimate power have been mixed: producing little impact under the Guanxi culture (Zhao et al., 2008), but invoking strong collaboration under the rational decision-making regime (Terpend & Ashenbaum, 2012). Though generally positive, use of expert power has, at times, veered recipients to a less cooperative posture when being viewed as a subtle form of punishment (Terpend & Ashenbaum, 2012).

In the context of an open triad, buyer's use of coercive power or joint use of coercive and reward power has not been effective in inducing manufacturer to engage supplier's to meet buyer's requirements (e.g., Marshall et al., 2019; Meqdadi et al., 2018). Buyer's use of legitimate, expert, or referent power, by contrast, have been relatively successful in motivating manufacturers to enlist their suppliers' support to meet compliance requirements (e.g., Marshall et al., 2019; Meqdadi et al., 2018).

2.2 Supplier Quality Assurance

Mainstream supplier management literature suggests SQM and SQC are two critical supplier quality assurance mechanisms (Vachon & Klassen, 2006). SQM refers to a firm's efforts to check suppliers' quality compliance in their operations (Akamp & Müller, 2013). SQC demonstrates a firm's efforts to work directly with suppliers to obtain quality-compliant raw materials or components (Yu & Huo, 2018).

In this study, we added MSSNs as another supplier quality assurance mechanism. MSSNs refer to expectations both manufacturer and supplier share about each other's behavior (Heide & John, 1992). They are self-regulated and self-enforced, rather than externally imposed, and work on the principles of mutual trust (Zhou et al., 2015). This is the predominant means businesses in a Guanxi-based market operate (Kam & Lai, 2018).

2.3 Power and Supplier Quality Assurance in Buyer–Manufacturer–Supplier Triad

Empirical evidence on the effect of power use in Guanxi-based cultures (e.g., Meqdadi et al., 2018; Zhao et al., 2008) generally concurs with those found in non-Guanxi-based contexts. Coercive power tends to be perceived negatively by power recipients (Zhao et al., 2008; Huo et al., 2018). In a triadic context, Meqdadi et al. (2018) have found that buyer's use of coercive power has failed to nudge manufacturers (or tier-one suppliers) to propagate sustainability practices upstream to tier-two suppliers. Their case study of multi-national corporations on power and diffusion of sustainability practices in supply networks also reveals that buyer's use of reward, legitimate, expert, and referent power, individually, has been effective in prompting Asian (i.e., China, India, South Korea, and Taiwan) suppliers to spread sustainability practices to upstream suppliers. On that account, we propose the following hypotheses:

H1. Buyer's use of coercive power is negatively associated with a manufacturer's (a) SQM, (b) MSSNs, and (c) SQC.
H2. Buyer's use of reward power is positively associated with a manufacturer's (a) SQM, (b) MSSNs, and (c) SQC.
H3. Buyer's use of legitimate power is positively associated with a manufacturer's (a) SQM, (b) MSSNs, and (c) SQC.

H4. Buyer's use of expert power is positively associated with a manufacturer's (a) SQM, (b) MSSNs, and (c) SQC.

H5. Buyer's use of referent power is positively associated with a manufacturer's (a) SQM, (b) MSSNs, and (c) SQC.

4 Moderation effects of Buyer-Manufacturer Relational tie

Studies on power use in Guanxi-based business contexts (e.g., Horak & Long, 2018; Liu et al., 2015) have also revealed strong links between power and relationship attributes, like trust (Horak & Long, 2018) and commitment (Jain et al., 2014). On the strength of those evidence, we posit that in a buyer-manufacturer-supplier triad operating in a Guanxi-based context, the buyer-manufacturer relational tie, manifested through the reciprocal trust each has on the other and the commitment to the relationship, would moderate the effect of buyer's use of power on the manufacturer's behavior toward use of different quality assurance mechanisms to manage upstream suppliers.

Under a strong relational tie, buyer's use of coercive power could be viewed as an expected performance-nurturing endeavor (Horak and Long, 2018). By contrast, buyer's use of reward power could be seen as unexpected if the relationship between buyer and the manufacturer is Guanxi-based: the manufacturer does not expect rewards but rather looks toward favorable treatments from the buyer (Liu et al., 2015). We anticipate a strong buyer-manufacturer relational tie would weaken 1) the negative effect of coercive power and 2) the positive effect of reward power on the manufacturer's supplier quality management efforts, leading to the following hypotheses:

H6. The strength of buyer-manufacturer relational tie will positively moderate the negative effects buyer's use of coercive power has on a manufacturer's (a) SQM, (b) MSSNs, and (c) SQC.

H7. The strength of buyer-manufacturer relational tie will negatively moderate the positive effects buyer's use of reward power has on a manufacturer's (a) SQM, (b) MSSNs, and (c) SQC.

Under a strong relational tie characterized by mutual trust and strong commitment, the buyer's use of legitimate power, such as exerting its authority to exploit values from the manufacturer (Brito & Miguel, 2013), would likely be resented by the manufacturer (Griffith et al., 2017) who would likely to decrease its supplier quality management effort, leading to the following hypothesis:

H8. The strength of buyer-manufacturer relational tie will negatively moderate the positive effect buyer's use of legitimate power has on a manufacturer's (a) SQM, (b) MSSNs, and (c) SQC.

Further, if the buyer overloads the manufacturer with expert power, the latter may be reluctant to collaborate (Byrne & Power, 2014). This cannot be truer under a strong tie: to assimilate new knowledge, a power recipient may have to put extra efforts into adjusting its well-established routines (Kim & Choi, 2018). Therefore, under a strong buyer-manufacturer tie, buyer's persistent use of expert power may result in the manufacturer finding it problematic to continuously reorganize its operations, leading to a disregard of the buyer's knowledge (Wilhelm et al., 2016). We thus hypothesize that:

H9. The strength of buyer-manufacturer relational tie will negatively moderate the positive effect buyer's use of expert power has on a manufacturer's (a) SQM, (b) MSSNs, and (c) SQC.

By contrast, buyer's use of referent power would be favorably received by the manufacturer as the relational tie between the two develops: power recipients' desire to be affiliated with power users' reputation grows when the relational tie between them becomes stronger (Kähkönen & Virolainen, 2011). This suggests that buyer-manufacturer relational tie would positively moderate the relationship

between buyer's use of referent power and manufacturer's supplier quality management effort, as follows:

H10. The strength of buyer-manufacturer relational tie will positively moderate the positive effect buyer's use of referent power has on a manufacturer's (a) SQM, (b) MSSNs, and (c) SQC.

3. Methodology
3.1 Survey Instrument and Data Collection
We tested our hypotheses using data collected from an online survey of manufacturers in Vietnam. We developed our questionnaire using items adapted from prior studies (see Table 1). For each item, respondents rated the level of their agreement with a given statement on a 7-point scale (1 = "Strongly Disagree", 7 = "Strongly Agree").

The questionnaire is structured into three key sections. The first section focused on respondent and company profiles. At the end of this section, respondents were asked to identify a key product their company produced, the buyer which placed the largest share of the order volume for this product in the past three years, and the supplier that provided the critical materials or sub-components for this product. This identification ensures that responses provided by the manufacturer are grounded in the context of a specific triad, i.e., where the responses pertaining to the "identified buyer" are linked to the "identified supplier" and vice versa. The second and third section consisted of items reflecting the relationship the responding manufacturer has with the identified buyer and the identified supplier, respectively.

The questionnaire, first developed in English, went through a rigorous iterative translation (to Vietnamese) and back-translation (to English) process, until all discrepancies between the original English questionnaire and its back-translated version were reconciled. The last-refined Vietnamese version of the questionnaire was then pre-tested with two academics, two logistics professionals and five manufacturing managers in Vietnam.

The questionnaire (in Vietnamese) was emailed to 2,213 companies identified from Vietnam Yellow Pages and two directories of Vietnam Manufacturing Associations. After three follow-ups, 295 responses were obtained, from which 76 incomplete responses were dropped, leaving 219 usable responses (9.9% return rate) for analysis. Responding companies were from 12 major industries, with mechanical and metal works, textile and apparel, and furniture constituting 47%. Over half (60%) of these companies had less than 100 employees. Over 80% of the responding officers were in a managerial role and about 56% had been in their current job for more than 5 years.

3.2 Data Analysis

Assessment of measurement model

The measurement model was assessed for convergent validity, construct reliability, and discriminant validity. Convergent validity was assessed through factor loadings and model fit indices. The factor loadings for all items were above 0.5 (p < 0.001) (see Table 1). The fit indices for the overall model (c2/df = 1.581, RMSEA = 0.052, CFI = 0.912, IFI = 0.915) indicate a good fit, providing further evidence for convergent validity. To check construct reliability, Cronbach's a was used: the values of a for most constructs except Dependence on Supplier exceeded the threshold of 0.7, indicating sufficient construct reliability. Discriminant validity was established because the correlation coefficients between any pair of constructs were lower than the square root values of the AVEs for each construct.

Endogeneity check and Hypothesis testing

Prior to hypothesis testing, endogeneity bias was checked, as the five predictors (i.e., buyer's use of five powers) may be correlated with error terms (Ketokivi & McIntosh, 2017). To address endogeneity, we followed the two-stage least square regression procedure suggested by Hamilton and Nickerson (2003).

In Stage 1, we regressed each of the five predictors on two instrumental variables, i.e., manufacturer's dependence on buyer and buyer-manufacturer tie strength (Huo et al., 2018) and obtained the residuals of each predictor which were free of influence of the two instrumental variables. The Stage-1 regression results show significant relationships between predictors and instrumental variables, suggesting potential endogeneity.

Independent Variables

Buyer's Use of Coercive Power (Zhao et al., 2018): **a = 0.75**
-The buyer would cancel order when it finds out we do not comply with what it requires *(0.66)*
-The buyer would withdraw its orders if we failed to meet its quality expectations as agreed upon *(0.76)*
-If we do not comply with its suggestions, the buyer would suspend its payment or delay its order *(0.70)*

Buyer's Use of Reward Power (Zhao et al., 2018): **a = 0.70**
-If we did not comply with the buyer requests, we would lose new business opportunities it offered *(0.65)*
-By going along with the buyer's requests, we had been favored on some occasions (0.64)
-By complying with the buyer's requests, we have avoided the penalties that other manufacturers faced from the buyer *(0.67)*

Buyer's Use of Legitimate Power (Zhao et al., 2018): **a = 0.84**
-It is our undeniable duty to follow the buyer's requests *(0.84)*
-We realize our obligation to comply with the buyer's expectations, though it isn't part of contract *(0.66)*
-While working with the buyer, we accept its quality system recommendations *(0.72)*
-The buyer has the right to expect us to go along with its quality requests *(0.78)*

Buyer's Use of Expert Power (Zhao et al., 2018): **a = 0.81**
-We obtained good advice from the buyer to comply with its quality requirements *(0.74)*
-The buyer has well-qualified people who know what must be done to manage quality *(0.78)*
-The buyer has the expertise to help us to manage and improve our product quality *(0.79)*

Buyer's Use of Referent Power (Zhao et al., 2018): **a = 0.85**
-We admire the way the buyer runs its quality program, so we try to follow its lead *(0.78)*
-We want to operate our quality management system similar to the way the buyer does *(0.82)*
-We share similar ideas with the buyer about the way a quality program should be run *(0.72)*
-Because we are proud to be affiliated with the buyer, we often do what it asks us to *(0.77)*

Moderating Variable

Buyer-Manufacturer Relational Tie (Kim & Choi, 2018): **a = 0.87**
-We perceive the buyer as a trustworthy partner *(0.76)*
-We and the buyer perceive each other as an important 'team member' *(0.94)*

-We and the buyer share similar values and believe in developing opportunities for gaining mutual benefits *(0.82)*
-We and the buyer have developed a good social relationship outside of business *(0.63)*

Control Variables

Manufacturer's Dependence on Supplier (Huo et al., 2018): **a = 0.61**
-The supplier supplies over 50% of raw materials, or manufactured components, we need to produce the key product line for the biggest buyer of this product line most of the times *(0.76)*
-It would be difficult for us to find alternative suppliers of the same materials or components *(0.58)*

Manufacturer's Dependence on Buyer (Huo et al., 2018): **a = 0.80**
-The buyer accounts for more than 50% of our quarterly revenue in the last three years *(0.83)*
-Our revenue would be significantly reduced if the buyer stopped ordering from us *(0.79)*

Dependent Variables

Supplier Quality Monitoring (Akamp & Müller, 2013): **a = 0.89**
-We set clear quality improvement targets for the supplier *(0.79)*
-We use a formal procedure to evaluate the supplier performance *(0.74)*
-We set clear metrics to measure the quality performance of the supplier *(0.80)*
-We closely monitor the supplier's quality performance improvements *(0.76)*
-Our contract with the supplier clearly specifies the quality requirements for all components (or materials) to be supplied *(0.76)*
-We closely monitor the quality of supplies from the supplier to ensure they comply with international standards *(0.65)*

Manufacturer-Supplier Supportive Norms (Heide & John, 1992): **a = 0.78**
-We adjust our relationship with the supplier to ensure our compliance with the buyer's quality requirements for key product line *(0.79)*
-We expect the supplier to make adjustments to address our changing quality requirements in our ongoing relationship *(0.74)*
-Whenever our quality requirements change, the supplier would be quick to embrace the new requirements and would not stick to the original ones *(0.67)*

Supplier Quality Collaboration (Yu & Huo, 2018): **a = 0.84**
-The supplier is often involved in our product design with positive contributions *(0.58)*
-The supplier works closely with us in our quality improvement programs *(0.82)*
-We help the supplier improve processes to ensure it meets our quality requirements *(0.85)*
-We help the supplier obtain quality system certification in our manufacturing areas *(0.74)*

Note: Item loadings were italicized and placed in parentheses

Table 1: Description of Constructs and Measurement Items

In Stage 2, we estimated the coefficients using the residuals for the five predictors to correct for endogeneity (Ketokivi & McIntosh, 2017) and performed the hierarchical regression following the procedure suggested by Aiken and West (1991). To mitigate multicollinearity, the moderator was mean-centered. The variance inflation factor (VIF) of the independent variables ranged from 1.08 to 5.52 (<10), indicating multicollinearity is not an issue (Hair et al., 2010).

	SQM			MSSNs			SQC		
Model	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Control Var.									
SIZE_CAP	0.28**	0.19*	0.19*	0.13	0.05	0.05	0.19†	0.13	0.13
LENGTH_S	0.27	0.47	0.48	0.34	0.34	0.36	0.04	-0.02	-0.01
LENGTH_B	-0.09	0.01	0.01	-0.60†	-0.50	-0.48	0.01	0.21	0.18
DEP_S	0.03	0.02	0.01	0.11†	0.09†	0.07	0.21**	0.19**	0.17**
DEP_B	0.06	-0.01	-0.01	0.08†	0.03	0.03	0.10†	0.05	0.05
Ind. Var.									
COER		0.00	-0.02		-0.10	-0.13**		0.05	0.06
REW		0.14*	0.16*		0.24**	0.27**		0.17†	0.17†
LEGI		0.30**	0.28**		0.11	0.06		0.02	0.00
EXPE		-0.03*	-0.03*		-0.02	-0.02		-0.02	-0.01
REF		0.02	0.03		0.14†	0.15†		0.13	0.13
Moderating Var.									
BMTS		0.27**	0.30**		0.20**	0.22**		0.17*	0.22*
Interaction									
COER x BMTS			0.08			0.11†			0.02
REW x BMTS			-0.06			-0.15†			0.07
LEGI x BMTS			-0.06			-0.16**			-0.03
EXPE x BMTS			-0.01			-0.01			0.01
REF x BMTS			0.02			0.11			-0.09
F statistics	3.63**	7.76**	5.64**	2.34*	5.14**	4.81**	4.27**	3.92**	2.82**
Adj. R^2	0.06	0.27	0.27	0.03	0.18	0.23	0.07	0.14	0.13

Table 2: Hierarchical Regression Results

Note: † $p < 0.1$; * $p < 0.05$; ** $p < 0.01$ (two-tailed)
Variables: SIZE_CAP: Size of Capital Asset; LENGTH_S: Length of Manufacturer-Supplier Relationship, LENGTH_B Length of Manufacturer-Buyer Relationship; DEP_S: Manufacturer's Dependence on Supplier; DEP_B: Manufacturer's Dependence on Buyer; COER: Buyer's Use of Coercive Power; REW: Buyer's Use of Reward Power; LEGI: Buyer's Use of Legitimate Power; EXPE: Buyer's Use of Expert Power; REF: Buyer's Use of Referent Power; BMTS: Buyer-Manufacturer Tie Strength (i.e., the Strength of Buyer-Manufacturer Relational Tie).

4. RESULTS AND DISCUSSION

Our hierarchical regression results (Table 2) show that a buyer's use of different power sources carries dissimilar effects in influencing manufacturer in invoking each of the supplier quality assurance mechanisms. The findings further reveal that only the strength of these effects on MSSNs is contingent upon the strength of the buyer-manufacturer ties.

Buyer's Use of Coercive Power

Coercive power only held a significant negative relationship with MSSNs (i.e., supporting H1b) but not with SQM and SQC (i.e., not supporting H1a and H1c). BMTS positively, though marginally, moderated the negative relationship coercive power had with MSSNs (i.e., supporting H6b), but produced insignificant moderation effect in the SQM and SQC models (i.e., not supporting H6a and H6c).

The above results suggest that buyers' use of coercive power not only has no influence on Vietnamese manufacturers' efforts to employ SQM and SQC to manage the quality practice of their suppliers, it also dampens their enthusiasm on cultivating MSSNs with suppliers as a means to secure quality compliance. This interpretation aligns with Nguyen and Rose's (2009) observation that businesses in Vietnam desire to "develop trust with their partners" (p. 165) and thus view coercive power as a deterrent to trust building. The positive moderation BMTS has on the negative relationship between Coercive Power and MSSNs concurs with Horak and Long's (2018) observation that manufacturers consider buyer's use of coercive power as a performance-nurturing endeavor in Guanxi cultures.

Buyer's Use of Reward Power

Reward power could prompt manufacturers to tighten SQM (supporting H2a) and build MSSNs (supporting H2b), but only weakly engage SQC (not supporting H2c). BMTS marginally weakened the positive effect of reward power in the MSSNs model (supporting H7b) but was not significant in SQM and SQC models. Compared with the effects of the other power sources, our findings suggest that use of reward power is most effective in prompting Vietnamese manufacturers to use all three supplier quality management mechanisms (SQM, SQC, and MSSNs) examined in this study.

Buyer's Use of Legitimate Power

Legitimate power only had a direct positive effect on SQM, supporting H3a, but bears no significant relationships with MSSNs and SQC (not supporting H3b and H3c). Further, the hypothesized negative moderating effect of BMTS is only significant on the relationship between legitimate power and MSSNs (supporting H8b). These findings indicate that Vietnamese manufacturers tend to leverage the authority of the buyers as a legitimate reason to monitor the quality processes of their suppliers to avoid relational conflict with the latter. When these manufacturers have a strong relational tie with their buyers, buyer's use of legitimate power would be resisted to the extent of decreasing their motivation to cultivate supportive norms with suppliers to ensure supplier quality compliance.

Buyer's Use of Expert Power

Expert power imparted a negative effect in SQM (i.e., reversing the prediction in H4a), and produced insignificant effect in instigating manufacturers to develop MSSNs (i.e., not supporting H4b) or engage in SQC (i.e., not supporting H4c) with suppliers. Neither of the interaction term between BMTS and expert power had significant effect on the three supplier quality assurance mechanisms, not supporting H8a, H8b, and H8c. These results suggest that buyer's use of expert power is largely for solving quality issues and has little bearing in prompting manufacturers to adopt three supplier quality assurance mechanisms.

<u>Buyer's Use of Referent Power</u>
The hypothesized effects of referent power is only (marginally) significant on MSSNs (supporting H5b) but not significant for both SQM and SQC (not supporting H5a and H5c). Neither are the effects of the interaction terms between BMTS and referent power on all three supplier quality assurance mechanisms (i.e., MSSNs, SQM, and SQC). These findings show that Vietnam's manufacturers are not motivated to utilize buyer's reputation to monitor (SQM), or collaborate with (SQC), tier-two suppliers.

From the perspective of employing the three supplier quality assurance mechanisms, it is noteworthy to mention that BMTS is significant in prompting Vietnamese manufacturers to utilize all three means. When power is used, SQC is not a mechanism of choice. However, supplier dependency is found to have the strongest effect in motivating manufacturers to undertake SQC to manage suppliers. These findings imply some relational constructs are at work at the manufacturer-supplier end of the triad, which needs further investigation.

6. Implications and Limitations
Vietnamese manufacturers are in the thick of gaining international recognition and are actively pursuing product quality compliance (Phan et al., 2019). Managing tier-two suppliers' quality compliance is an instrument to achieve such a goal. Our findings provide useful hints on power use to buyers seeking outsourcing partners in Vietnam. Buyers would benefit from understanding how power use in situations of different relational ties may, or may not, be receptive to manufacturers, especially if the intent is to enlist the latter's support to propagate its quality requirements to upstream supply chain partners.

Our research is not without limitations. Drawn from a cross-sectional data based on a single partner of a triad, our research cannot claim to have fully captured the dynamic relationship between buyer's use of power, buyer-manufacturer relational tie and manufacturer's supplier quality management efforts. Future investigations through multiple case studies to explore the power-relational dynamics across the triad would be a productive avenue.

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VALUE CHAIN ANALYSIS FOR INFRASTRUCTURE INVESTMENT PLANNING: THE CASE OF THE MONGOLIAN LIVESTOCK VALUE CHAIN

Jan Havenga[1], Zane Simpson[1], Stefaan Swarts[1], Bernard Aritua[2]
1: University of StellenboschSouth Africa, South Africa; 2: The World Bank
E-mail: zane@sun.ac.za

INTRODUCTION

In the ongoing quest for economic development, winners and losers are arguably differentiated by their ability to successfully coordinate the factors of production. In developed economies, capital has productively been employed to create an environment in which further investment would enhance competitiveness and growth. On the other hand, many developing economies are struggling to unlock their drivers of growth in a meaningful, sustainable, and integrated manner. Many developing countries are endowed with mineral resources, which if properly exploited, could significantly improve their economic outlook. Infrastructure investment, which is the backbone for natural resources exploitation and one of the most expensive inputs, often takes place in a piecemeal fashion, and growth remains elusive in the face of inefficient investment decisions (Lenz, Mynyehirwe, Peters & Sievert, 2017; Muller & Zandamela, 2018; Turok, 2015).

VALUE CHAINS

Value chains have long been employed as a construct to facilitate the competitiveness of firms. In the inception of its definition, Porter (1985) conceptualized a competitive environment in which firms would benefit, and unlock value, by investing to position themselves optimally in the value chain. An understanding of the levers of value creation, and investment in unlocking such value, would facilitate competitiveness and strengthen the firm's gains in the economy. Examples of successful adoptions of value chain approaches for unlocking value are numerous, and include Unilever, IBM, Cisco Systems, Starbucks, and others (Verwijmeren, 2018). The value chain approach enables firms to take a holistic view of areas of weakness and strength and identify where finite resources need to be targeted to achieve maximum overall impact. These firms can take a local, regional, and global view of their market position and make informed decisions. At the national level, these firm-level investments would translate into enhanced economic development. As per Adam Smith's concept of the Invisible Hand (Smith, 1904), market forces would facilitate a trickle-down of investment, that would ultimately benefit all. However, implicit in the above narrative is the assumption that firm value is unlocked within a healthy enabling environment, where the factors of production are employed appropriately, and where investment would indeed have the potential to stimulate further economic development. In the case of many developing economies, this narrative does not hold true.

In rare instances, a structured approach to value chain development has facilitated economic development through the establishment of selected sectors. These approaches have shifted the burden of control from the enabling environment of the economy as Invisible Hand to that of the state. For example, in the aftermath of the First World War and the 1933 Depression, an entire industrial value chain was developed in South Africa through the establishment of state-supported enterprises to extract its natural resources to provide affordable energy, establish steel manufacturing capabilities, and develop military and marine manufacturing industries (Schonland, 1950; ToxiNews, 2012). Similarly, the coordinated post-World War II efforts of the German government facilitated the establishment of a successful manufacturing industry (Godart & Görg, 2011). At the time, the concept of a value chain was of course undefined, and its exploration in the structured development of an economy was not explicitly adopted.

In the current environment, developing economies are struggling to achieve the economic advances that are required to support growth. Global value chains, now accounting for more than two-thirds of global trade, offer opportunities for countries to increase income and create employment (UNDP & WEF, 2019). However, successful participation in global value chains requires reliable infrastructure, efficient processes at borders, fast and accurate information transfer, and low transaction costs (Luo & Xu, 2018; World Bank Group, 2020). Analysis shows that countries with poor logistics performance are not central

to global value chains (World Bank, WTO, IDE-JETRO, OECD & the Research Center of Global Value Chains at the UIBE, 2017). This inadequate performance could partly be ascribed to their inability to facilitate a structured, integrated approach to infrastructure development (Lenz *et al*., 2017; Muller & Zandamela, 2018). Economic development that is left to its own devices by a struggling economy, as opposed to appropriate facilitation of coordinated decision-making by the state, is of concern.

This research contributes to the discipline by exploring the development of competitive national value chains as a means of guiding infrastructure development decisions, based on the Mongolian livestock value chain as a case study. Mongolia has access to the rich, but an unexplored, resource of livestock husbandry as a factor of production and potential driver of economic growth. This pastoralist meat producing sector is considered as a fertile ground for unlocking significant value and is explored as a case study to illustrate the application of value chain approaches for economic development.

INFRASTRUCTURE FOR DEVELOPMENT

Literature has paid significant attention to transport infrastructure investment in developing countries, with many studies confirming the contribution thereof to economic growth and structural transformation (Berg, Deichmann, Liu & Selod, 2017; Setboornsarng, 2006). However, a complex relationship exists between infrastructure and growth (Fay & Rozenberg, 2019) with a strong dependency of trade on the transport network: better networks are associated with reduced transport cost and improved market access, which in turn leads to improved trade. Similarly, agricultural production could be stimulated by better access to towns and markets; however, such improved access could also attract workers to other labour markets, and thus away from agriculture (Berg *et al*., 2017). Limao and Venables (2001) estimated a 12 percent increase in transport cost if infrastructure deteriorated from the median to the 75th percentile, and a 17 percent decrease if infrastructure improved to the 25th percentile; further, halving the transport cost (from the median value) would increase trade volumes by 42 percent.

Transport corridors, which could include roads, railways, and access to ports, and allow the flow of people and goods along the route, can be developed to increase trade within a region or to facilitate exports. Transport corridors are especially beneficial for stimulating trade with landlocked countries (OECD & WTO, 2013). The Inter-American Development Bank highlighted the important contribution of transport networks and efficient logistics towards reducing trade costs and increasing competitiveness. Delays in the movement of goods increase the cost to the final consumer and reduce competitiveness (OECD & WTO, 2013).

Agricultural development projects often focus mainly on improving smallholders' production without paying much attention to market linkages, although market access could improve livelihoods and alleviate poverty (FAO, 2019). On the other hand, infrastructure development is not always aligned with the needs of the value chains that will use it. The Asian Development Bank (2012) identified nine criteria that are essential for the development of pro-poor agricultural value chains. These include the "provision of rural infrastructure that reduces postharvest losses and transport costs, and shortens transit time, while increasing overall rural mobility". Roads should link agricultural production areas with strategic markets while the locations of storage facilities and markets influence the success of the value chain (Asian Development Bank, 2012). Analysis showed that better access to transportation, information, and water is associated with a higher income from livestock sales (Meurs, Amartuvshin & Banzragch, 2017).

Straub (2008) conducted a literature survey of research on the economics of infrastructure in developing countries. Approximately two-thirds of the reviewed studies identified a significant positive link between infrastructure investment and growth. However, no conclusions could be drawn about the desired levels of spending at different levels of development. The most common way to evaluate the success of infrastructure spending is to calculate the economic rate of return. Average returns of 30–40 percent were obtained for telecommunications, 40 percent for electricity generation, and 80 percent for road investment projects (Estache, 2004). Returns showed a tendency to be higher in low-income countries than in middle-income countries.

Finally, ongoing development of the concept of macrologistics, and consideration of the macroeconomic cost of logistics, facilitates improved competitiveness by providing a means of managing logistics as a national production factor (Havenga, 2018).

SMALLHOLDER LIVESTOCK VALUE CHAINS

The Mongolian livestock value chain is selected as a case study for its potential to unlock value for the Mongolian economy. By way of background, this section presents the challenges of, and limitations to, economic development of smallholder livestock value chains across the globe, and the role of infrastructure decision-making.

Based on the value chain definition of Kaplinsky and Morris (2001), the livestock value chain can be defined as the full range of activities required to bring a product such as live animals, meat, milk, eggs, or skins, through the different phases of production, processing, and delivery to the final consumer, including final disposal after use. It can also be defined as "a market-focused collaboration among different stakeholders who produce and market value-added products" (Rota & Sperandini, 2010).

The relative benefits from the livestock value chain to lower-income rural households are significant, although their absolute benefits are smaller than those of higher-income households. This supports the case for livestock as a pro-poor policy instrument (Otte, Costales, Dijkman, Pica-Ciamarra, Robinson, Ahuja, Ly & Roland-Holst, 2012; Rota & Sperandini, 2010).

The livestock sector contributes about 40 percent of agricultural GDP and represents nearly 1 billion smallholder livestock producers in developing countries (Rota, 2015). Pastoralists are considered to be smallholders irrespective of their herd size, as their limited resources constrain their sustainability (FAO, 2019). Approximately 34 percent of global human protein consumption and 18 percent of global calories is obtained from livestock (AGA News, 2018). It is projected that the world population will be 9.6 billion by 2050, of which 70 percent will be living in cities, and with an average income almost double the current average. This will result in a significant increase in the demand for livestock products, which play an important role in human nutrition, but are usually more expensive than crops (FAO, 2019; AGA News, 2018; Rota, 2015).

CASE ANALYSIS: DEVELOPMENT OF LIVESTOCK VALUE CHAINS FOR THE MONGOLIAN ECONOMY

Mongolia is a developing economy, and its economic performance lags significantly behind best performers and its immediate neighbours. While its export economy is largely dependent on minerals, it has a vibrant but unexplored meat production sector that mostly provides for domestic consumption. This sector evolved from pastoralist roots and is deeply embedded in the culture of Mongolia. As such, production is based on traditional approaches, and a sophisticated logistics infrastructure does not exist to support its export potential. This provides a significant opportunity for improvement and the application of targeted infrastructure decision-making in support of economic growth.

Mongolia in context

Mongolia is the least densely populated country in the world. With just over 3.2 million people inhabiting a territory of 1.564 million square km (more than six times the size of the United Kingdom and less than a third the population of London), Mongolia has a population density of 2.1 people per square km. About half of the population—some 1.4 million people—live in the capital city Ulaanbaatar. The rest of the population is spread across small urban centres and vast steppes where people herd sheep, goats, horses, cattle, yaks and camels. Currently, there are over 70 million livestock owned, increased from 33 million in 1999 to 44 million in 2009, and raised by 233 000 households, compared with 269 950 in 1999 and 226 650 in 2009. Nearly 26 percent of Mongolian households are traditional nomadic pastoralists whose livelihoods are still vulnerable, with livestock often their only source of income and alternate job opportunities scarce in rural areas (National Statistics Office of Mongolia & The World Bank, 2020).

Poor infrastructure connectivity, resulting in underperforming economic corridors, inhibits diversification of the economy and competitiveness of sectors with growth potential. Mongolia's agriculture sector, specifically wool, cashmere and meat, has underperformed relative to the country's comparative advantage. This is partly caused by the underdeveloped economic corridors that link herders and international trade. Difficult access to energy networks together with poor transport connectivity has hindered efficient logistics and storage, resulting in large amounts of waste.

Mongolia's meat industry is an important contributor to food security, with potential as an export contributor. The global demand for meat is rapidly growing and has quadrupled over the past 50 years (Ritchie & Roser, 2019). The country borders China, with its growing population and insatiable demand for protein. Further, it is relatively unchallenged in the region – unlike the steel industry, which has made limited progress with a fragmented logistics system against China's dominance.

The meat industry has been under-exploited, and the potential for productivity increases has been well-researched (Munkhdelger, 2020; Swiss Agency for Development and Cooperation SDC, 2015; Altangerel & Yi, 2014). It is estimated that Mongolia could earn US$1bn annually from agricultural exports to China (World Bank Group, 2020). However, operationalization of the export potential has been hampered by Mongolia's inability to supply the required quality, quantity, and consistency of products.

The meat industry is unsophisticated and relies on herder households throughout the country as a source of production. Key producer challenges include low productivity, poor animal health, and the perishing of meat in the absence of a cold chain (Swiss Agency for Development and Cooperation SDC, 2015).

Figure 1 outlines the meat freight flows (the line thickness indicates flow density). The flows indicate that meat is sourced from many locations, and then transported to the capital city Ulaanbaatar through a very inefficient logistics system. Given the long distances and poor infrastructure, most of the meat value is lost along the chain, thus impairing its export value.
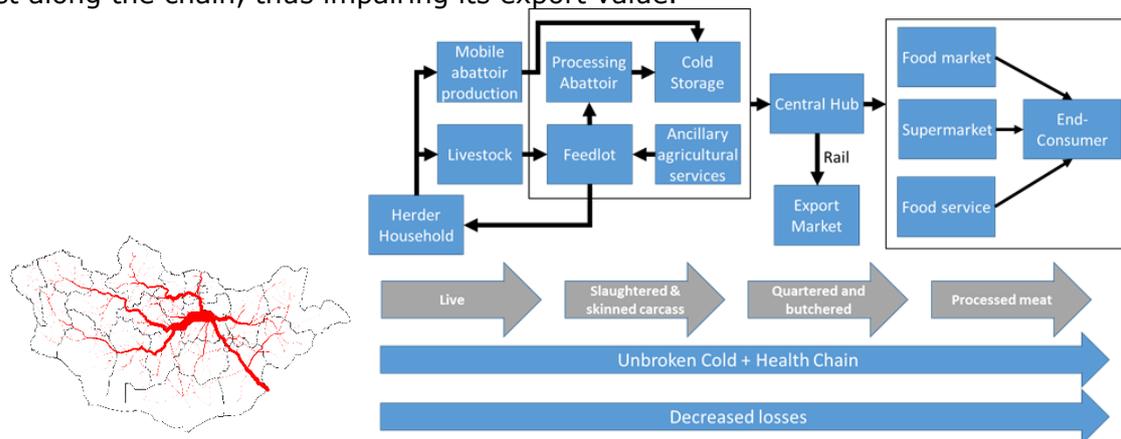
Figure 1. Flow of meat products in Mongolia (left) and proposed structure (right)

Relative performance
The supply chains of successful meat exporters are structured to reduce the loss of value at each stage from farm to market. For example, the New Zealand and Australian meat sectors have a strong commercial focus and consolidate operations through commercial farming, feedlots, and sale yards. The latter serves as a market mechanism for optimal livestock distribution. The sale yards supply abattoirs with livestock that will yield meat of both domestic and export quality (Australian Beef Sustainability Framework, 2020).

However, a commercial approach may not be transferrable to sectors that are driven by rural household producers, where cultural and religious considerations, as well as tradition, often dictate the production potential of the sector. In Mongolia, the social structure of herder households and their reliance on their

livestock play a significant role in productivity and realization of export potential (Meurs, Amartuvshin & Banzragch, 2017).

From a spatial perspective, Mongolia's current challenges are not insurmountable. Other spatially challenged environments have developed working solutions. For example, Namibia has structured its commercial livestock sector around auctions and transporters, which serve as a market mechanism to distribute livestock within the supply chain. This has enabled the country to earn, in addition to its branded FAN organic meat, more than three times more than Mongolia from meat export with nine times less livestock. However, Namibia facilitated the competitiveness of its commercial livestock sector by enabling the factors of production through financial support for livestock purchases, infrastructure development, access to a subsidized marketing system, and provision of expert technical advice (Legal Assistance Centre, 2005).

A revised value chain structure
Key points of concern in the current value chain are a lack of control over its supply, as well as losses throughout the supply chain due to poor animal health and carcass spoiling. The proposed meat supply chain in Figure 1 for Mongolia aims to position the sector for high productivity. It comprises consolidation of animal health and processing services and integrates herder households as its cornerstone based on additionality. This approach is deemed to be minimally disruptive to the status quo.

The proposed supply chain includes mobile abattoirs to reach multiple households and reduces transport by consolidating rural carcass supply. Feedlots are proposed to increase the reliability of livestock supply, mitigate harsh winter conditions, and hence improve the quality of herder households' livestock. Agro-processing freight villages (hubs) will provide veterinary and agricultural support services and will facilitate cold chain maintenance by providing cold storage. Slaughtered carcasses are transported to, and processed at, larger centralized freight villages for export and urban markets.

These additions to infrastructure enable the utilization of animals that would have been unsuitable for inclusion in the value chain. By developing appropriate infrastructure for the meat supply chain, Mongolia can unlock around US$800 million from meat export (World Bank, 2020).

Infrastructure investment for improved performance
Following the structural reconfiguration of the value chain as proposed in the previous section, spatial reconfiguration is considered. This is approached here by analyzing the flow of freight between key points of supply and demand. The freight flow model indicates that the *aimags* (provinces) Uvs, Khövsgöl, Bulgan, Arkhangai, Övörkhangai, Töv, Khentii, and Sükhbaatar are ideal locations for freight villages (hubs) to consolidate the meat market (see Figure 2). These are well aligned with the meat flows, as illustrated in Figure 1. Each *aimag* hub is supplied by the nearest surrounding *soums* (districts) through mobile abattoirs. Three meat transportation scenarios were evaluated. In the first scenario, meat is processed at the hubs for direct export to China. For the other two scenarios, the carcasses are consolidated for optimal transportation to the major hub in Bagakhangai for final processing. The processed meat can then be consolidated in refrigerated containers for export via rail or road. In the second scenario, the meat is exported by rail and in the third scenario by road. Bagakhangai is located approximately 90 kilometres southeast of Ulaanbaatar in the Töv *aimag* and could conceivably become a 'sustainable' city with a highly advanced service and ICT sector.
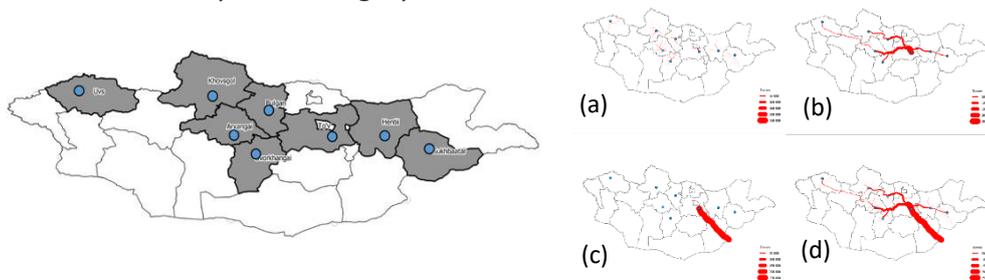
Figure 2. Location of the identified agro-processing freight villages (left) and (right) Typologies of additional meat-processing flows. (a) flows from soums to aimag hubs, (b) flows from aimag hubs to Bagakhangai, (c) export flows from Bagakhangai to China, (d) combined flows of (a), (b), and (c) (Created by the authors)

The consolidated meat flows are visualized in Figure 2. The cost calculations for the three transportation scenarios are summarized in Table 1. The *unconsolidated* scenario requires upgrading and adequate maintenance of 3999 kilometres of roads between the eight hubs and the border, with an estimated transportation cost of US$32.0 million. If meat is exported from the major hub at Bagakhangai by rail, the estimated transportation cost is US$27.2 million, and 2954 kilometres of road need to be maintained adequately between the hubs and Bagakhangai. The consolidation at Bagakhangai with road-based export to China requires 3528 kilometres of good quality roads, with an estimated transportation cost of US$33.3 million.

Three transportation scenarios	Ton-kms million	US$ million	Kilometres of roads utilized
Soums to *aimag* hubs to China (direct)	321.8	20.9	3999
Soums to *aimag* hubs to Bagakhangai to China (rail)	343.6	16.1	2954
Soums to *aimag* hubs to Bagakhangai to China (road)	353.1	22.2	3528

Table 1. Estimated transportation cost for three transport scenarios (Created by the authors)

The consolidation scenario at Bagakhangai with rail-based export results in the lowest transportation cost as well as the shortest distance of roads to be maintained in good condition – approximately 1000 kilometres less than the *unconsolidated* scenario.

It is estimated that these supply chains require 2,954 km of well-maintained roads as well as rail capacity on the North-South corridor from Bagakhangai to China to operate efficiently. Of the 2,954 km of roads required between hubs, 2,668 km is asphalt concrete. Of the asphalt roads, 105 kilometres are in very good condition, 1,327 km are in a good condition, 1,084 km are in fair condition, and 152 km are in a poor condition. The remaining required road consists of 104 kilometres of cement concrete, 13 km of gravel, 12 km of graded earth, 128 km of ungraded earth road, and 24 kilometres of road that passes Ulaanbaatar to the south. The hubs could be connected to Bagakhangai as shown in Figure 3.
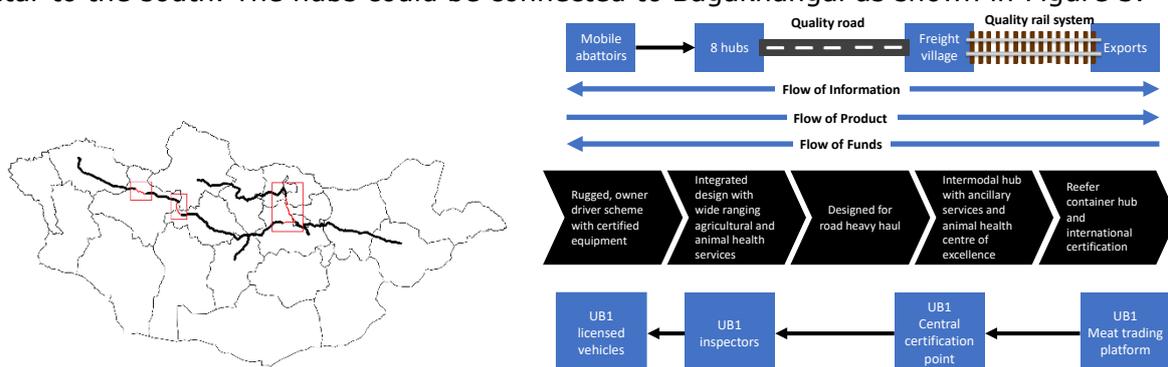
Figure 5. Required road infrastructure to facilitate meat value chain (Left) and Supply chain design to facilitate the additionality meat scenario (Right)

The integrated supply chain is outlined in Figure 3. It indicates the physical infrastructure requirements, their specifications, and the soft infrastructure. It is proposed that a globally recognized certification system (for example, branded as "UB1 meat") be adopted to facilitate export market access beyond China and to legitimize the trade through ethical and welfare standards as well as sustainable practices, which protects both the herder households and the animals. The branded meat can be marketed as disease-free, organic, and free-range, in addition to conforming to UB1 standards and practices.

CONCLUSION

The export potential of Mongolia's meat industry is limited by smallholder production practices and approaches, spatial challenges, and a value chain configuration that is not supportive of an export orientation. The reconfiguration of the value chain, and assessment of infrastructure with consideration of freight flows, provide evidence-based support for infrastructure investment that could unlock significant value from Mongolia's meat production sector. It does so with due consideration of local practices while enhancing practice for export gain. Targeted investment in the improvement of specific roads, border posts, and railway lines to enable economic growth by lowering logistics costs and enabling value chain optimization could have a positive disruptive effect in this industry.

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Challenges of fast delivery of locally grown food to the customer's door

Branka Leskovšek[1], Alen Kahvedžić[1], Kristijan Perčič[1], <u>Andrej Lisec[2]</u>
1: Post of Slovenia, R&D department; 2: University of Maribor, Faculty of Logistics, Slovenia
branka.leskovsek@posta.si

Abstract Local food system has been subject to rapid and deep changes in recent decades. Short supply chains are the new reality of this area. It is common knowledge that local supply chains are often very environmentally friendly. But there is also a lack of proper infrastructure to be considered, which makes it inefficient. This paper explores local supply chains, where food typically travels from local farms to the final customer in suburban and urban areas. The industrialized model of food provisioning clearly no longer meets all the wishes and needs of end customers. Their behaviour did change drastically, due to the evolution of society and economic systems. Food processing and distribution need to provide a growing number of functions and operations to meet customers' new needs. The high number of steps, and the increasing distance between production and consumption, are at the basis of the "revolution" brought by Short Food Supply-Chains initiatives (SFSCs), especially in Europe and in the United States, although a number of interesting opportunities is also pointed out for other countries, included developing ones (Moustier & Renting, 2015).

Keywords: 1. Local foods, 2. Distribution strategies, 3. Supply chain, 4. Best practices, 5. Aggregation.

1. Introduction

Food supply chains have been strengthened and are moving towards sustainability and transparency. Customers are demanding more information – where did the food come from, who and how did transport the food, how long did the whole transport from the farm to their door take, what is the carbon footprint of their food? The term "short food supply chains" (SFCSs) covers different typologies and models of operation. Farmers might sell their food in farmers 'markets, in their own shops, in food festivals or fairs, through farm-base delivery schemes, through cooperative shops, or supermarkets, they might sell their products directly to public institutions' collective catering, to restaurants, hotels and private catering companies. Overall, the goal is to reduce the distance between agriculture and the final consumption, which directly reconnects farmers with consumers. SFCSs is basically presenting the crossroads of economic, environmental and social issues and end-users' needs. Local food supply chains are the important shift towards sustainability since they are notably helping to reduce emissions by eliminating long distance transport and minimizing "food miles" (Nestle, 2002). Shortening of the distance can be interpreted from different points of view. One is the reduction of the physical distance between the production in the farm and final user. The second one is the reduction of the number of steps from farmer to final user. Finally, the increase of cultural and social proximity between farmers and final customers is crucial.

SFSCs are often labelled as "alternative" supply chains (Goodman, DuPuis, & Goodman, 2011). SFSC can be understood as just another opportunity to differentiate ways of marketing agriculture food products, so they are placed alongside conventional forms of distribution. All the above, without a doubt about the basic principles of industrialized agriculture food system. Furthermore, SFSCs are designed as carriers of an alternative message, so they are radically opposed not only to conventional forms of distribution, but also to the same industrialized model, as they want to radically change the rules of the game. It is important to understand whether the final user is driven by "economic" principles, or his purchasing act responds to ethical and social principles of "transformative" content (Belletti & Marescotti, 2020).

The concept of local food is perceived as one of the pillars of SFSCs initiatives. Consumers demand higher intrinsic quality and the potential to benefit the local community and foster rural development, environmental preservation, agrobiodiversity, and social justice. Local food is a product that has been produced close to the consumption area or close to the place of purchase. The widespread importance of local food presupposes a different interpretation of the locality, looking at the connection between the product and the place of its production in terms of the specifics of local resources used in the production process, product history and production and consumption traditions, and its collective dimension.

In the last decades there has been a huge increase of marketplace and logistics platforms that enable direct connection between farms and end users. Interest in home-grown products is growing as all consumers become increasingly aware of the importance of seasonal food, which is often tastier than that brought overseas and found on the shelves of major stores. By supporting the locals, we also avoid more intermediaries and thus growers get more money, which they can also use directly to produce new food. However, if we support the local farmer, we will enable a greater flow of money and more work and profit for the farmer and consequently the local community. This also creates more jobs and more employees, thus contributing to the better development of the place.

Based on many SFCSs case studies around the globe it can be said that the lack of logistics infrastructure represents a constant. Countries have begun to consider local needs in local food allocation and decision-making processes. Also, the case of COVID-19 has made a significant contribution to recognizing the need for change in local supply chains model. Due to health and safety restrictions, it has become harder to source food globally. The World Economic Forum advised consumers for the "post-COVID need" to support "local food systems with shorter fairer and cleaner supply chains that address local priorities" (Ewing-Chow, 2020).

Logistics are essential to these supply chains and directly affect supply chain performance (Rantasilia & Ojala, 2012). The use of food hubs as intermodal distribution centers has become increasingly popular. Food hubs are one of many strategies identified for scaling up local and regional systems. Their added value lies in the fact that they act as coordinating intermediaries, combining the sorting, distribution, and transformation of food products in short food supply chains. As defined by United States Department Agriculture, a food hub is "a business or organization that actively manages the aggregation, distribution and marketing of source-identified food products, primarily from local and regional producers to strengthen their ability to satisfy wholesale, retail and institutional demand" (Barham, et al., 2012). Efficiency in logistics is the ability to reduce distribution costs without generating correspondingly higher costs for farmers and consumers, thereby increasing the benefits for actors operating at both ends of the supply chain. Logistics encompasses many activities, from order processing to warehousing, from warehousing to transport and packaging. In long food chains, activities are carried out by several specialized companies operating along the supply chain, while in short one's intermediate actors are eliminated or greatly reduced. The transition from long and standard production-distribution-consumption systems to SFSC requires both the removal and redeployment of functions performed by actors excluded from the supply chain, which must be at least partially taken over by actors at the ends of the same chain, farmers and consumers.

In certain cases, the distances between farms and urban centers, as final consumers' points, are so small that the establishment of hubs does not seem to make economic sense. In these cases, the establishment of digital logistics and technology infrastructure support involving locally produced food providers and a well-organized logistics network is crucial. Digital logistics and technology infrastructure can offer competitive advantages if the system supports a supply chain strategy that meets product demand. The SFSC, which enables digital technologies, will be short, flexible, traceable and able to manage interference. Efficiency can be improved and resilience further increased.

Products and especially food brought from afar are mostly brought by planes or larger ships, which are certainly not environmentally friendly, as such means of transport have a huge emission of greenhouse gases. Food produced in our place and its surroundings significantly reduces the emission of these gases.

The paper is structured as follows: Section 2 explains the varieties of food supply chains. Section 3 presents the experience gained so far with pilots in the field of locally produced food delivery and the experience gained from the findings of two postal operators in Europe. It also introduces the methodology for the next pilot project which is currently under preparation. Section 4 presents conclusions of the study and presents areas for future research.

2 The variety of short food supply chains

There is no shared and unique definition of SFSC within the scientific community (Kulak, Graves, & Chatterton, 2013). The most frequently cited feature of SFSC is proximity between producers and consumers, where the distance is a function of the morphological and demographic characteristics of a territory. The SFSC is based on direct contact between farmers and consumers and their relationships based on trust and honesty. SFSC clearly focuses on a social and ethical matter, but it also encompasses environmental objectives. The short food supply chain wants to impact on each of the four dimensions of sustainability – good governance, environmental integrity, economic resilience and social well-being.

2.1 On-farm selling

The most traditional form of selling local food is selling on the farm itself or on roadside stalls. In this case consumers are devoting their time and resources to get to the farm location. Some slight variations in selling are possible, namely – customers may buy seasonal products, special products or they may even collect their product themselves directly on the field. This typology of on-farm selling is known as pick-your own (PYO). It is usually a common practice for farms growing berries, vegetables, and fruits. An increase in "rural recreation" as people drove to the countryside from the cities for leisure, also influenced the popularity of PYO marketing (Leffew & Ernst, 2014).

Figure 1: Tomato plantation on the organic farm Kabolca in Primorska (Slovenia), PYO marketing
Source: https://kabolca.weebly.com/aktualnodnevnik.html

2.2   Selling on farmers' markets

Farmer's markets are generally considered to be markets in certain locations, where larger groups of people usually gather, where farmers sell their agricultural products directly. The sale takes place under a common organization and under the same image and/or certain common rules. The most of these markets are held
once or twice a week or also once a month. Markets can be promoted by producers' organizations, public institutions that aim at enhancing local production and local gastronomic traditions and culture. The organization of a farmers' market implies several resources and costs. The use of public spaces often requires paying a fee to the local municipality. There are also costs for energy and cleaning.

Figure 2: Local food market in Ljubljana
Source: http://dominstil.si/ljubljanska-trznica-v-mrazu/

2.3 Selling in farmers' shops, box schemes

Farmers might also open shops outside the farm, which are retail outlets, managed by one or more associated farms. They might also engage in so-called box-scheme operations. The latter entails subscription by customers to the regular (weekly, biweekly, monthly) delivery of specific fresh products. Delivery occurs either at the farm of to the collection point or even at the doorstep. Food delivered through box schemes is usually seasonal, locally grown and sustainably produced.

2.4   Consumer-driven initiatives

We basically distinguish so called Solidarity Purchasing Groups and consumers' managed shops (SGP) and Community Supported Agriculture (CSA). SGP in an informal group, including 30 to 80 households. Main motivations to engage with an SGP include the need to engage with responsible consumption practices. Producers are usually selected by the members according to shared principles such as the farm's size, distance of the farm, direct relationship and knowledge (reputation), the farmers' attitude to transparency and knowledge sharing, environmental performance, social and ethics principles, price and affordability of the products. In most cases, an SGP has an autonomous, flexible and informal management of activity.

Community Supported Agriculture (CSA) is a direct partnership based on the human relationship between customers and producers. Members anticipate the costs for cultivation operations. They get a sense of satisfaction for taking part in the agricultural work and a part of the farm produce in return when the season comes. Farmers are able to save some money since they are selling directly to members-customers, which means they do not need to spend money on marketing activities.

2.5   Public procurement

This variety of local food supply chain mainly refers to purchase agricultural and food products by schools, hospitals, and in general collective residences. Food public procurement represents an opportunity to ensure high quality services and protect the public interest both in terms of food quality and the positive externalities for the environment and the local economy. Public authorities may use different approaches to provide opportunities to introduce local or regional food into their food procurement, depending on structural specificities related to national legislation, the maturity of specific initiatives such as green and sustainable public procurement, and general governance and organization of public canteens. Public food procurement can provide small farmers with an accessible market channel by reducing the risks and uncertainties associated with market participation.

2.6   Hotels, Resturants, Catering (HoReca)

Local retailers, restaurants, hotels, markets, street food vendors may source directly from local farmers. In this way they get fresh products, they reduce transport costs, they have day-by-day delivery and consequently they have less need for storage. Restaurants may promote local food to attract customers, emphasizing both the local provenience and typicalness of food prepared. Together with local recipes and tools (Belletti & Marescotti, 2020).
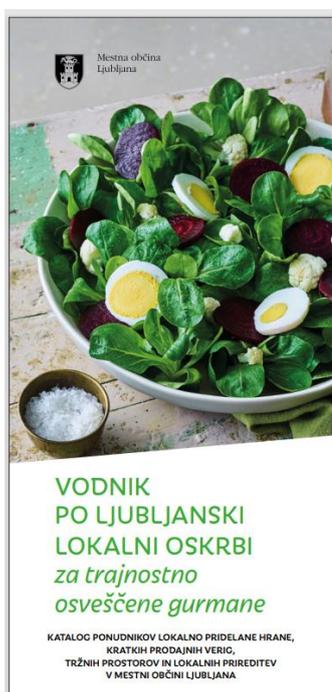
Figure 3: Cover of the publication Vodnik po ljubljanski lokalni oskrbi za trajnostno osveščene gurmane
Source: https://www.ljubljana.si/assets/Vodnik-po-ljubljanski-lokalni-oskrbi.pdf

3. Solving the problem taking into account the needs of the Slovenian market

Already in 2014, Pošta Slovenije decided to execute a pilot project, where it delivered food for the needs of a major Slovenian retailer. For this purpose, the approach of establishing a separate logistics and delivery network, independent of the existing delivery network, was used. Food delivery was carried out all working days of the week in the area of Maribor (radius 30 km), with one or at most two refrigerated vehicles. We delivered in five time slots of the day, chosen by the client, namely:

- 9 am to 11 am
- 11am to 1pm
- from 1 pm to 3 pm and
- from 3 pm to 5 pm).

It never took more than two hours from the time the package was picked up to delivery to the final customer. We performed the test for a period of 6 months. We received initiatives for a similar test from additional three major retailers on the Slovenian market. The agreement was not reached due to a gap in expectations in the price of delivery and the provision of a fleet of refrigerated vehicles. Pošta Slovenije has already established the distribution of food that does not require a refrigerated regime (wine, honey, pasta and similar products) and is sent via the existing delivery network, in classic packaging and on pallets.

We came to additional useful conclusions by analyzing similar cases of pilots carried out by the Croatian and Austrian Post. Both mentioned post offices have already introduced the delivery of locally produced food into their regular delivery process on the basis of successfully implemented pilots. The delivery process at both post offices is carried out in the existing parcel network. The special feature of the delivery of local food in the Croatian Post is that they deliver only products that do not require a cold regime, which significantly impoverishes the offer (https://www.zutiklik.hr/klikni-na-domace).

A special feature of the Austrian Post is that they have developed dedicated insulation boxes (Post-Isolierbox) for food distribution, which are capable of providing a temperature regime of 2 - 8 degrees Celsius for a period of 48 hours.
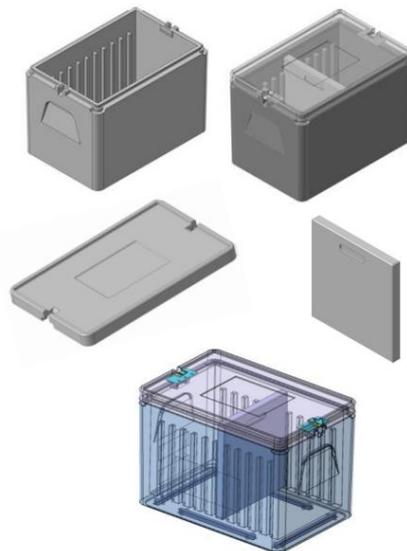
Figure 4: Specially designed food box for fresh food orders by Austrian Post

Source: https://www.post.at/en/g/c/food-delivery

Based on all the experience gained so far, the analysis of the needs of providers and potential customers, the decision was made to ensure the delivery of locally produced food within the existing parcel network of Pošta Slovenije, where food that requires a cold regime (2-8 degrees Celsius) will be delivered in appropriate insulating boxes. As a company with a good name, we want to avoid potential risks. For this reason, we have identified several challenges that will be examined in several steps. We will highlight two key challenges:

- durability of boxes in distribution in the existing parcel network (devices for directing shipments can damage the boxes, negligent handling of parcels and damage to the packaging or contents of packages),
- achieving temperature regimes in the existing parcel network of Pošta Slovenije.

For this purpose, we will use sensors developed by company Agitron - SmartLogistics, which manufactures sensory elements and an IT system for monitoring data with which we will thoroughly test the mentioned challenges. Based on the measurements, we will be able to properly adjust the logistics chain for the delivery of food and other sensitive products.

Figure 5: Agitron Smart Sensors Label
Source: https://www.agitron.io/products/sensor

All parcel distributors are aware that the cost of damaged shipments is not just about product replacement, claims and customer dissatisfaction. There are a number of other costs, such as:

- the work of support services,
- lost revenue,
- disruptions and delays,
- administrative costs,
- lost trust and devotion,
- lost reputation and good name.

We want to avoid all of the above right from the start.

In the case of successful implementation of logistical support for locally produced food, we have already prepared further steps, namely the establishment of a hub and connection of all stakeholders in the digital application, which is also already in the development phase. We strongly agree with the theory that food hubs play an important role in scaling up local and regional food system.

4. Conclusion

Even though SFSCs have grown over recent years, their logistics is still a challenging issue affecting their performance. Most previous research work from this field has been concentrating primarily on the different forms of supply chain and the benefits and limitations associated with SFSC. Logistics is one of the main weak points for the development and the effectiveness of SFSC. An efficient management of logistics operations is crucial for the achievement of traceability in the food supply chain (Ringsberg, 2014). The short distance between farmers and consumers is linked to a reduction in food miles and, consequently, a decrease in Greenhouse Gas, CO2 emissions and noise.

Short food supply chains have proven to be a new model of organization in agriculture that seeks to combine economic principles with social and environmental issues. Lack of farmers at the local level, low quality, poor product availability and low diversification of product offerings, insufficient knowledge and experience, poor collective organization, poor equipment and logistics infrastructure are just some of the obstacles that can hinder the perception of opportunities offered by SFSC. Both human competences and physical infrastructure are crucial to launch SFSC initiatives. Logistic issues are very important and sensitive to the economic sustainability and efficiency of the system. Information should circulate both within producer-consumer networks and in the wider public-private network. Governmental and non-governmental organizations can support producers in designing effective SFSC initiatives, help them overcome problems, and achieve a number of public goals.

However, we must not forget the important role of the logistics service provider. As a leading provider of parcel services in the country, we basically access almost every address in the country every working day. Providers could not want a better logistics network. We have the largest vehicle fleet in the country. It is also not insignificant to mention that we have a very ambitious fleet electrification strategy in place, which is also based on the requirements of The European Green Deal (EC, 2019). With the activities so far, we have already proven that for the needs of delivery of locally produced food with existing vehicles and in the existing network, individual adjustments will certainly be needed. In any case, we are convinced that these adjustments will be economically significantly more acceptable than the introduction of completely new players who would only deliver food. However, it is necessary to maintain the awareness that the society is already trying to achieve a reduction in the number of delivery vehicles, a reduction in the number of kilometers traveled, less pollution, less noise. At the same time, the expectations of end customers are increasing, especially in terms of time-efficient delivery. We believe that, as a leading national provider of parcel services, we have excellent preconditions for being the optimal provider of locally grown food delivery.

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AN AGGREGATOR BUSINESS MODEL FOR ENTERPRISE AND SUPPLIER DEVELOPMENT: AN EMERGING ECONOMY PERSPECTIVE

Nandi Rankeng, Rose Luke
University of Johannesburg, South Africa

BACKGROUND

SMMEs play a crucial role in the stimulation of economic activity, job creation and advancement of broad-based economic empowerment (B-BBEE) (Bureau for Economic Research (BER), 2016). Since South Africa's democratic transition, the promotion of SMMEs has been a continuous policy objective, as one of the country's strategies to address unemployment (Stern, 2018). Targeted efforts in the growth of this sector will enable and accelerate inclusive growth and job creation across the entire economic market (Dhanah, 2016). These efforts include Enterprise and Supplier Development (ESD), supported by relevant enablement programs such as business incubation (BI), whose results are intended to stimulate SMMEs' economic activity (Black Umbrella, 2017).

In South Africa, ESD refers to a set of affirmative action plans for big corporations that combine preferential procurement, supplier diversity, supplier development and enterprise development (New Generation Mindset, 2018). Introduced in 2013 as part of the B-BBEE Codes of Good Practice policy (Department of Trade and Industry, 2015), large corporations' compliance with the policy is measured and scored in an attempt to encourage corporate responsibility to the social needs of the country (Black Umbrella, 2017). Big corporations are encouraged to buy goods and services from SMME suppliers with a strong B-BBEE recognition level.

However, executing an effective and impactful ESD program that will ensure the survival and success of SMMEs is a complex task that requires (1) considered long term planning, (2) access and allocation of resources, (3) willingness from all involved stakeholders, (4) a supportive ecosystem and, most importantly, (5) the development of a mutually beneficial business relationship between the big corporation and the SMME (SME South Africa, 2019). An effective ESD program will address the development of SMMEs based on a careful assessment of where that business resides in the supply and demand equation (Letsema, 2019). That is, the corporation should consider developing enterprises whose business functions are closely aligned to their business model and demand, and SMMEs should align with corporations whose business needs are aligned to their supply (Thulo, 2016). Supply is firstly focused on the creation and implementation of strategically-driven enablement interventions such as BI, that have been developed for the SMME with target businesses in mind – this enables the SMME to position itself as a solution to the targeted business and create an incentive for collaboration (Letsema, 2019). Secondly, is to use research and analysis in identifying the entrepreneurial talent needed to guide and nurture SMMEs towards opportunities of increased revenue without a substantial increase in resources (Letsema, 2019). In comparison, demand creates opportunities for the SMMEs to enter existing markets or identifies and responds to entrepreneurial opportunities presented in emerging markets (Letsema, 2019). However, creating these linkages is a complex process; careful management is required for SMMEs to become operationally and financially sustainable participants in the economy (Masutha & Rogerson, 2014). To promote ESD efforts and circumvent the challenges experienced by SMMEs, South Africa has adopted BI as a value adding intermediary (Kohlborn & Korthaus, 2009).

The Department of Trade and Industry (DTI) (2014) defines business incubation as a physical and/or virtual facility that supports the development of early stage SMMEs through a combination of business development services, funding, and access to the physical space necessary to conduct business. BI's offer dedicated business and technical support services to accelerate the growth of emerging enterprises in South Africa (Masutha & Rogerson, 2014), with a focus on establishing and/or growing enterprises that will graduate to sustainable enterprises (DTI, 2014). Across a range of developed and developing countries, business incubators have been identified as potential strategic tools for helping to grow the country's entrepreneurial base while reducing the SMME failure rate (InfoDev, 2010).

Business support services, as provided by the BI, provide access to markets for the SMME (Hattingh et al., 2018). Unlocking such market access opportunities requires a real meeting of minds and collaboration between key functions such as procurement, finance, marketing and corporate affairs within a big corporate and a broad range of external stakeholders within the value network (Morifi, 2019). Various vehicles exist that provide for the unlocking of market access opportunities; the aggregator business model being one that provides for scalable SMME growth through market access (Hattingh, et al., 2018). This model refers to a business ecosystem where one organisation, usually bigger and better resourced, assembles multiple goods or service providers in an industry – partnering with them to sell their goods or services under their organisational brand (Feed Dough, 2018). The service providers never become employees of the aggregator, they maintain ownership of the goods or services provided but, since the aggregator is a brand, all the services and goods are sold at uniform prices with uniform quality (Feed Dough, 2018). This business relationship is governed by legal contractual agreements, where the partnership approach to service delivery could drive future success of SMMEs (Fersht, et al., 2018).

Despite having enterprise supplier development programmes (ESDs) and business incubators, whose agenda is to support small businesses, South Africa has one of the highest SMME failure rates in comparison to other developing economies (Leboea, 2017). The current SMME support structures in the market are inadequate to support business start-ups and ensure sustainable growth, leading to a SMME failure rate of over 70% within the first two years of operation (Business Tech, 2018). The primary objective of this study was to consider the possibility of developing an aggregator business model in business incubation in the promotion of ESD efforts, SMME participation and development. The introduction of the aggregator business model in building these impactful incubators presents the opportunity to (1) improve SMME competitiveness and their ability to participate in certain markets, (2) nurture entrepreneurial talent through activities such as mentoring, (3) establish a supportive partnership ecosystem around the entrepreneurs to enable success and, (4) align and re-design business structures, if necessary, so they are commercially viable and present long-term strategic value-add to the market (Ray, 2017).

The transportation industry, being a key participant in the business services sector, contributes approximately 6% to the country's gross domestic product (GDP). For an industry that has a direct influence on the cost-effectiveness of business operations and potential contribution to GDP, there is an opportunity to increase SMME participation (Business Community, 2017). There is however little research into how the South African SMME haulage transportation industry can benefit from operating within an aggregator business model. Additionally, no research that addressed how such a model could relate to existing business incubation and ESD models could be found. Therefore, this research sought to investigate the operationability of an aggregator business model among transportation SMMEs in South Africa.

METHODS
The aggregator business model in business incubation has been identified as a possible solution to previously disadvantaged businesses (Feed Dough, 2018). The objective to develop an aggregator business model in business incubation in the promotion of ESD efforts, SMME participation and development required (1) analysis of the current business challenges experienced by SMMEs in the FMCG road transportation industry in South Africa, (2) identification of the critical success factors required of ESDs and business incubators in facilitating the growth and success of SMMEs in the transport sector, (3) identification of the critical success factors, potential benefits and possible challenges associated with an aggregator business model in the SMME transport sector, and (4) an understanding of the requirements for integrating current ESD/BI models with an aggregator model in the SMME transport sector in South Africa. This study employed a qualitative research design.

The relevant population chosen for this research consisted of:

- SMME business owners or senior business managers in the transportation industry catering to FMCG companies – to give insight on the live climate of the business ecosystem, detailing experiences of operations and difficulties.
- ESD and BI professionals in selected FMCG companies – to provide an understanding on the current operations undertaken by corporations in the country to assist SMMEs. Insight was provided on previous attempts and actions, and failures and learnings.
- FMCG procurement professionals - as the link between SMMEs and industry, they were able to describe the current compliance standards by which corporates are governed; actual commitment of corporations to SMMEs; limitations encountered during the implementation of the policies; and their experience of SMMEs in the industry.
- Business professionals within the aggregator business environment – to offer insight into the business, existing frameworks, key success indicators and limitations.
- Practitioners in the current BI environment – to provide opinions on the design of a model that would incorporate the functions of BIs and aggregators to determine the best combination of factors to produce better support for South African SMMEs.

Purposive sampling, combined with snowball sampling, was used to identify participants. As the hub for South African business and currently hosting the most start-up businesses in the transportation industry (BER, 2016), the Gauteng province was chosen as the focus for SMMEs for this research. The final sample consisted of two ESD specialists, two aggregator managers, four FMCG procurement professionals and two SMME representatives. Semi-structured interviews were used to collect data. Ten interviews were conducted until reasonable data saturation was achieved and all angles and factors that influenced this phenomenon and its success since the onset of the programme had been identified (Vasileiou, et al., 2018). The sample size was, therefore, determined and justified by the wealth of insight, perspective and understanding that was derived from each interview. Atlas.ti software was used to analyse the results and produce sensible findings.

RESULTS
Challenges faced by SMMEs
The interviewees highlighted a number of challenges that were faced by SMME transporters operating in the FMCG sector. Issues related to competition, market access and market structure were firstly related to market structure, where there were too many small, fragmented SMMEs, implying a low preference for using SMMEs as suppliers by FMCG organisations. Additionally, SMMEs faced high price competition from established operators and struggled to effectively compete in the market. Market access was a major issue.

Financing and capitalisation challenges were limited access to finance and therefore undercapitalisation. This implied that there were issues related to fleet size and the ability to expand. Some of the procurement specialists highlighted that it was difficult to contract with SMMEs as their operations were too localised and lacked national coverage. Economies of scale were therefore problematic.

Strategic issues that were identified related to poor infrastructure, service quality issues, the lack of appropriate skills and expertise, poor organisational structures and high levels of crime, that impacted the cost of security. The regulatory environment was also problematic with highlighted issues being punitive labour regulations, and inefficiency in government bureaucracy, particularly relating to aspects such as the issuing of permits.

It was concluded that SMMEs in the road transport industry faced four key challenges, i.e. competition, market access and market structure, financing and capitalisation, strategic challenges and regulatory environment constraints. Limited access to finance and lack of market access were the most prominent of these. The challenges also occurred despite the existence of ESDs and business incubators signalling inadequacies in these models.

Solutions to SMME challenges

When questioned on the potential solutions to resolve these challenges, aggregators, ESDs and SMMEs shared similar sentiments on the extent to which organisational and process-related challenges impeded the survival and growth of transporter SMMEs. Key areas for attention were, firstly, to encourage SMMEs by creating a culture of entrepreneurship, with focused inputs from industry leaders. Entrepreneurs should also take the initiative of seeking the right assistance. Secondly, a supportive regulatory environment was critical. There are many informal businesses in the transport sector, which is a factor that limits access to the mainstream market. Many SMMEs were not aware of the regulatory requirements, indicating a need for skills development in business compliance.

Increased financial access for SMMEs, with low or no cost financing was identified by SMMEs. Although some FMCG procurement specialists offered finance through interest free loans and advances, these were limited to SMMEs under their ESD programmes. There was an opinion that financing was the domain of the financial institutions and SMMEs should approach institutions that offer short-term unsecured loans, which could stimulate activity.

Access to markets was a key requirement, with SMMEs highlighting that limited exposure to the wider market exacerbated by low experience made SMME growth difficult. Along with this was the need for business and operational support, which should include "workflow process efficiency and effectiveness" and "general business development and support (for pre- and post- intervention)". SMMEs also mentioned that access to information was a critical component of the broader need for operational support.

Aggregator, Business Incubator and ESD Models for SMME Support
The interviewees individually provided perspectives on the scope of three models in terms of how they worked to reduce the challenges and constraints faced by SMMEs. The respondents expressed their views on the **scope of the aggregator model** including its benefits to SMME transporters. The aggregation model was centred around an information technology platform that was accessible to all member SMMEs. Using this platform, they will be visible to all clients who will be able to order their services directly. The model used a single pricing structure, and this therefore eliminated the price competition that was mentioned as being problematic to small transporters. It is also possible that operating as a single large entity, SMMEs can bargain more powerfully for competitive rates from FMCGs than when operating as individual entities. The front-end of the platform provided market access to SMMEs who, in addition, were able to consolidate small loads from several clients. The back-end functions supported small businesses with operational and administrative services, including financial management and human resources management. Thus, it eliminated the problems that SMMEs faced in establishing efficient organisational structures. SMME respondents highlighted that they lacked adequate knowledge on the inner workings of an aggregator model but knew that it "operated like the Uber platform".

Key features that were highlighted were:
- Technology platform integrating various, independent businesses
- Secondary operational support like administration, financial management, operations, human resources
- A globally popular model that was still new to South Africa
- Was different from brokerage as the aggregator did not broker deals for SMMEs. Was also different from subcontracting

Generally, the interviewees, including those from SMMEs, saw an aggregator model as a positive development that resonated with current trends.

The respondents provided inputs on the **ESD model**. An ESD consisted of three broad programmes, the first of which is the market access facilitation programmes which included, amongst others, identification of supplier opportunities within the ESD as well as outside its confines, including in international markets. The second was business development support, which involved capacity building through coaching and mentoring; providing access to human resources, legal, finance, administration and other necessary

support services. The last was facilitating access to funding by teaching entrepreneurs how to apply for funding through networking with financial institutions. In some cases, ESD also provided funding to participant SMMEs, although the "focus is on transformation and not the SMME", which could affect the success of the SMME, as the focus was on meeting B-BBEE regulatory requirements rather than providing concrete solutions to the operational challenges faced by SMMEs. Despite this, the ESDs believed that they offered better chances of success than BIs because they linked SMMEs to their supply and value chains. The SMMEs understood an ESD to be a "contract dependent private sector programme" in which suppliers are preferentially selected to serve a single client. They also stated that, like the aggregator model, most SMMEs did not have full knowledge of the details of how ESDs benefitted SMMEs and were therefore, unable to utilise them.

The key features and characteristics of an ESD model were summarised as:
- Facilitates market access
- Business development support
- Facilitates access to funding
- Focused on transformation

Overall, the groups shared the common view that ESDs existed to support smaller contractors to participate in wider supply chains of established businesses.

Respondents indicated that they did not see many differences between the ESD and the **Business Incubator (BI)** models, but did express the view that an ESD was a form of an incubator that was run by an independent, usually large, corporation. It did not specialise in business development but supported a selected number of SMMEs for development by way of incorporating them in its supply chain and systems. A BI, on the other hand, was an institution that specialised in offering business development support to starting enterprises. One ESD interviewee asserted that collaboration was necessary, stating that "To enhance chances of incubation success, corporates need to collaborate with incubation institutions prior to onboarding of incubates". Some interviewees were of the opinion that BIs provided basic business knowledge to SMMEs, were centres of knowledge and therefore had better understanding of the business environment. The SMMEs did not see much distinction between ESDs and BIs and were sceptical about their effectiveness, as they were seen as theoretical rather than practical solutions.

Highlighted features were:
- Business skills and knowledge development through training
- Networking with business stakeholders including clients
- Facilitating access to funding
- Independent from corporates though they may be supported by them

The critical success factors of ESDs/BIs were thus the ability to avail business opportunities through enhanced access to the competitive markets and the ability to financially support SMMEs. They therefore needed to have wide networks of clients and financiers that made it possible for them to extend the required assistance to transportation SMMEs. ESDs were also expected to have the ability to capacitate SMMEs with adequate skills and knowledge to effectively compete in the transportation industry. They, therefore, needed to have highly experienced, committed and knowledgeable human resources to develop the SMMEs. ESDs/BIs were therefore expected to have the ability to resolve the main operational and strategic challenges that transporter SMMEs faced.

The key success factor of the aggregator model was that it needed to have business knowledge and expertise that it could transfer to transporter SMMEs. Aggregators needed to be transparent in their dealings and needed to create mutually beneficial relationships with participating SMMEs to gain their trust and interest. They also needed to have a market appeal and customer-focussed operations and strategies that facilitate market access and competitiveness among member SMMEs. Additionally, they required functional technical and operational systems that supported SMMEs' operations.

There were however a number of challenges that were identified within the models that could impede SMME success. Both ESDs and aggregators listed conflict of interest as a potential issue, where the party

in a dominant position may impose their will on the smaller SMMEs, even if this is not in the interest of these SMMEs. The business goals of the SMME are thus likely to be subservient to those of the host. There was also a requirement that business opportunities existed, with the broad observation that ESDs and aggregators were of little value without such opportunities, and if volumes reduced, SMMEs were most likely to be affected. Compliance with B-BBEE regulations post implementation tended not to be well articulated, with aggregators highlighting that they may actually fail to meet B-BBEE requirements despite its inclusion of SMMEs. Financial support could potentially be limited. Other limitations were that the models were not well known by the SMMEs and that they may suffer from low levels of buy-in from major FMCG clients. Additionally, ESDs/BIs as models were not readily available to transportation SMMEs.

From the results: the two models needed to share a vision and strategy. Thus, they needed to complement each other in developing and supporting transporter SMMEs with a specific focus on helping them to overcome their common challenges: market access, access to finance, knowledge and skills and operational and technical resources challenges. As noted, an aggregator model had certain advantages that an ESD model did not have. This included its potential for being more widely available to SMMEs as it did not rely on a single anchor. Additionally, an aggregator model provided SMMEs with a powerful brand and technical resources and systems that enabled greater market access. The ESD/ BI model had some advantages that were not readily available in the aggregator model. These were its ability to facilitate and support skills and knowledge development in SMMEs. An ESD/BI model also focuses on providing access to funding to SMME transporters, despite facing some challenges in this area. Thus, combining the unique advantages of each model can result in a single entity that could benefit SMMEs through availing more market opportunities, skills and knowledge and better chances of getting funded.

DISCUSSSION

As an exploratory study on the idea of an aggregator model for enterprise and supplier development in the transport industry in South Africa, this research has determined that for organisations intending to foster SMMEs and relationships with SMMEs, the following be considered:

- From an exploratory perspective, an aggregator model can be integrated with a BI where the BI provides the services of an aggregator. In doing so, a BI will provide the technological and technical support that includes information systems and software for the aggregator. The incubatees will become members of the aggregator under the same brand. To enhance the model, recommended support includes:
  o Financial support to start-up and expand businesses under the aggregator
  o Effective branding and marketing as well as buy-in from major industry clients
  o Management and facilitators with strong technical and strategic expertise in both aggregation and business incubation
  o Transparency of operations, costs, revenue and profit-sharing
  o Clear legal agreements assigning responsibilities, roles and duties as well as powers, limitations and rights of all parties involved (service-level agreements)
  o Independence between the integrated aggregator/incubator model and members to avoid conflict of interest
- Government and developmental financial institutions should be engaged to assist in enhancing financial support to incubatees and ESDs as a way of increasing their capitalisation and therefore ability to attain the scale necessary in serving large FMCGs.
- Business incubators and ESDs should be marketed more widely to SMMEs in the transportation industry, as there are businesses that could benefit from their services but cannot do so because they either lack access or information. The components of the proposed model are shown in Figure 1 below:
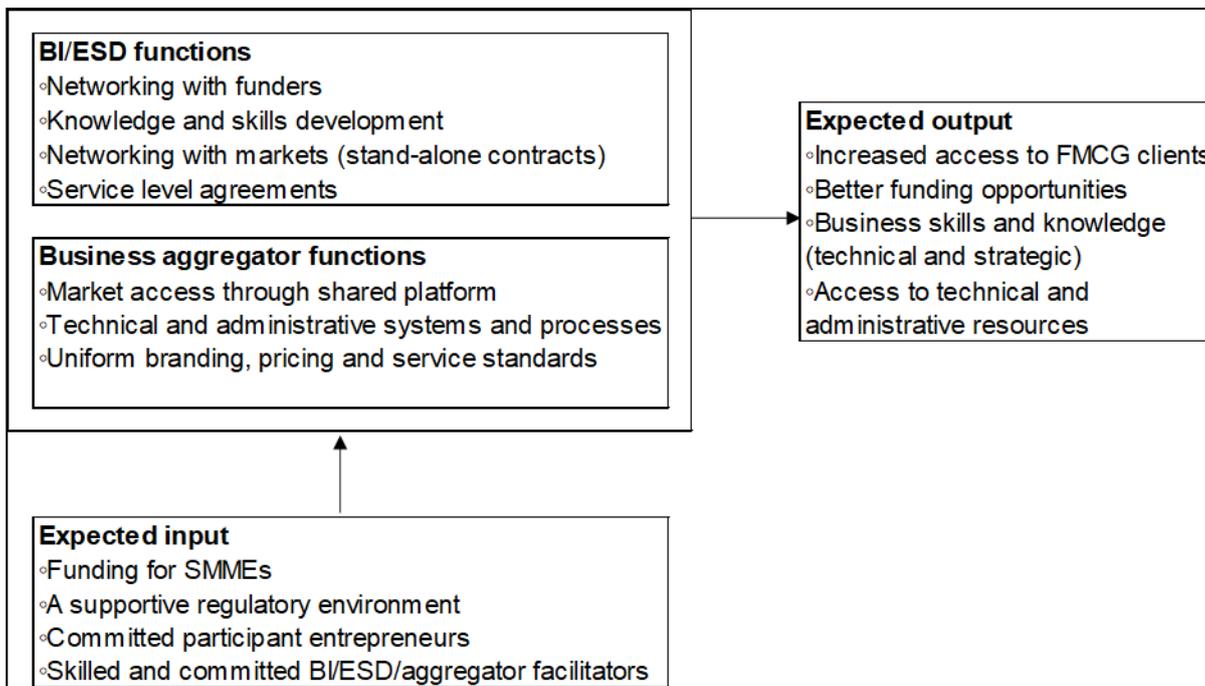
Figure 1: Proposed incubator-aggregator model

CONCLUSION

This paper aimed to explore whether an aggregator model for enterprise and supplier development in the transport industry in South Africa could work as a solution to the challenges faced by SMMEs. The existing ESD and business incubator models continued to play their part in attempting to reverse the challenges of SMMEs and to spur their growth with economic growth, job creation, transformation and innovation being among the expected outcomes. Nonetheless, the challenges that transport sector SMMEs faced persisted in the presence of current support models. It was established that an aggregator business model could be a solution to some of the SMME challenges that ESDs and BIs were not able to resolve, especially access to the mainstream transport markets and the availing of technical systems and processes. At the same time, it was noted that aggregator models mainly provided technical and operational support and market access without focusing much on skills and knowledge development, or support with access to funding. It was proposed that an integration of the BI model with an aggregator model could be the solution to the market and funding access challenges of SMMEs as well as skills and knowledge deficits and limited access to adequate administrative and technical support. The two models could be successfully integrated as they shared some common objectives. An incubator-aggregator model consisting of an intermediary who collected client data on services required and distribute potential contracts with members, who will also be under incubation, was proposed as a possible solution that could enhance the operationality and effectiveness of the current ESD and business incubator structures.

A limitation to the research was that the interview approach limited the number of participants and findings can therefore not be generalised to other contexts and environments. The study was also not able to test the applicability of the proposed model. Finally, the impact of macroeconomic factors such as economic growth and inflation on SMMEs in the transport sector and the proposed model were not considered. Therefore, it is recommended that, to further enhance the understanding of the key constructs in the proposed model, a quantitative study be conducted to test the success factors of an ESD-aggregator model using structural equation modelling to assess the network of relationships between the variables. Other suggested areas of research include studies to test the impact of external variables such as economic growth, inflation, and technological factors on the proposed incubator-aggregator model; and studies to determine the levels of funding available to transport SMMEs within business incubator and aggregator networks and the challenges in accessing such funds.

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DIGITAL SUPPLY CHAIN MANAGEMENT

OBSTACLES, INCENTIVES AND IMPACTS OF INDUSTRY 4.0 IN PHARMACEUTICAL SUPPLY CHAINS

Marianthi Omiriadou[1], Dimitra Kalaitzi[2]
1: School of Business Administration, European University Cyprus; 2: Department of Engineering Systems & Supply Chain Management College of Engineering and Physical Sciences Aston University
E-mail: mo205341@students.euc.ac.cy

INTRODUCTION

Industry 4.0's vision promises prosperous future with increased productivity. In comparison with previous industrial revolutions, the 4th Industrial Revolution offers more opportunities in industries. The fourth Industrial revolution among others is based on the cyber physical systems (CPS) and the dynamics of data processing (Resman et al., 2020). In particular, the new Industrial revolution may bring new technological applications in the pharmaceutical industries and in this way increase their productivity, improve the quality of medicines, have easy and immediate compliance with the guidelines lines of organizations that belong, but also to have rapid growth. Some of the main technologies of Industry 4.0 are robotics, 3D Printing, Artificial intelligence, Internet of Things, Cloud, and a few others is the simulation of operations, Big Data, Augmented reality and Cyber security.

The chances of human error are reduced significantly, and the production is more efficient, more productive, but also cheaper and less time-consuming compared to the Third Industrial Revolution. Specifically for the pharmaceutical companies, the adoption of new technologies based on Industry 4.0 will help pharmaceutical companies to introduce production processes more flexibly, to have fewer outages, fewer defects, and higher levels of quality assurance (Ding, 2018). For example, Big Data Analytics identifies and reduces material waste, overproduction, and energy consumption (Branke et al., 2016). According to Sony et al. (2021), the five biggest benefits for industries are: Improve customer satisfaction, reduce costs, maintain competitive advantage, improve decision-making, responsiveness and the achievement of organizational efficiency (Sony et al., 2021).

The application of technologies requires industries to be ready and flexible. Not all industries have sufficient maturity and preparedness in IT to explore the potential of Industry 4. 0 and it is not so easy to transform and adapt to production operating systems with IoT or other technological capabilities achievements. Kagermann (2013) identified the main obstacles related to the implementation of the Industry 4.0. These are linked to the need for standardisation, organisation of processes and tasks, availability of technology, the need to develop new business models, problems that related to the protection of know-how (e. g. cybersecurity) and the lack of skilled staff who would need training and ongoing professional development.

For pharmaceutical companies, at every step along the way to the creation of factories with Industry 4.0 technologies, the production environment should be transformed to a more autonomous production system with improved process controls and controlled quality management. These changes should reduce the variability in batches and produce consistently available products. Another main reason for the delay in the adoption of new technologies is related to the vast institutional and regulatory lack of knowledge (Arden et al., 2021). Shortage of labour potential with knowledge of advanced technological systems, lack of online coverage in industries and lack of experience to control non-compliances are some of the obstacles that pharmaceutical companies may face. McKinsey (2016) conducted a survey, and they identified the top 5 barriers which are: (1) Difficulty in coordination of actions, (2) Lack of courage, (3) Lack of necessary knowledge, (4) Concerns for cybersecurity; and (5) Lack of a clear business strategy.

This study will focus on pharmaceutical companies operate in Greece where most use various technologies developed in the Third Industrial Revolution, as the pharmaceutical sector evolves slower than others. The lack of resources money, people etc. for the implementation of these technologies is the main obstacle. However, there are more and more arising obstacles that will delay or even prevent industries from joining the new industrial revolution. Until now there are no study that tried to explore the benefits and especially the obstacles and challenges posed by the new Industrial revolution in the pharmaceutical Industry and particularly in Greece. There is a lot of research conducted in the following industries: textiles, automotive and few from pharmaceutical. Specifically, Nimawat et al. (2021) try to

prioritize the obstacles of the implementation of Industry 4.0, but only refer to India and not particularly for pharmaceutical companies. Arden et al. (2021) refer to pharmaceutical companies and make some really significant results, but they did not refer to pharmaceutical sector in Greece. Yiannakis et al. (2021) refer to Greece and focus on the pharmaceutical Industry, but they refer to the workspace and the changes of the work life due to Industry 4.0. Thus, the aim of this study is to explore the obstacles, incentives and impacts of Industry 4.0 in pharmaceutical industry based on data collected by a Greek pharmaceutical company.

THE METHODOLOGICAL FRAMEWORK

Five semi-structured in-depth interviews were conducted with senior managers of a pharmaceutical company based in Greece (it will be referred as Company A). A semi-structured in-depth interview consists of a set of predefined, predetermined questions and is used frequently, so there is flexibility in terms of modification of the content of the questions depending on the individual, in terms of the depth of some issues, but also in the order in which the questions are asked and in the adding or removing questions or topics for discussion (Mason, 2009; Robson 2007). The aim of these interviews was to provide useful insights of Industry 4.0 in the pharmaceutical industry. The topic of the interviews included the strategies for implementing Industry 4.0, but also the challenges faced during implementation phase and the readiness to adapt these new technologies. Each interview lasted about 30 minutes. The interviews recorded and then transcribed.

Thematic analysis was followed which consists of systematic identification, organisation and understanding repeated patterns of meaning or a set of data (Braun et al., 2012). The steps for the analysis are as follows: i. Transcription: conversion into written text of a recorded interview ii. Careful reading of written texts iii. Coding: understanding and interpreting written texts, but also organising them in the same way. iv. Transition to themes: meaning of the texts. v. Report of the conclusions.

ANALYSIS
Maturity & Obstacles

All respondents express the common view that all pharmaceutical companies implement some kind of automation regardless of their size due to the requirements that imposed by the European Medicines Agency. In fact, the quality control manager said that: *"The control and traceability in pharmaceutical companies and the recording of all steps of the processes are crucial aspects. Therefore, it is important for pharmaceutical companies the use of Industry 4.0 technologies. Clearly, the automation and implementation of the new technologies are more necessary to larger and financially stronger pharmaceutical companies"*.

A large percentage of 80% believes that there was lack of strategy and direction from management as they do not really have a good understanding of the data needed in the new Industrial revolution and how the new technologies could be smoothly implemented in the production and supply chain processes. Another interviewee supported that there is a lack of readiness in the implementation of these new technologies: *"We did not even know their benefits. Yes, there was a will to evolve, but no one gave us the model and methodology to see how these technologies will be properly implemented. There was no proper guidance. Therefore, there were many problems, stress, distrust, and insecurity in the application of technologies. However, after implementing a few of these technologies we have developed a better understanding, and everything changed in the production process. Production time improved and we could work 60% faster and more productively than before. Beyond the partial distrust of a small percentage of employees, most of us feel more productive in our work and more controlled. There is no mistake, only evolution. For sure, there are still many steps to be taken by pharmaceutical companies. As we are now, of course, we cannot compete the industries abroad"*.

Another interviewee mentioned that: *"The transition to new technologies was gradual and very slow and perhaps at the request of the Medicines' Agency, accelerated the adoption process. The main obstacle to the application of new technologies we could say it was the budget. The application of new technologies was done based on prioritization and budget and not on belief in deep changes to turn the factory into a factory based in automation and interaction"*.

There was a subsidy to cover 80% of the costs for production equipment from a Greek government programme (Corporate Agreement for Development Framework), but it was not enough support, as the

change to better equipment requires qualified staff, internal seminars that take time and money, and the need for new equipment to be developed, new technological tools were needed. Moreover, there was no guidance from the government regarding strategy to be followed for a smooth integration into the new technologies and no further financial compensation to balance any disruptions or miscalculations.

4 out of 5 agree that the staff needed at least 1-3 months to be trained and almost 80% agreed that there was no effort to educate the staff but only some minimal efforts during the integration of technologies. Thinking that training the workforce required money and time, employers pushed their workforce and did not train them properly according to the respondents. "*We were forced to train ourselves and learn from our mistakes. The only training was a few hours at the beginning during the transition to new technologies and after enough money was wasted, the employers decided to stop the training as it was taking time and money*".

80% responded that the company faced many impacts and barriers to the smooth transition of new technologies in particular, workers in the production process felt insecure, as it was perceived that there would be a reduction in staff due to increased productivity and automation. Besides, 3 out of 5 interviewees stressed that there was distrust towards the unknown, as most of them did not know how to apply and work with new technologies. There was a difficulty in adapting to the new requirements.

Incentives

Interviewees agreed that there was a will to continuously improve the performance of their company, but also the aim was to be a reduction in manpower, which would reduce costs and increase productivity and automation. A senior manager stated that: "*Human error in a pharmaceutical industry can cause many problems and through new technologies could help to avoid these errors. This could be achieved using innovative technologies. This is a crucial motivation for a pharmaceutical company. The biggest fear of a pharmaceutical industry is probably the human-made machine error and in general, the human error that would cause customer dissatisfaction and distrust. Every move, mistake and recklessness counts*".

It was required by the Medicines' Agency that Company A has to use smart sensors that monitor product conditions 24 hours a day, 7 days a week and to achieve data integrity. Therefore, the company was partly forced to set some of the new technologies as a priority, because they were vital to stay in operations in the pharmaceutical sector.

Impacts

Most of the head of departments agreed that by having overcome barriers of workforce training and gathering know-how, employees were able to work and perform faster than before the implementation of new technologies. They felt more productive and were able to identify more quickly and efficiently errors in batches, non-conformities and trace their actions. The robotics application offered new capabilities in material handling and the equipment based on real time data analysis offered information on any deviation from normal data. An increase in competitive advantage was achieved, as better production process management brought better production time, but also higher quality in the product. It is stated that: "*The implementation of new technologies has contributed to the reduction of complaints from customers. Therefore, it contributed to customer satisfaction*".

The reduction of human error, universal and 24-hour real-time monitoring offered by Industry 4.0, the sensors, the robotic systems are some of the applications that place a crucial role in the operations, but also holistically in all the stages in the supply chain. Sensors analyse real-time conditions, temperature and humidity are important for transporting and maintaining the quality of medicines. Determining stock levels and monitoring waste in real time is considered another important advantage.

DISCUSSION AND CONCLUSION

The new industrial revolution offers several advantages, and it is therefore imperative for industries to increase their competitiveness, flexibility, automation, and interaction by applying all new technologies. It is important to mention that the digital maturity and readiness of Greek businesses in comparison with countries of the European Union is at a low level due to all the economic difficulties facing the Greek economy, making it even more difficult for Greece to adopt the new technologies. Based on all the research and analysis carried out, it could be considered that the transition of Greek pharmaceutical

companies to new smart factories based entirely on Industry 4.0 technologies is a challenge for the Greek context. The following analysis is provided below the most basic conclusions of this paper.

Obstacles

Through the research conducted, the economic constraints are the ones that constitute the biggest obstacle to the implementation of the new Industry 4.0 technologies in the supply chains of pharmaceutical companies. The main barrier to implementation of Industry 4.0 technologies is the lack of resources (Sommer, 2015). According to a study, the absence of investment at 12.7% is still a major obstacle for companies in their digital transformation, but also for the implementation of new technological advances (SEV, 2019). The reason cited as the most important barrier to compared to the others is, of course, the socio-political crisis that Greece has been experiencing in the last few years, which was further triggered by the pandemic COVID-19 crisis. The industries, and especially in Greece, do not have the necessary financial resources to invest in modern technologies (Faller et al., 2015). According to Fotakis et al. (2018), Greece is among the member states of the European Union, which are reluctant to the new Industrial revolution because Greece lacks a reliable industrial base, while there are fiscal problems that do not allow for immediate growth (Fotakis et al, 2018). It is important to mention that the second most important obstacle is the lack of administrative support and commitment. Businesses have not realized that without digital transformation they risk losing customers, marginalizing products and business obsolescence (SEV, 2019). To build a smart factory based on new technologies that is backed by skilled personnel needs the necessary commitment and a solid management plan. Industries should aim to improve the factory, but also the workforce with skill enhancement programs and support programs. Deliverable 1 of 2021 states that there is a weakness in the linkage of entrepreneurship with educational/research institutions (knowledge providers), which transfer knowledge and promote research and innovation, which is a key factor in adapting to digitisation and Industry 4.0, as well as green and circular economy (Deliverable 1, 2021). In this area it is necessary to implement a different approach, as so far, the efforts made to create partnerships between businesses and knowledge producers have not yet yielded the desired results (Deliverable 1, 2021). Without the necessary support from management and managers it is logical that new ideas cannot be implemented (Nimawat et al., 2021). According to deliverable 1 (2021), Greece is one of the last countries in Europe without a national strategy for Industry 4.0. Therefore, it is logical that the same ideology is reflected in the strategies of Greek companies. It is worth noting that it is the lack of maturity and preparedness that considered, in a context of strategic choices by management, to be a major obstacle to transition to the new industrial revolution. According to the SEV study (2019), digital and technological maturity of Greece remains low. In addition to the above, high in the ranking is the obstacle of lack of know-how on the part of employees. According to a study, the level of skills of the employee in the workforce is also low (SEV, 2019). Frangos (2020) says that the Greek education system and society in general does not seem ready to provide the necessary skills. To this end, radical changes are first required in classical concepts such as meritocracy, to welcome the positive aspects of the 4th Industrial revolution with confidence (Fragos, 2020). According to Orzes et al. (2018), there is an uncertainty about investing in new technologies and the transition of an industry into a smart factory. Especially in Greece, there are steps of evolution, but they are very small and slow compared to the pharmaceutical industries abroad. The lack of understanding of the concept of Industry 4.0 is not considered a major obstacle according to the survey, which comes in conflict with the theory of Sommer (2015) and Orzes et al. (2018), who consider it as the main one, but without the necessary readiness, financial resources, and maturity it is not possible to implement the technological developments of the new industrial revolution (Sommer, 2015; Orzes et al., 2018).

Incentives

With a brief look at the results of the research, the reduction in costs and the increase in productivity are the main motives identified. Apart from these, the increase in traceability and more automation are among the most important motives as well. This is because in the pharmaceutical industry it is a serious issue to eliminate human error, but also the traceability of the error to find the side effects in the other processes, and of course, to find other possible errors. Automation plays a key role in the productive process and customer satisfaction is one of the key motivators for pharmaceutical companies to join the

world of the new Industrial revolution. According to the SEV study (2019), with the introduction of robotic systems in production, utilization of robots in logistics operations (sorting, storage, inventory), as well as providing instructions for assembly and maintenance tasks through Augmented reality (VR), cost reduction can be achieved (SEV, 2019). According to Deliverable 1 of 2021, a programme is proposed in which the benefits of digitisation for businesses. It states that by applying new technologies, there will be an improvement in productivity, promoting the productive growth of industrial enterprises and accelerate their maturity. In addition, there will be a strengthening of industrial research and development of applications in cutting-edge technologies, the creation of domestic supply for the development of Industry 4.0 systems and technologies, which will demand needs, contributing to the maturity of a significant part of industrial enterprises and this will contribute to their productive growth in view of Industry 4.0 (Deliverable 1, 2021). In addition, an important incentive is the more efficient management of the production process. A smart factory is flexible. It can adapt and change according to the needs without human intervention. There is prediction of possible outcomes and scenarios in a production process. A smart factory responds more easily to changing demands. In addition, the benefits of this automation and interaction include lower lead times to customers and lower overall costs, a 25% improvement in production capacity as well as 50% fewer defective products (Sun-won, 2017; Sotiropoulos, 2018).

Theoretical, managerial and policy implications
This is the first study tried to give helpful insights of the situation in the pharmaceutical industry in Greece. Through the application of new technology, specifications are improved, and innovative products can be created.
Some managerial implications are the need for managers to develop a strategic plan and inform all employees about the need of these technologies. In addition to these, Francisco (2017) states that industries that will choose to transform themselves into smart factories will be more likely to increase their competitive advantage and will be able to co-exist in the most demanding global markets. Companies need to train their employees and take important decisions about the steps of the implementation and monitor the progress. According to a 2015 Deloitte survey, companies are not taking the next step of exploring the potential of new technologies, as they believe that it will not benefit their profitability. The small size of a firm implies in higher risk and fewer benefits (Sommer, 2015). The Greek government plays a crucial role in order to help companies in the pharmaceutical industry to adapt the cutting-edge technologies and without governmental support, it would be difficult for companies to adopt Industry 4.0 technologies.

Limitations of the paper and proposals for future research
The investigation was limited to findings from one pharmaceutical company in Greece. The study could focus also on the suppliers. Greece, according to deliverable 1 (2021), is one of the countries that have not proceeded to full and/or smooth integration into the technologies of the new Industrial revolution. It is a fact that while there are several emerging pharmaceutical companies in Greece, there is no support to compete with foreign pharmaceutical companies. As the research provided conclusions that confirmed several barriers, as well as incentives for the implementation of Industry 4.0, but also identified new ones, the present study gives the impetus for research on the applications of Industry 4.0, the barriers that surround it, and the incentives that exist. There is room for research on pharmaceutical companies abroad, but also a comparison of these with the Greek ones.

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Management of traffic flows at intersections

Asma Khelifi[1], Jean-Patrick Lebacque[2], Habib Haj-Salem[2]

[1] Université de Lorraine, IAE Metz School of Management, 1 Rue Augustin Fresnel, 57070 Metz France, asma.khelifi@univ-lorraine.fr,

[2] Université Gustave Eiffel, IFSTTAR/GRETTIA; 16 Boulevard Newton, 77420 Champs-sur-Marne France

Abstract— This study is concerned with the higher order macroscopic traffic flow modeling and simulation of traffic flow on junctions. More precisely, we deal with a generic class of second order models, known in the literature as the GSOM family which embeds a large variety of traffic models. While classical approaches focus on the Eulerian point-of-view, here we recast the model using its Lagrangian coordinates and we treat the junction as a specific discontinuity in Lagrangian framework. We propose a complete numerical methodology based on a finite difference scheme for solving such a model which is compatible with micro and macro description, and satisfy the constraints of the invariance principle.

Keywords— Traffic flow; junction; GSOM models; Lagrangian; numerical scheme.

Introduction

In this study, we are motivated by road network modeling, thanks to macroscopic traffic flow models. First order traffic flow models have been used for quite a long time for modeling traffic flows on networks (see [2]; [6] for instance). In particular, the seminal LWR model standing for [12]; [14] has been widely used. However, first order models do not allow to recapture accurately specific and meaningful traffic flow phenomena. Thus, we focus on the Generic Second Order Models (GSOM) family which encompasses a large variety of higher order traffic flow models. GSOM models have been already well studied on homogeneous sections but they have attracted little attention for their implementation on junctions, as it is discussed in Section 4. However, junctions are the main source of congestion for traffic streams on a network. In this paper, we want to develop a junction model which is compatible with microscopic and macroscopic descriptions, and satisfies classical constraints coming from engineering, as for instance the invariance principle discussed in [7]; [15]; [1]. The microscopic representation of traffic flow is particularly suited for traffic management methods, while staying compatible with a macroscopic representation allowing global evaluation. The key idea for conciliating both microscopic and macroscopic representations is to recast the macroscopic model under its Lagrangian coordinates. Indeed the Lagrangian framework focuses directly on the particles and incidentally it allows to keep track of individual behaviors (see for instance [11] in the case of first order LWR model).

The article is organized as follows. In Section 2, the generic class of second order macroscopic traffic flow models called GSOM family, is introduced. We then review and discuss the literature for solving GSOM models posed on junctions. Our aim is to show that the Lagrangian framework is well-suited for designing the solution to GSOM problems even if incorporating discontinuities. In Section 3, we describe the numerical resolution of the GSOM model using the Lagrangian discretisation method. The complete numerical methodology on junction is described in Section 4 and a numerical example is given incidentally in Section 5. Finally, we provide some conclusions on this work and give some insights on future research in Section 6.

GSOM Family

Review of the literature

There already exist a few works on the Lagrangian modeling of junctions based on GSOM models; see for instance [13]; [16]; [4]. However, some of these works are based on very specific examples extracted from the GSOM family. But it is not straightforward to extend the numerical methodologies presented in these papers to the generic GSOM model. In [4], the authors consider the Godunov scheme and extend this particle discretization to networks, addressing the problem of junction modeling through a supply-demand approach. The authors make the choice to introduce an internal state model (see [10]; [5]) and assume that the particles share the same attribute once they have passed. The authors deal also with densities and flows which is not particularly convenient with GSOM models in the Lagrangian framework. Hopefully, dealing with spacing instead of density will ease the resolution of the model. While boundary conditions can be treated within the framework of supply-demand flows methodology (see [7], [9] and [4]), expressions of upstream and downstream boundary conditions into Lagrangian coordinates can be obtained in the framework of variational approach for GSOM models (see [8]). It will be developed in next section.

Structure of the GSOM Model

The GSOM model combines the conservation equation with the fundamental diagram of specific driver behavior attribute. The main GSOM traffic model variables on a road network are: density ρ, flow q, speed v: function of the density ρ and the invariant I ($V = \Im(\rho, I)$ with $\Im$ the fundamental diagram speed-density, and the attribute I (it can be a vector, type of vehicle, driver behavior, origin/destination…)).

It can be expressed as follows:

$$
\begin{cases}
\dfrac{\partial \rho}{dt} + \dfrac{\partial \rho v}{dx} = 0 & \textit{conservation of vehicules} \\[2mm]
\dfrac{\partial \rho I}{\partial t} + \dfrac{\partial \rho I v}{\partial x} = -\rho f(I) & \textit{conservation attribute driver I} \\[2mm]
v = \Im(\rho, I) & \textit{driver dependent fundamental diagram}
\end{cases}
\tag{1}
$$

The function $f(I)$ is a relaxation function. I is a Lagrangian driver attribute that characterizes the behavior of each driver. It is preserved along the trajectories of vehicles. The fundamental diagram: $v = \Im(\rho, I)$ and $\rho v \overset{def}{=} \Re(\rho, I)$

$\Re$ is assumed to be concave with respect to ρ, for all values of I. Note that the equation of I can be reformulated as an advection equation: $\dot{I} = \dfrac{\partial I}{\partial t} + v \dfrac{\partial I}{\partial x} = \varphi(I)$. In this context, the function $\varphi(I)$ can express the relaxation of I to a reference or an equilibrium value (specific to the driver) ($\varphi(I) = f(I)$), or can express a disturbance process, in the case of stochastic attribute.

A note on Supply-Demand functions

The quantities of demand $\delta(x,t)$ and supply $\sigma(x,t)$ of the GSOM model are evaluated on the basis of demand and supply functions in equilibrium which are defined by:

$$
\begin{aligned}
\Delta(\rho, I; x) &= Max_{0 \leq r \leq \rho} \Re(\rho, I; x-) \forall (x,t) \\
\Sigma(\rho, I; x) &= Max_{r \geq \rho} \Re(\rho, I; x+) \forall (x,t)
\end{aligned}
\tag{2}
$$

Due to the transport driver attribute, supply must take into account both upstream driver attribute, I, and downstream driver attribute, J, according to the following expression:

$$\Theta(\rho, I, J; x) \overset{def}{=} \Sigma\left(\mathfrak{I}^{-1}\left(\mathfrak{I}(\rho, J, x+), I, x+\right), I; x\right)$$

Thus:

$$\delta(x,t) = \Delta\left(\rho(x-,t), I(x-,t); x\right)$$
$$\sigma(x,t) = \Theta\left(\rho(x+,t), I(x-,t), I(x+,t); x\right) \tag{3}$$

Where $q(x,t) = Min\left[\delta(x,t), \sigma(x,t)\right]$ calculates the flow of vehicles and $I \overset{def}{=} p(x,t) = q(x,t) I(x-,t)$ calculates the flow of I. The boundary conditions are derived from functions of supply and demand.

Lagrangian setting of the GSOM family

The common expression of GSOM models in Eulerian coordinates (t,x) is given by equation 1. However, it is well-known that Lagrangian framework (t,n) is particularly convenient for dealing with flows of particles and it is especially true in traffic flow modeling (see [11]; [16] and references therein).

Thus, equation 1 is equivalent to the following numerical scheme:

$$\begin{cases} \partial_T r + \partial_N v = 0 & \text{on } (0, +\infty) \\ \partial_T I = 0 & \text{on } (0, +\infty) \\ v = \vartheta(r, I) \overset{def}{=} \mathfrak{I}(1/r, I) \end{cases} \tag{4}$$

With initial conditions: $\begin{cases} r(0,n) = r_0(n) \\ I(0,n) = I_0(n) \end{cases}$.

Considering that $x_n(t)$ the trajectory of the nth vehicle $(N(x,t) = n)$, the discrete model is then given by:

$$\begin{cases} \dot{x}_n(t) = \mathfrak{I}\left(\dfrac{1}{x_{n-1}(t) - x_n(t)}, I_n(t)\right) \\ \dot{I}_n(t) = -S\left(I_n(t)\right) \end{cases} \tag{5}$$

The model shown in Equation 1 can be then written as follows:

$$\begin{cases} x_n(t+\Delta t) = x_n(t) + \Delta t \mathfrak{I}\left(\dfrac{x_{n-1}(t) - x_n(t)}{\Delta N}, I_n(t)\right) \text{ with } \Delta t = dt \\ I_n(t+\Delta t) = \Psi\left(I_n(t), \Delta t\right) \end{cases} \tag{6}$$

Where $\Psi(I_0, \tau)$ is the solution to the moment τ of $dt/d\tau = -S(I)$ and $I_{\tau=0} = I_0$.

Therefore, the Lagrangian form of the GSOM model is:

$$\begin{cases} x_n\left(t+\Delta t\right) = x_n\left(t\right) + \Delta t . v_n\left(t\right) \\ v_n\left(t\right) = \Im\left(\dfrac{x_{n-1}\left(t\right) - x_n\left(t\right)}{\Delta N}, I_n\left(t\right)\right) \\ I_n\left(t+\Delta t\right) = I_n\left(t\right) + \Delta t . S\left(I_n\left(t\right)\right) \end{cases} \tag{7}$$

Where $S\left(I_n\left(t\right)\right) = -\dot{I}_n\left(t\right)$ and $I_n\left(t\right)$ represents the invariant associated to the nth vehicle.

In the second case, the appropriate numerical scheme is defined as follows:

$$\begin{cases} r_n\left(t+\Delta t\right) = r_n\left(t\right) + \dfrac{\Delta t}{\Delta N} . \left(v_{n-1}\left(t\right) - v_n\left(t\right)\right) \\ v_n\left(t\right) = \Im\left(r_n\left(t\right), I_n\left(t\right)\right) \\ I_n\left(t+\Delta t\right) = I_n\left(t\right) + \Delta t . S\left(I_n\left(t\right)\right) \end{cases} \tag{8}$$

Then the scheme shown in Equation 8 is simply deduced from Equation 7. Note that both schemes are first order schemes. The first discrete model (Equation 7) is an explicit Euler scheme and the second scheme (Equation 8) can be interpreted as the seminal Godunov scheme (see [3]) applied with demand and supply.

To ensure that vehicles comply the minimal spacing, the following CFL stability condition must be respected:

$$\Delta t \leq \frac{\Delta N}{\rho_{\max}\left(I_+\right) W_{\max}\left(I_+\right)} \tag{9}$$

Where $\rho_{\max}$ is the maximum density for $\Im\left(\rho, I\right) \geq 0$ and $W_{\max}\left(I\right) = \partial_\rho \Im\left(\rho, I\right)_{\big|\rho = \rho_{\max}\left(I\right)}$. I_+ is defined by the Godunov scheme as the largest value taken for the invariant I and this value will depend on initial conditions, the input and the function $S\left(I_n\left(t\right), \Delta t\right)$.

Methodology for the Lagrangian modeling of junctions

In this section, we describe the numerical scheme adapted for the generic Lagrangian GSOM model posed on junction. We partially follow [8] in which the authors describe boundary conditions for the Hamilton-Jacobi equation associated to the Lagrangian GSOM model (Equation 4). In the beginning, it is necessary to converse the supply and demand functions classically expressed in Eulerian coordinates denoted respectively by Δ and Σ into Lagrangian ones. In Eulerian, the passing flow q is given by the minimum between upstream demand and downstream supply. In Lagrangian, one may expect that the upstream demand is given by the speed of the next vehicle which will pass through the junction. The difficult point is that the speed is computed with respect to the spacing with the leader vehicle. If the leader vehicle gets into the junction, the following vehicle has no more leader vehicle. The idea is then to assume a point-wise junction model with an internal state (first introduced in [4] and [5]) that is used as a buffer between incoming and outgoing branches of the junction. We recall that this buffer has internal dynamics and we can define an internal supply which depends on the number of stored vehicles. To solve the problem of defining a spacing when the leader vehicle has entered the junction point, we set a new speed function which only depends on the distance to the junction (which is assumed to contain the "fictitious" leader vehicle).

For deducing a Lagrangian discretization of a traffic flow model on a junction, it is necessary to take into consideration different elements:

i.   The link model, which is given by either (7) or (8);
ii. The upstream (resp. downstream) boundary conditions for any incoming (resp. outgoing) link;
iii. The internal junction model, say the way particles are assigned from incoming road to outgoing road and eventually the internal dynamics of the junction point;
iv. Link-junction and junction-link interfaces.

These constituting elements are addressed in what follows.

Downstream boundary condition

It is assumed that we are located at the downstream boundary of a given outgoing road. Consider the exit point S located at the position x_S. The downstream boundary data at x_S is given by the discrete downstream supply σ^t at time step t. Let $(n+1)$ be the last particle located on the link (or at least a fraction $\eta \Delta N$ of it is still on the link, with $0 < \eta \leq 1$), and η is the proportion of the particle $(n+1)$ still on the link at t, as is shown in the following Fig.1:
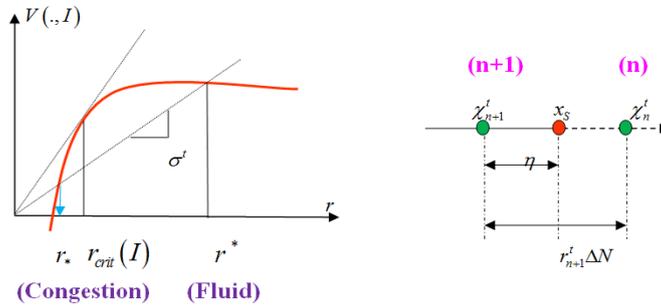
Fig. 1. Downstream boundary conditions

We define the spacing associated to particle $(n+1)$ as:

$$r_{n+1}^t = \frac{x_S - \chi_{n+1}^t}{\eta \Delta N} \tag{10}$$

The fraction η is instantiated at the first time step t_n following the exit of particle (n), as follows:

$$\eta = \frac{x_S - \chi_n^{t_n}}{r_n^{t_n} \Delta N} \tag{11}$$

With t_n is the entry time of the behind of the particle n (i.e. the entire particle is on the link for $t \geq t_n$) and creation of the particle (n).

Indeed, the algorithm is composed as follows:

1) Initialize η,
2) Calculate r_{n+1}^t,
3) Distinguish two cases:
a) Either $V\left(r_{n+1}^t, I_{n+1}^t\right) \leq \sigma^t r_{n+1}^t$ and $\chi_{n+1}^{t+1} = \chi_{n+1}^t + \Delta t . V\left(r_{n+1}^t, I_{n+1}^t\right)$: the downstream supply is sufficient to accommodate the demand on the link and the spacing is conserved.

b) Or $V\left(r_{n+1}^{t}, I_{n+1}^{t}\right) > \sigma^{t} r_{n+1}^{t}$ (unmet demand): the demand on the link cannot be fully satisfied since the downstream supply limits the outflow. Then, we have to solve $V\left(r_{n+1}^{t}, I_{n+1}^{t}\right) = \sigma^{t} r_{n+1}^{t}$ and we choose the smallest value $r_{n+1}^{t} = r_*$ (see Fig.1). It means that we select the solution corresponding to the congested phase (see Fig.1).

4) Update the particle index and the position of particle $(n+1)$ as usual, using Equation 7. We also need to update the fraction η if the particle has not totally exited the link if $\chi_n^{t+1} < x_S$.

Upstream boundary condition

It is assumed that we are located at the upstream boundary of a given incoming road. Consider the entry point E located at the position x_E. The upstream boundary data at x_E is given by the discrete prescribed upstream demand δ^t at time step t. Let (n) be the last particle entered in the link. The next particle $(n+1)$ is still part of the demand and they will enter in the link at time $(t+\varepsilon)\Delta t$, as is shown in the following Fig.2:
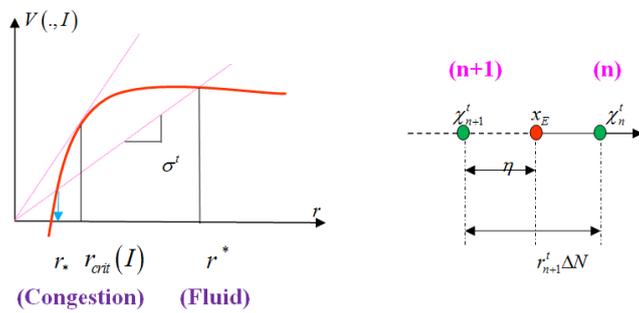
Fig. 2. Upstream boundary conditions

Our objective in this section is to adapt to the upstream boundary condition, the methodology developed for the downstream boundary condition by introducing a proportion η of the particle that has already entered the link. The problem here is that, unlike for the downstream where we know exactly the position of the last particle which has exited the link, we do not know precisely the position of the next particle which will enter the link; that is why the algorithm is not so simple.

Thus, we have to position the next particle that will enter the link. If one consider that the last particle that has entirely entered the link at time t is labeled n, we introduce a fraction η^t of the particle $(n+1)$ which has already got into the link at time t. We note that q^t is the effective flow at the upstream entry and at time t while $\left(t\Delta t, (t+1)\Delta t\right)$ (see Fig.3).
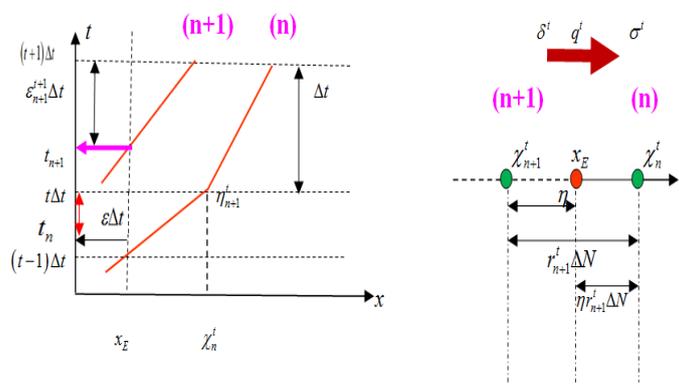
Fig. 3. New upstream boundary conditions

Indeed, the algorithm is composed as follows:

1) Initialize η : Assuming that the particle (n) completely entered the link at time $t_n = (t+\varepsilon)\Delta t$, the proportion η^{t+1} at $(t+1)$ is given by the following expression :

$$\eta^{t+1} = \frac{q^t(1-\varepsilon)\Delta t}{\Delta N} \qquad (12)$$

Where $\varepsilon\Delta t = t\Delta t - t_n$ and $t_n = (t-\varepsilon)\Delta t$ is the exact date at which the rear of particle (n) enters the link at x_E.

2) Calculate the effective flow of particles that enter the link q^t and the local downstream demand σ^t by the following expressions as follows:

$$q^t = \min\left(\sigma^t, \delta_z^{\,t}\right)$$
$$\sigma^t = \sum_{tron\varsigma on}\left(r_{n+1}^t, I_{n+1}^t\right) \qquad (13)$$

Where $\delta_z^{\,t}$ is the cumulative demand of junction (z)

3) Calculate the spacing at time t according to particle $(n+1)$:

$$r_{n+1}^t = \frac{\chi_n^t - x_E}{\eta_{n+1}^t \Delta N} \qquad (14)$$

In the junction (z), there is then $(1-\eta^t)\Delta N$ vehicles below of the particle $(n+1)$.

4) Compare $(1-\eta^t)\Delta N$ and $q^t\Delta t$, we can distinguish two cases:

a) If $q^t\Delta t < (1-\eta^t)\Delta N$, then the particle $(n+1)$ does not completely extend the node and we update η_{n+1}^{t+1} as follows:

$$\eta_{n+1}^{t+1} = \eta^t + \frac{q^t\Delta t}{(1-\eta^t)\Delta N} \qquad (15)$$

b) If $q^t\Delta t \geq (1-\eta^t)\Delta N$, then $(n+1)$ extend completely the junction, with the outing time is $(t+\varepsilon)\Delta t$ and we update ε_{n+1}^{t+1} as follows:

$$\varepsilon_{n+1}^{t+1} = \frac{(1-\eta^t)\Delta N}{q^t\Delta t} \qquad (16)$$

We compute then the trajectory of particle $(n+1)$ for the following time steps as follows:

$$\chi_{n+1}^{t+1} = x_E + \varepsilon\Delta t V\left(r_{n+1}^t, I_{n+1}^t\right) \qquad (17)$$

Where $\varepsilon\Delta t$ is the travel time.

5) Initialize $\left(\eta^t, \varepsilon, q^t\right)$ and we itemize by considering the next particle $(n+2)$ (if it has been generated) and so on.

Internal state junction model

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We consider an internal state junction model used as a buffer between the incoming and outgoing branches of the junction. It assumes that the junction (z) has a physical dimension and acts as a buffer and that vehicles are stored before extending the outgoing branches. The internal state has specific attributes such as: $N_z(t)$ is the total number of vehicles in the node, $N_{z,j}(t)$ is the number of vehicles registered in the node and destined to link (j) and $I_z(t)$ is the driver attribute of vehicles stored in the node.

The number of vehicles registered in the node is calculated using the following ordinary differential system reflecting the vehicle conservation:

$$\begin{cases} \dfrac{dN_{z,j}(t)}{dt} = -R_j + \sum_i \gamma_{ij} Q_i(t) \quad \forall j \\ N_z(t) = \sum_j N_{z,j}(t) \qquad\qquad (18) \\ \dfrac{d(N_z(t) I_z(t))}{dt} = \sum_i Q_i(t) I_i(z^-,t) + \sum_j R_j(t) I_z(t) \end{cases} \tag{10}$$

Indeed, about the upper boundary of the node capacity, in our opinion we also need to introduce an upper boundary on $N_z(t)$ corresponding to the maximum physical number of vehicles that can be stored in the node. We introduce the coefficients $(\beta_i)_j$ that represent the fraction of the available space for vehicles coming from (i) behind the total available space for all incoming branches.

We can then define the partial functions of supply and demand as follows:

$$\begin{cases} \sum_i(t) = \beta_i \sum_z \left(N_z(t), I_z(t) \right) \\ \Delta_j(t) = \dfrac{N_{z,j}(t)}{N_z(t)} \Delta_z \left(N_z(t), I_z(t) \right) \end{cases} \tag{19}$$

To avoid loss of information on the driver attribute, we note that in equation 19, the traffic composition of $I_z(t)$ in the node is assumed to be stored on outgoing branches. We may think of a different rule outside the junction, drivers are not constrained and they can resume their original attribute. We assume that we have only the particles allocation information i.e. the matrix $(\beta_{i,j})_{i,j}$, which describes the particles proportion coming from branch $i \in I$ that want to leave the junction on the branch $j \in J$. In this case, it is considered that a particle that enters the junction of branch i released on branch j with probability $\beta_{i,j}$.

This law of probability to describe the internal dynamic of the junction satisfies the following equation:

$$\sum_j \wp(i \to i) = \sum_j \beta_{i,j} = 1 \tag{20}$$

Considering that once particles entered the junction, whatever their origins, they are immediately assigned to the buffer corresponding to their expected outgoing.

Numerical example

We consider one junction with two incoming and two outgoing roads. We have chosen the 1-phase Colombo GSOM model (see [9]) to represent the speed function.

The results are the following figures:
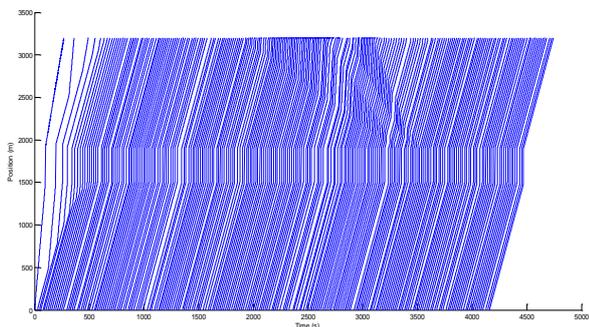
Fig. 4. Lagrangian particle trajectories
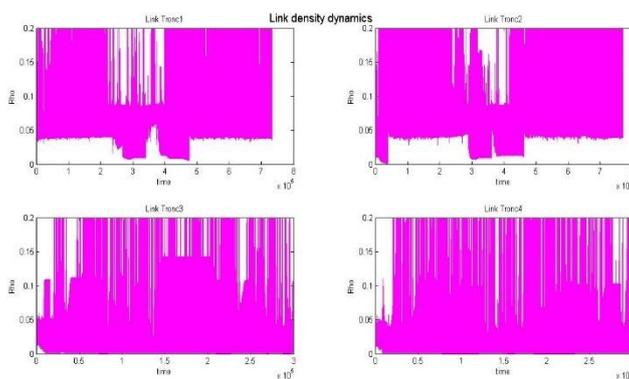
Fig. 5. Link density dynamics
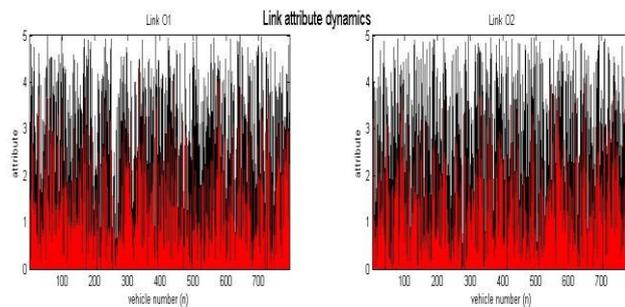
Fig. 6. Link attribute dynamics
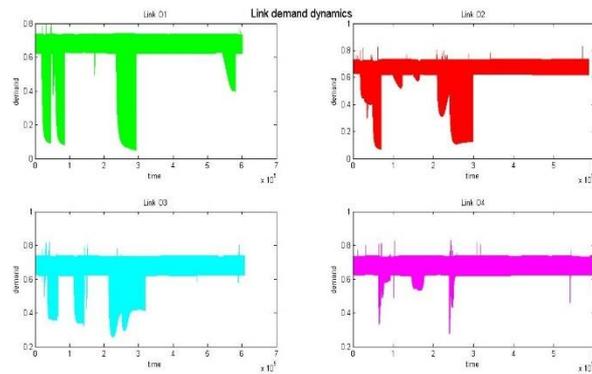
Fig. 7. Link demand dynamics

The distribution of particle trajectories and attribute are respectively displayed on Fig.4 and Fig.6. The density and the demand for the two incoming links and the two outgoing links are respectively plotted in Fig.5 and Fig.7.

We see that our numerical method can recapture blockages in the junction after formation of shock waves due to the congestion and then the rarefaction wave and rarefaction waves due to the decrease of the upstream demand.

Conclusion and next step

In this study, we have discussed a new numerical method to deal with the generic class of second order macroscopic traffic flow models, known as the GSOM family, posed on a junction. The generic GSOM model is recast in the Lagrangian framework and we have a careful look at the boundaries conditions for links and junctions. By decomposing the problem into two cases (the downstream boundary conditions and upstream boundary conditions), intersections modeling is well studied in this paper. It requires taking into account the principle of invariance to ensure the stability of the numerical scheme. One direction of future research would be to compare the numerical results obtained with our monotone scheme and those obtained from the variational approach [8] adapted for junction modeling, which has not been done right not.

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Real time location system for Internet of Things based on the Bluetooth

Augustyn Lorenc, Jakub Szarata, Michał Czuba
Assistant Professor Cracow University of Technology Poland, SKK S.A., Poland
E-mail: alorenc@pk.edu.pl

Purpose of this paper: The problem of localization of object in indoor environment is very important to make the company effective and find logistics system disruption in real time. Present research investigate how the IoT location system based on Bluetooth can be implemented for this solution.

Design/methodology/approach: To be sure that location system based on the Bluetooth can be implemented for real case, the analysis of signal strength amplitude and disruption was made. To stabilize the signal the Kalman filter was used.

Findings: The location based on the Bluetooth is hard to predict. For the signal disruption impact other devices, steal, containers with water and more. But proper data processing and stabilise the RSSI impact on the location precision.

Value: In the paper the R&D works was done, the practical test in real cases was done. The results causes that it is possible to implement this solution in Real Time Location System (RTLS).

Research limitations/implications: The solution based on the own developed transmitter. The typical one are inaccurate. And can not be implemented.

Practical implications: The presented research was used to develop IT system. This system is working for few months in the SKK S.A. client company.

Introduction

The location of objects inside buildings is becoming more and more important for companies wishing to increase their efficiency and reduce their resources. The use of GPS / Glonass / Beidou technology in buildings is not possible due to wave attenuation.

The currently available real-time location systems (RTLS) solutions are based on a location based on Wi-Fi, RFID or UWB technology. These types of systems enable the location and identification of objects in real time in a closed and open environment, but due to the technology used, they cannot be used in a dynamically-changing environment characteristic of large production companies. In such an environment, the accuracy of the location differs significantly from the actual location. It is influenced by the phenomenon of refraction of waves, overlapping and other types of disturbances caused by the diversity of the environment surrounding the locating transmitters.

Table 3. Comparison of object location technologies

	Wi-Fi	Radio-frequency identification (RFID)	Ultra WideBand (UWB)	Bluetooth Low Energy (BLE)
Frequency	2400 ÷ 2485 MHz 4915 ÷ 5825 MHz	125 kHz up to 0.5 m 13,56 MHz up to 3 m 868÷956 MHz up to 6 m 2.4 GHz 5.8 GH up to 6 m	3.1÷10.6 GHz in USA 6.0÷8.5 GHz in Europe	2402 ÷ 2480 MHz
Transmission speed	900 Mb/s	256 Kb/s	2 Gb/s up to 10 m	0.27÷1.37 Mbit/s

Standard	IEEE 802.11	Tiris, Unique, Q5, Hitag, Mifare, Icode	IEEE 802.15.3	Bluetooth 5.2
Reception	500 m	6 m	10 m	100 m
Date of creation	1991	1983	2002	2001

The difficulty in adapting the currently functioning solutions results, among others, from the need to build a basket infrastructure (power supply network, Lan / Wi-Fi network). Standard BLE receivers are able to download data packets every 10 seconds. In addition, one receiver can only read one data packet for each transmitter in the same time interval. Therefore, it would be possible to read one packet at the beginning of the time interval and the other at its end. Thus, the maximum difference between packets can be almost 20 seconds. This is a significant problem because the maximum speed of vehicles on the premises of enterprises can be up to 40 km / h. Therefore, the trolley could cover a distance of 111 meters in 10 seconds. However, in the case of a human moving on foot, this distance would be about 14 meters (not taking into account disturbances related to signal level fluctuations). Therefore, such a solution would be completely unacceptable. To ensure the accuracy of the location of objects, it is necessary to obtain a reading frequency of less than 1 second.

1.Materials and Methods
2.1. Materials
2.1.1. Reciever
The main task of the receiver is to scan continuously to pre-process raw BLE pac-kets and send them for further analysis via Ethernet using one of the communication protocols. For this reason, an important component in this element of the system is the BLE module and the radio system.
When selecting the electronic part of the receiver, many variants of solutions were considered and tested.The ESP32 system and RaspberryPi enabled the quickest and hassle-free pre-testing procedure. Compared to the rest of the devices, it has a more refined and matched system, as well as the greatest support. Based on the RaspberryPi and the Bluetooth module in the form of *LaunchPad CC2640R2* connected in series, a special receiver was prepared, which was named as the *Localistation Test Box*.
The prepared device was a prototype allowing to more precisely define the requirements for the receiver, resulting from practical tests. In addition, it initially allowed to exclude and familiarize with the proposed solutions regarding the location method, as well as all the elements related to it.

2.1.2 Transmitter
The transmitter is one of the key elements of the system, because this module will be assigned to the tracked object and then registered by the receivers. After a thorough review of ready-made solutions available on the market, just like in the case of a receiving device, it was decided to make own electronics. Own design of the circuit board made it possible to be versatile, which in the event of required changes or problems will allow for a wider range of modifications and expansion of the device. During research and testing, several versions of the device were made based on the first guidelines.
The transmitter will also be called SKK Hive Beacon or SKK Hive Sensor - with sensors. Each of the iterations presented is based on the SaBLE-x-R2 module. The power range of the device depends on the radio power settings and the antenna used. The heart of the device is the LSR Sable-X chip, which includes the CC2640R2 microprocessor with the power supply and antenna system.

2.2 Object location methods
Object localization is performed based on a set of receivers and transmitters using one of three methods:
- distance analysis based on signal level (RSSI) - trilateration method,
- signal reception account analysis - (Angle of Arrival, AoA),
- time analysis between signal transmission and its reception - (Time of Flight, ToF).

Method I – signal strenght (RSSI)
The first of the described methods is based on the level of the RSSI signal (*Received Signal Strength Indication*), i.e. the strength indicator of the received radio signal. It should be remembered that it is not the same as the quality indicator. The value of the parameter is given in dBm, and its range is from 0 to 100, where 0 is a number representing the strongest signal level, corresponding to the shortest distance between the transmitter and receiver. Typically, the RSSI signal level is presented in negative notation. The method based on RSSI signals is not very precise, but it allows to calculate the potential zone location with the use of one receiver and transmitter.

Method II – Angle of Arrival (AoA)
Angle of Arrival (AoA) is a technique that allows you to determine the direction from which a BLE packet came. This is the basis for triangulation, which is one of the methods of finding a location. The technique mentioned requires the use of at least two receivers (in the 2D model scenario). Having the angle of receiving a packet from the transmitter, we are able to determine the point of intersection by the receiving devices, which is the calculated location. The case is illustrated in the figure below.

In order to obtain the angle in the receiving devices, it is required to use a minimum of three antennas that are within the transmitter's range at the same time. During scanning, it quickly switches between the given antennas. This makes it possible to observe phase shifts resulting from small differences in the length of the signal path to different antennas. The differences depend on the direction of arrival of the BLE packet, which in the *AoA* solution must contain a *Continuous Tone (CT) section* , where there is no phase shift resulting from te signal modulation.

2.2.3. Method III – Time of Flight (ToF)
Time of Flight (ToF) is a technique that allows the distance of the receiver to the transmitter to be determined based on the delay time traveled by BLE packets during data exchange between devices. Knowing the distance between the receivers and the transmitter, you can perform the triangulation algorithm. The method consists in drawing circles around receivers with a radius equal to the specified distance, in this case ToF . The intersection point represents the probable location of the transmitter being tracked. A typical requirement is a minimum of three receivers to find one point in a 2D scenario.

There are several implementation solutions in the *ToF* system infrastructure , active and passive. A popular configuration is the active implementation, i.e. *Master-Slave* , where the *Master* device controls communication and sends packets, and the *Slave* responds after a strictly defined time. In this way, the control device is able to calculate the delay in arrival of the response packet. The time is counted between the transmission of the control packet and the response received from the *slave* device , then the value of the fixed and predetermined fixed travel time is subtracted.

The accuracy of the designated location depends on the number of calculations performed in the time interval. The higher the frequency of *ToF* measurements , the greater the precision can be.

2.Results
3.1. Analysis of the influence of broadcasting channels on signal quality

The tests were performed with the use of transmitters with embedded software for the first version and on the board in the second version. The measurement distance was 5 m, the measurement time was 25 minutes. In the second test, the distance was 30 cm and the measurement time was 30 minutes. Embeded software enables marking of broadcasting channels.

The number of readings on individual channels at a distance of 5m is shown in Figures 2-4.
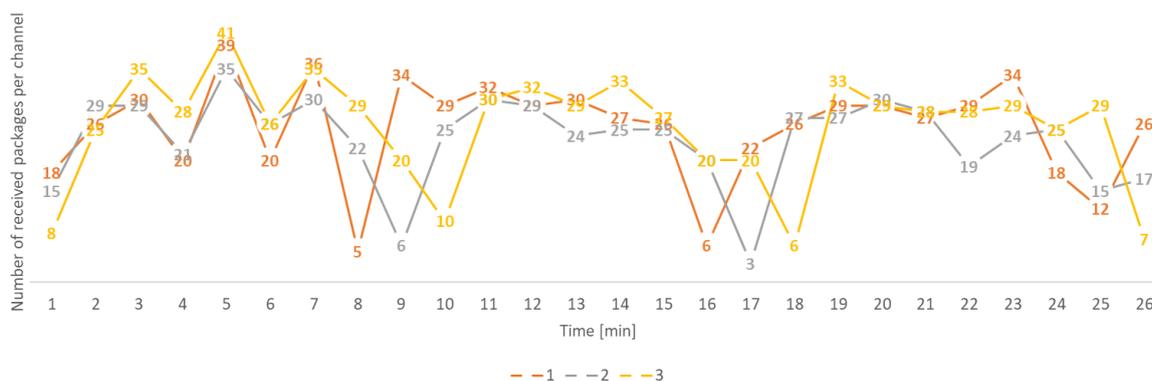
Figure 2. Number of readings depending on the transmission channel for the transmitter, distance 5m

From the above data, it can be seen that there is no significant difference between the number of readings on a given transmit channel for individual transmitters. Instability in the number of readings may result from momentary disturbances on a given channel or problems on the receiver side.

The previously noticeable cyclicality of the decrease in the number of measurements, occurring every 7-9 minutes, did not occur during the tests at night. This precludes a malfunction of the receiver. The cyclicality was caused by the influence of the environment - a Wi-Fi hotspot which was disturbed by radio waves on the BLE frequency.

3.3. The sampling rate required to achieve the specified level of localization accuracy

The sampling rate was tested for BLE modules: Raspberry and ESP32.

Table 4. Dependence of the RSSI level on the length of the scan time

Receiver	Value	Time of scanning							
		1s	2s	3s	4s	5s	6s	8s	10s
Raspberry	Mean	-63.4	-62.1	-62.3	-62.1	-62.1	-62.0	-62.0	-62.0
	Min	-78.6	-74.8	-73.8	-72.5	-71.6	-71.9	-71.8	-69.7
	Max	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0
ESP32	Mean	-62.3	-60.6	-60.4	-60.1	-59.9	-59.8	-59.7	-59.6
	Min	-91.0	-88.0	-80.0	-80.0	-80.0	-76.0	-76.5	-77.0
	Max	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0

By averaging the values of the RSSI signal level for the entire time interval from 1 to 10 s, an increase in the average signal level decrease for:
- Raspberry about:
    a. 1.3 dBm, 2.1% between 1s and 5s,
    b. 1.4 dBm, 2.2% between 1s and 10s,
- ESP32 about:
    a. 2.4 dBm, 3.8% between 1s and 5s,
    b. 2.7 dBm, 4.3% between 1s and 10s.

Aggregating the results from the time interval (5-10 sec.) To the averaged RSSI value, additionally allows to improve the signal quality by 4-15% depending on the length of the time interval in which the aggregation was performed.

During the measurements performed with the settings of the transmission frequency every 200 ms, it was possible to receive 2.8 packets per second. The remaining packages have not been received. Thus, a maximum of three signal levels per second can be obtained. It is a value sufficient to achieve the assumed goals.

The measurement of the number of transmitters detected by the receiver in a specific scanning time interval was performed for the Raspberry receiver and the ESP32 system. The number of BLE transmitters in the room was 8. Measurements were made at a distance of 5 m.

Table 5. Number of scanned transmitters in a specific time period

Receiver	Value	Scan time							
		1s	2s	3s	4s	5s	6s	8s	10s
Raspberry	Mean	6.7	7.6	7.7	7.8	7.8	7.8	7.8	7.9
	Min	2	5	5	6	6	6	6	7
	Max	8	8	8	8	8	8	8	8
ESP32	Mean	1.9	2.6	3.1	3.6	3.6	3.7	3.8	3.9
	Min	1	1	1	2	2	2	2	3
	Max	4	4	4	4	4	4	4	4

General observations for the analyzed systems:
- ESP32 - has a slow scan speed
- ESP32 - you have frequent, unpredictable jamming of the system. Reason unknown.
- ESP32 - receives transmitters with a signal about 2 dBm smaller than Raspberry.

The influence of the signal level on the frequency of scanning transmitters in the room was tested using the Raspberry RnD03 receiver and the ESP32 devkit system. The number of BLE transmitters in the room was 8. Measurements were made at a distance of 3m, 5m and 8m.

3.4 Correlation of other moving objects with the speed of the analysed objects

Signal fluctuations in radio technologies are a major technological problem. The key is the proper selection of transmission and reception parameters, the selection of antennas and the method of signal processing that allows for its stabilization. To select the parameters of the devices, the sampling frequency should be considered depending on the type of object. The higher the speed of the object, the smaller the sampling should be. However, at a certain sampling rate, it is not possible to improve the signal quality, so constantly increasing the sampling rate is not a good solution. In order to determine the required sampling frequency, an algorithm was prepared that changes the Bluetooth parameters, such as: Maximum Scan Responses, Scan Interval, Scan Time, Scan Window. 180 seconds was set as the measurement time on one setting. A number of measurements were made.

The best result was obtained for the sensor with the antenna with the ANT406 antenna, but for the receiver located at a distance of 40 m, an increased range was observed in which the signal level fluctuated (-97 to -86 db), which can be limited by cutting the lower and upper quartiles (-88 to -94 db), i.e. the signal level varies in the range of ± 6 db. For comparison, the sensors with the 100 ms version of the embeded software and the sensors transmitting the signal in the BLE 5.0 standard had the signal range within ± 2 dB, but it was much weaker by even 18 dB at the short distance and 6 dB at the long distance.

By analyzing the parameters of Bluetooth itself. It can be concluded that the best results were obtained for setting no.5, i.e .: Maximum Scan Responses: 20; Scan Interval: 240; Scan Time: 100; Scan Window: 160. The highest number of packets were received for such settings (they were rarely lost).

The quality of the received signal is shown in the figure below (Figure 6) in the form of a mustache frame graph.
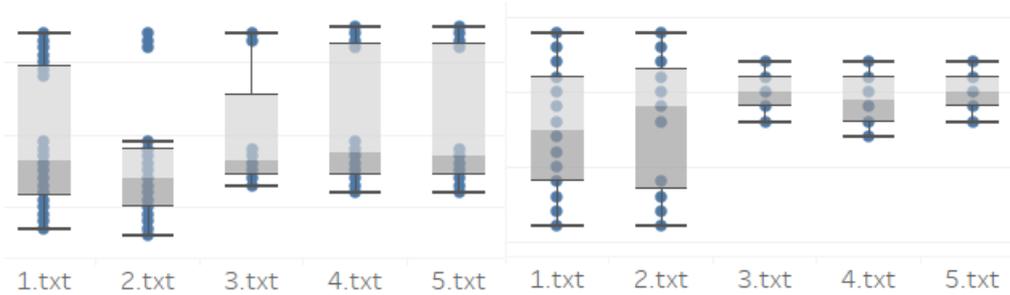
Figure 3. Signal quality for receivers (receiver No. 2 on the right, receiver No. 1 on the left)

As can be seen for the receiver No. 2 located at the greatest distance, the signal quality assessed due to its fluctuations was the best for parameters No. 3, 4 and 5. However, for the receiver No. 1, the quality was the best for parameters No. 1, 4, 5. Taking into account However, taking into account the number of packets received, it should be clearly stated that the signal quality is the best for the parameters No. 5. The dependence of the angle divergent from the real angle as a function of distance was determined.

The acceptable measurement angle error is up to 5 °. For such an error, it is still possible to achieve measurement accuracy of up to 3 m. These calculations do not take into account signal stabilization, which will increase the accuracy of the location.

Further research related to the number of nearby objects and their mutual interference will be carried out at the stage of implementing the system pilot.

3.5. Kalman filter and its influence on distance estimation

Signal measurements in the target work environment were carried out in a printing materials warehouse, a photograph of them is shown in Figure 5.1. Four transmitters were used for it, which moved along a designated track and stopped at a distance of 1m, 3m, 5m, 10m, 15m, 20m from the receiver. The idle time was 5 minutes and the transmission interval was 1 second. As a result, for each sensor, more than 300 RSSI signal strength measurements were obtained for each distance. The measured signal level is shown in the figure below.
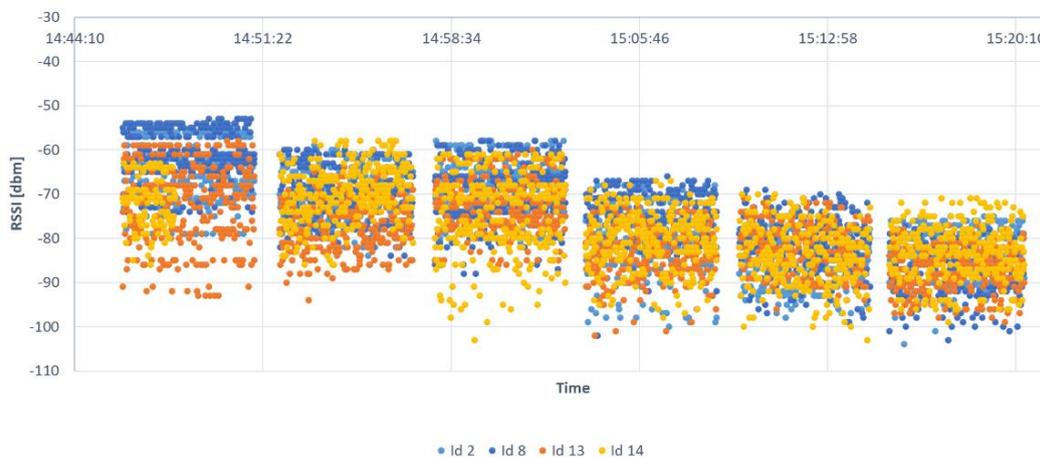
Figure 4. The measured signal level

The figures below show the graphs for the entire measurement period for all distances with the smoothing constant amounting to a maximum of 200 and a minimum of 10. According to the assumption that for a large value of the noise covariance matrix, the Kalman gain will be greater, for the smoothing constant equal to 200, the Kalman gain is approximately 0.954, while for the smoothing

constant of 10, the Kalman gain was about 0.620. The orange color shows the signal after applying the Kalman filter, while the blue color shows the measured signal without using the Kalman filter.
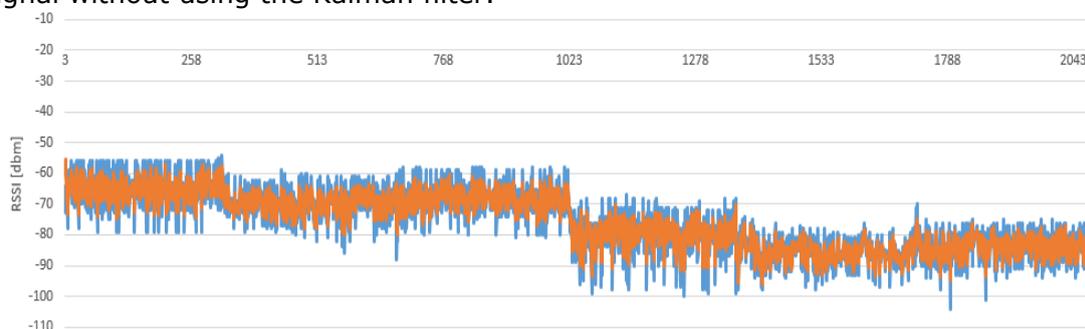
Figure 5. RSSI for raw data (blue) and after using Kalman filter (orange)

The diagram above shows that the measured signal almost coincides with the signal in which the Kalman filter was applied, but the signal fluctuations are much smaller. You can on average change the position of the sensor every 300 measurements, so there are significant limits when the position is changed. The farther away the point, the greater the value of the RSSI signal, so the signal is less well received.

On the basis of the results obtained for the Kalman filter, the distance of the transmitters from the receiver and the measurement errors were calculated. The data of all measured smoothing constants for the sensors were used for this. The calculations are presented in the tabular form below. The determination of measurement errors for the smoothing constant value 200 is shown below.

Table 6. Measurement error after applying Kalman filter

RSSI							
d [m] real	1	3	5	10	15	20	Mean:
d [m] counted	x	2.80	4.30	9.70	16.50	21.40	10.94
measurement error [m]	x	0.20	0.70	0.30	1.50	1.40	0.82
measurement error, max [m]	1.5						
RSSI	-63	-69.2	-71.2	-78.8	-85.2	-82.6	-77.40
n	x	1.1	0.5	1.5	1.8	1.4	1.26

Conclusion

The solution presented in the paper based on the own developed transmitter. The typical one were inaccurate, and can not be implemented. Presented research confirm that the location system based on the Bluetooth technology can be implement in industry. The location based on the Bluetooth is hard to predict. For the signal disruption impact other devices, steal, containers with water and more. But proper data processing and stabilise the RSSI impact on the location precision. The maximum measurement error by using data pre-processing and the Kalman filter can be about 1.5 m. The presented research was used to develop IT system. This system is working for few months in the SKK S.A. client company.

ACKNOWLEDGMENTS

Applications of Data Science/Data Analytics Models in Supply Chain Management- An Advisory Research

Reza Pouraghabagher, Puneet Agarwal

California Polytechnic State University,
San Luis Obispo, CA, USA

Abstract

The volume of academic research for the applications of data science/analytics (DS/A) in the field of supply chain management is rapidly increasing. Although most of the research is rather conceptual, technical and algorithmic-based model building in solving the above problems are becoming more relevant and present in the literature. However, in a great majority of this field of research the voice of industry is absent. This paper discusses the results of a first time, exploratory industry survey to understand the types and extent of the related applications in the U.S. manufacturing companies. The findings were quite encouraging and revealed that our sample companies are broadly active in utilization of DS/A methods in supply chain/logistics business analysis. Additionally, the industry survey showed a few related application areas that can indeed be expanded upon and enhanced with further collaboration between industry and the academic research community.

Background

In the past 10 years, the body of literature contains a variety of publications and information dissemination related to the applications of data science/analytics (DS/A) in the field of supply chain/logistics (SC/L) planning and control. Realizing that the domain for SC/L is quite vast, we may define the aforementioned domain into the following categories. Market research and forecasting as the business front-end, a variety of suppliers related analysis (suppliers' selection; evaluations of lot-sizing policies; quality, on-time delivery, flexibility/responsiveness/risk analysis and financials of suppliers; overall evaluation of suppliers) as the tactical business parameters. The back-end of the business would be contractual obligations/field services. Additionally, internal logistics including the inbound planning/control and warehouse management system (VMS) as well as the external logistics including outbound planning/control, routing and transportation, traceability, regional/international rules regulation and customs requirements add to a large number of business factors generating an incredibly out of control, meta-size data files, both structured and unstructured.

Utilization of DS/DA for the analysis of SC/L problems and scenarios is becoming more relevant and economically attractive in business decision-making. Gartner Research Group has reported $24.6 billion sales of DS/A related software and tools in 2019. Furthermore, the same entity has estimated sales of $1.88 billion of prescriptive analytics software in 2022 (Thomas Reuters, ONESOURCE; August 2020). Since 2016, the World Customs Organization (WCO) has been advocating the strategy of "Digital Customs" while the World Customs Journal is promoting the above concept for enhancing the performance of Customs (Desidero D., 2019). The statistics on the market growth for DS/A applications in SC/L are indeed too many to include within the limitations of this paper. However, what is clear is that industry and commerce are rapidly embracing DS/A methods as a strategically valued approach in business competition.

The body of literature in the above field generally consists of two categories. One is conceptual and informative while the second category is technical and algorithmic-based analysis. On the conceptual theme of this topic (to be referred to as DS/A-SC/L), a comprehensive coverage of literature for the period of 2010-2016 is

conducted along with an introduction to various DS/A methods and areas of applications in industry (Tiwari, S., et al, 2018). A number of examples are provided but mainly on big data collection through industrial sensors; however, specific DS/A methods/algorithms used for solving industrial problems are not provided. The paper concludes the needs for applications of DS/A in specific industries to assist in decision-making for supply chain agility and sustainability. Another paper offers very practical recommendations about the potential areas of SC/L that DS/A may be applied to in the industry (Waller, M., et al, 2013). The authors provide examples where the practitioner may apply DS/A techniques while facing the three important axes of data volume, velocity, and variety, (3Vs). Another excellent summary and graphical depiction of DS/A data collection areas, versus the big data 3Vs, is documented by Rozados (2014). To include another worthy reference, especially for a beginning researcher, IntechOpen provides an easy-to-follow chapter on DS/A-SC/L applications with numerous definitions and references (Darvazeh, S.S., et al, 2020).

On the technical and algorithmic coverage of DS/A-SC/L, a literature review on machine learning applications in SC/L is included in the Hamburg International Conference of Logistics (Wenzel, H., et al, 2019). It provides an explanation of supervised, unsupervised, and reinforcement learning and provides some clues in application limitations. The paper includes future research that reveals industrial practices. Meanwhile, a number of other researchers have actually applied machine learning algorithms in solving SC/L problems. Examples include a collaborative filtering-based approach of KNN machine learning data classification algorithm to recommend the selection of suppliers for manufacturing companies (Pouraghabagher, R., et al, 2018); an inductive learning algorithm to assess inventory replenishment policies (Priore, et al, 2019); and enhanced hybrid ensemble machine learning for forecasting the credit risk on supply chain finance (Zhu, et al, 2019). The authors of these three research citations have shown the details of their algorithms for other researchers to replicate in related scenarios.

However, both types of research activities in DS/A-SC/L, conceptual/general and technical/algorithmic, are missing an essential element; that of the voice of true customer (= industry). As far as we have searched, we could not find any DS/A-SC/L research project that has been validated by an industry partner. Hence, we had the following question: Is our research community going in the right direction in this highly transformative field?   It became necessary to conduct an exploratory industry survey to see the practices that are taking place in DS/A-SC/L by business enterprises and to attempt a topical mapping between research and practice with the goal of providing more clarity and future guidelines for researchers on this topic.   Most of our survey questions were on the technical aspects of DS/A-SC/L applications as we will discuss them later in this paper. However, before presenting the survey analysis, and to pave the way for a better understanding of our questions, the next section will provide the reader with a practical summary of DS/A methods. (Courtesy note to the reader: In the next section, publication's page limitations have resulted in somewhat packed but hopefully informative contents.)

Practical Summary Guideline for Data Science/Analytics Methods

The following section provides the researcher with a set of specific, practical and informative guidelines related to the three types of DS/A methods: Descriptive, Predictive, and Prescriptive analytics.

Descriptive Analytics

It is the process of using historical data to identify patterns, trends, and anomalies for improved planning and decision-making. It is the simplest and quickest form of data analysis that often serves as a backbone for predictive and prescriptive analytics. Descriptive statistics are used to describe the main features of the dataset using numerical values, summary tables, or visualizations. When dealing with numerical features, descriptive statistics can help answer the following questions: what the most typical values are (central tendency), how do values vary (variability), are the values symmetrically or asymmetrically distributed (shape), are there values representing abnormalities (outliers), and how can we graphically represent values (visualization) for effective storytelling and communication. When dealing with summary measures of numerical features, different types of visualizations can be used such as a histogram to show the frequency distribution of a numerical feature and a box plot to illustrate the standard quantiles, shape, and outliers of data. When dealing with categorical features, it is often useful to understand the number and percentage distribution of observations within each category or combinations of categories. Bar charts are most frequently used to visualize categorical data. An effective approach to analyzing the relationship between two features is to use correlation analysis. Pearson's correlation coefficient is a widely used statistical metric to assess the strength of the linear relationship between two features. Although a very useful metric, it can be difficult to visualize the exact association between two features based on this single statistical measure. In contrast, a scatter plot provides a graphical representation of the linear pattern between the two features. A scatter plot matrix shows the whole collection of data features arranged into a matrix. This is useful for exploring the relationships between groups of features. After completing exploratory data analysis, univariate and multivariate statistical inference can be used to deduce statistical properties of data such as confidence intervals, hypothesis testing, and comparing means of multiple groups.

Predictive Analytics

It is the process of building and using models that can make predictions about future events based on patterns extracted from historical and real-time data. Most of the existing research on Predictive Analytics has used Machine Learning (ML) as the main approach to automate the process of extracting patterns from data. The main advantages of using ML in complex and dynamic environments such as manufacturing, supply chain, and logistics are: (a) the ability to efficiently handle high-dimensional and multivariate data, (b) the ability to extract implicit relationships within large data sets, and (c) the ability to learn from and adapt to changing environments automatically (Köksal, G., et al, 2011). Machine learning approaches are broadly classified into three categories: supervised learning, unsupervised learning, and reinforcement learning. Supervised learning techniques are used to learn the relationship between a set of descriptive features and a target feature based on a set of historical examples (called *training* dataset). After the model is trained, it can be used to make predictions for new, unseen instances (called *test* dataset). In contrast with this, unsupervised learning techniques are used in the absence of a target feature to model the underlying structure within descriptive features in a dataset. Finally, reinforcement learning is an ML approach that enables an agent to learn in an interactive environment by trial and error using its own actions and experiences.

Based on the type of prediction output, supervised learning is classified into two categories: classification and regression. In classification, the goal is to predict discrete values such as classifying emails into spam and non-spam. Whereas the goal of a regression model is to predict continuous values such as house prices, losses due to wildfires and other business and socio-economics factors, Table 1 shows different learning paradigms as well as the corresponding algorithms used to build supervised learning models.

Table 1: List of Supervised Learning Paradigms and Algorithm

Learning Paradigm	Common Algorithms
Information-based Learning	Decision Tree (DT), Random Forest (RF), XGBoost (XGB), AdaBoost (AB)
Similarity-based Learning	k-Nearest Neighbor (k-NN)
Probability-based Learning	Naïve Bayes (NB)
Error-based Learning	Multiple Linear Regression (MLR), Logistic Regression (LR), Support Vector Machines (SVM)
Deep Learning	Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN)

In DT, the training instances are classified into a tree structure using decision rules that are heuristically derived using a recursive partitioning algorithm. DTs are easy to understand, interpret, and visualize. The disadvantage of DT is that it is highly unstable and even a small change in the training dataset can result in a large change in the tree structure and decision rules. RF, XGB, and AB are ensemble models that make a prediction by aggregating the predictions of different decision trees in the ensemble. Ensemble models are robust to outliers and noise, and thus offer better predictive performance in comparison to using a single DT. The k-NN algorithm makes predictions by measuring similarity between training instances using distance metrics. When the size of the dataset grows larger, k-NN proves to be computationally expensive. NB is based on Bayes' Theorem with an assumption of independence among descriptive features. Due to its simplicity, it works efficiently even with large datasets and is found to provide good results for natural language processing (NLP) tasks. In MLR and LR, a parameterized prediction model is initialized with a set of random parameters. An error function is used to iteratively adjust the values of the parameters to create an accurate model. SVM works on the principle of finding a hyperplane in an N-dimensional space to distinctly classify the data points. SVM uses different kernel functions to transform the data in raw representation into a high dimensional feature space wherein operations such as inner dot products are computationally cheaper. ANN is composed of an input layer that receives the signal, an output layer that makes a prediction about the input, and several hidden layers that learn complex relationships. ANN uses the backpropagation technique to iteratively adjust bias and weights so that the error between the actual output and the desired output is minimized. CNN is a type of ANN that is primarily tailored to process grid-like data, such as image data.

There are two main use cases for unsupervised learning: clustering and representation learning. Clustering is a technique that divides the instances into groups or clusters that are similar to each other, such as groups of customers based on their purchasing behaviors. Algorithms that are commonly used for clustering are k-means clustering, agglomerative hierarchical clustering, and Density-based Spatial Clustering of Applications with Noise (DBSCAN). Representation learning is used to learn new sets of generated features to represent an instance in a dataset. Commonly used models for representation learning are Principal Component Analysis (PCA) and Auto-encoder which is a special type of neural network. While reinforcement learning has been a topic of much interest in the field of artificial intelligence, its widespread, real-world adoption has remained limited. The common application of reinforcement learning is in learning to control the behaviors of autonomous systems such as training robots to perform tasks and automated players to play games.

Challenges that are typically faced while working with predictive analytics can be broadly categorized into model-based and data-based issues. Selecting an ML algorithm depends on many factors and there is no single algorithm that is universally the best performing algorithm for all prediction problems – also known as the No Free Lunch Theorem. In ML, the main goal is to find the prediction model that generalizes well beyond the training dataset and is not influenced by noise in the dataset. This

allows us to make predictions in the future on data the model has never seen. Overfitting and under-fitting are the two main causes of the poor performance of machine learning algorithms. Under-fitting occurs when the prediction model is too simplistic to represent the underlying relationship in the dataset between the descriptive features and the target feature. Overfitting occurs when the prediction model is so complex that the model fits the dataset too closely and becomes sensitive to noise in the data. Typical data issues that are identified when working with predictive analytics include the presence of missing data, outliers, and imbalanced observations. Missing values are generally handled using the imputation method that replaces missing values for a feature with a measure of the central tendency of that feature. The commonly used approach to handle outliers is to use clamp transformations that clamp all values beyond the upper and lower thresholds. The thresholds can be set from domain knowledge or can be calculated from data. Imbalanced data commonly appears in classification problems with skewed class proportions. An effective way to handle imbalanced data is to use resampling techniques such as under-sampling and oversampling.

Prescriptive Analytics

It uses the outcomes of descriptive and predictive analytics, and other analytical techniques such as mathematical optimization, simulation, game theory, multi-criteria decision-making, and expert systems to provide adaptive, automated, constrained, time-dependent, and optimal decisions (Lepenioti, K., et al, 2020, Fontecha, J. E., et al, 2021). Currently, the majority of academic research, software, and industry activity in SC/L analytics focuses on prescriptive analytics as a standalone approach with limited use of information derived from descriptive and predictive analytics as inputs.

Tools that are commonly used for DS/A applications are Excel, SQL, Python, R, Tableau, and Power BI. Excel is a simple tool that can be used for basic data manipulation and analysis. It can also be used to quickly create graphs and charts such as bar charts, pie charts, scatter plots, and box plots. However, Excel is not well suited for complex data analysis and manipulation since it cannot handle data that has more than 1 million rows. SQL is a database language designed for the retrieval and management of data in relational databases. SQL is much more efficient than Excel in handling big data but has a steeper learning curve. Python and R are free, open-source programming languages that can efficiently handle big data. Python is not just used for DS/A, but also for a wide variety of tasks such as web application development, automation, and scripting. R is a statistical programming language built primarily for statistical computing and data visualization. Tableau and Power BI are frequently used to create interactive dashboards and graphs. Although R and Python are better suited for processing data and creating predictive and prescriptive models, Tableau and Power BI offer better ways to communicate data-driven insights to non-technical people through interactive dashboards.

Industry Survey Results

Our industry survey consisted of 20 clear and pointed questions. The respondent were assured that their companies' names would be kept confidential. Eleven companies responded to our survey with a response rate of 65% (11/17). The general profile of the respondents are summarized below. **Due to the page limitation requirements, the beginning bold statements are shortened versions of the survey questions.** The responses from 11 participating companies are underlined.

Type of business: Manufacturing (1/11); Design + Manufacturing (9/11); Retail (1/11)

Size of company: Small (1/11); Medium (2/11); Large (8/11)

Market segments: Civilian/Commercial (5); Defense/Military (2); Civilian+ Military (4)

Types of business model (number of companies in the sample size of 11)

A. BTS	B. ATO	C. BTO	D. ETO	A+B	A+C	B+C	A+B+C
0	0	1	2	1	1	0	6

BTS: Built to stock, ATO: Assemble to order BTO: Build to order, ETO: Engineer to order

Do companies have a specific DS/A function or group? Yes (9/11); No (2/11)

Organizational model for DS/A function: Centralized (5/9); Decentralized (4/9)

Does DS/A function have a strategic value? Yes, definitely (6/9); Yes, but reluctance to use DS/A as some staff do not understand it (1/9); No, need more education and training (1/9)

Do companies have a specific SC/L function or group? Yes (10/11); No (1/11)

Organizational model for DS/A function: Centralized (5/9); Decentralized (4/9)

Does DS/A function have a strategic value? Yes, strongly ((7/11); Yes, but equal to other areas (2/11); Yes, somewhat (1); No (1/11)

Total number of domestic + international suppliers: 1 to 20 (1/11), 50 to 100 (2/11), 300+ (8/11)

IS SC/L function data driven? Yes (4/11); Often + subjective opinions (6/11); Mainly subjective opinions (1/11)

Does SC/L function use DS/A methods to solve business problems? Yes, frequently (5/10); Yes, occasionally (3/10); No (2/10)

Why doesn't SC/L function use DS/A methods? SC/L Does not understand DS/A methods and DS/A does not understand the SC/L function (2/3); Other organizational issues (1/3)

Table 2- Question: What are the main DS/A approaches used in solving SC/L problems? **Please select all the answers that apply.**

Descriptive Analytics	Predictive Analytics	Prescriptive Analytics
100% (response rate)	78 %	67%

Table 2 shows how companies use all areas of data analytics with descriptive analytics being a unanimous application. One note of caution is necessary about the relatively high response rate for the utilization of prescriptive analytics (67%). As discussed in the previous section, the outcomes of descriptive and predictive analytics can be, and should be, used as guidelines to model the prescriptive analytics. Presumably, some practitioners may have applied the prescriptive analytics as a stand-alone approach for solving SC/L problems. However, using the findings from the previous two stages (descriptive and predictive analytics) can indeed provide a better-defined framework and more clear input to the process of prescriptive analytics.

Table 3 - Question: In which of the following areas has your DS/DA Group collaborated with and helped your SC function? **Please select all the answers that apply.**

Area of Collaboration	% of responding companies (rounded)
Marketing	38
Sales forecasting	100
Lot sizing policies	38
Warehouse Management System (VMS)	25
Logistics (external)	63
Suppliers selection	25
Suppliers overall evaluation	50
Suppliers Quality	63
Suppliers flexibility	25
Suppliers on-time delivery	63
SC financials	50
Field services and contractual obligations	63
Other	50

Table 3 reveals that U.S. companies utilize DS/DA methods in every aspect of SC/L decision making. However, sales forecasting is reported to be used by all respondents while external logistics (domain of data for inbound/outbound, transportation, traceability, international borders/customs regulations) was ranked second (63%), along with suppliers' quality and on-time delivery. Supplier selection and VMS (along with supplier's flexibility) were the lowest areas for which DS/A methods were used. However, the field of academic research contains a number of useful DS/A models that may be of interest to industry for those topics. Furthermore, the field of VMS is rather rich in terms of the 3-Vs of DS/A which makes it a potential area for experimentation by industry.

Table 4 - Question: Which of the following applications of SC/L function in your company experiences Large/high data volume, variety and velocity? **Please select all the answers that apply per each V.**

Potential SC/L Areas for DS/A Utilization	Volume	Variety	Velocity
Marketing	28 % response	37 % response	30 % response
Sales forecasting	73	73	60
Lot sizing policies	28	46	30
Warehouse Management System (VMS)	37	19	40
Logistics (external)	82	64	60
Suppliers selection	28	46	30
Suppliers overall evaluation	55	46	40
Suppliers Quality	37	27	50
Suppliers flexibility	37	19	20
Suppliers on-time delivery	46	28	40
SC financials	37	46	40
Field services and contractual obligations	28	28	30
Other	28	28	30

Table 4 summarizes various areas of SC/L functions that companies have experienced the 3-V qualifiers as potentials for DS/A utilization. Seemingly, all areas indicate possibilities of DS/A utilization with sales forecasting, external logistics, and suppliers' overall evaluation at the top with relatively high 3-Vs. An interesting observation is despite the fact that manufacturing companies typically receive a large volume and variety of field services data, this particular area of application has received relatively low responses across 3-Vs.

Table 5 - For Data visualization aspects of SC problems, what specific methods does your DS/DA Group or staff employ? **Please select all the answers that apply.**

Data Visualization Methods	% of Responding companies (rounded)
Two-dimensional graphics	100
Multi-dimensional graphics	30
Time series	90
Single-variate visuals	60
Multi-variate visuals	40
Pie charts and other similar charts	60
Statistical distributions graphics	60
Correlation analysis	60
Regression analysis	60
Other	40

Table 5 shows that our industry respondents utilize most of the popular data visualization methods, while 2-D and time-series graphics seem to be the most used. It should be noted that multi-dimensional graphics was the lowest rank category despite the fact that it is indeed a sophisticated and highly effective graphical communication method. However, experience has shown that it is often challenging to explain the results to inexperienced users.

Table 6 - For predictive analytics aspects of SC problems, which of the following methods have been utilized by your DS/DA Group or staff? **Please select all the answers that apply.**

Predictive Analytics Method	% of Responding companies (rounded)
Regression using Supervised Machine Learning	56
Classification using Supervised Machine Learning	67
Unsupervised Machine Learning	45
Deep Learning	34
Time Series Forecasting	78
Reinforcement Learning	34
Other	44

Table 6 reveals that industry is indeed applying well-established predictive analytics methods with time series forecasting and classification using supervised machine learning being the top choices. It is not surprising that our survey has revealed lower percentage rates for the use of unsupervised machine learning, deep learning and reinforcement learning as these three methods are the most complex among the DS/A models.

Concluding Remarks

The purpose of this research project was to conduct an exploratory investigation using an industry survey to reveal the commonality, as well as the differences, that may exist between the research community and industry practices in the field of DS/A applications for conducting SC/L business analysis. The results of the survey revealed that there is indeed a large overlap of activities in the above field across both communities. However, there are some differences in applications that we presume are due to the lack of communication/linkage between the academic research and industry. These gaps of technical commonality for DS/A-SC/L can hopefully be improved through future collaboration and joint projects.

Our research has several limitations that should be countered in the future. The responding companies were all but one U.S. manufacturing enterprises. We recommend future research to be conducted by including a larger number of companies in both manufacturing and retail, from different countries or regions of the world, especially Europe and Asia. Furthermore, the types of questions need to be more probing in terms of the details of the technical aspects of DS/A methods and models in all three areas of descriptive, predictive, and prescriptive analytics.

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MACROLOGISTICS SUPPLY CHAINS IN SOUTH AFRICA:
The case for measurement
Zane Simpson, Jan Havenga, Anneke de Bod, Stefaan Swarts
University of Stellenbosch
E-mail: zane@sun.ac.za

INTRODUCTION

Macrologistics refers to the strategic management of a country's supply chains to support the attainment of macroeconomic goals. These goals frequently focus on supply chain cost reductions to increase the competitiveness of industries, but could also include, amongst others, guiding spatial development, creation of local beneficiation clusters and upliftment of rural economies. The objective is, in fact, to achieve the lowest cost of ownership (considering all production factors) of an economy. (Havenga, 2018). The macrologistics prerequisite for informing the inherent trade-offs underlying these macroeconomic goals is the estimation of granular freight flows based on an understanding of disaggregated commodity-level volumetric supply (origins) and demand (destinations) in the economy. (Havenga et. al. 2019).

The results of such a freight-flow model for South Africa indicated that surface freight transport volumes (i.e. road and rail) amounted to 865 million tonnes in 2019 – i.e. to facilitate the interaction between supply and demand in the economy, origin-destination pairs for 865 million tonnes of freight are created (refer Figure 6 for a geographical depiction of these flows). However, actual shipment volumes exceed supply and demand volumes because of the nature of value and supply chains. The use of consolidation and distribution centres, common-use facilities and other requirements in supply chains could all cause multiple shipments for a single supply-and-demand pair. In South Africa's case, this resulted in 1 635 million tonnes shipped in 2019, i.e., on average, each freight tonne is shipped nearly twice (1.89 times).
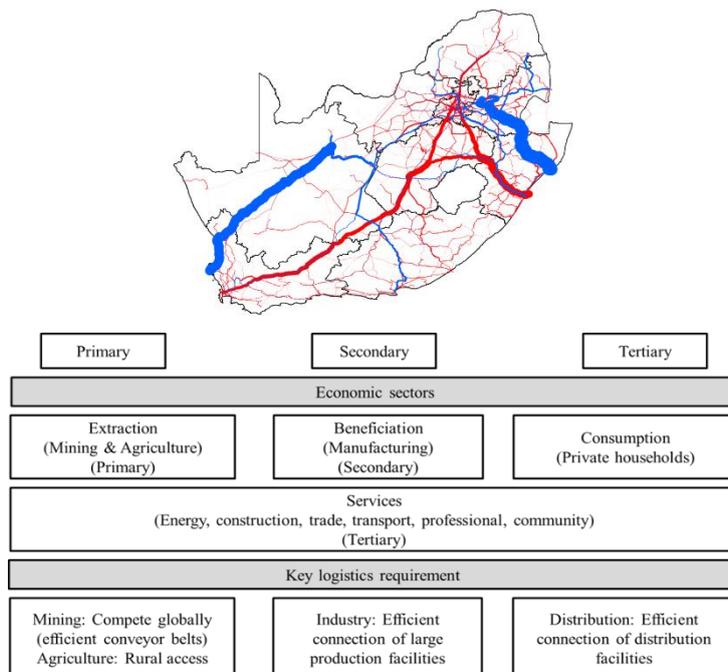
Figure 6. All South African freight flows (road freight in red and rail freight in blue) based on 2019 data from the FDM™ and the resultant value chain of these flows.

This average however obscures the fact that large volumes of bulk export minerals and domestic mining minerals (totalling 421 million tonnes in 2019) are mostly shipped only once, and coal produced for mine-mouthed power stations (totalling 108 million tonnes in 2019) are not shipped at all. This implies that the remaining cargo,

mainly comprising intermediate and final manufactured commodities, currently require complex supply chain solutions with many shipments between supply and demand points facilitated by an array of logistics facilities. One of the goals of macrologistics management is to define and quantify these macrologistics supply chains to identify potential opportunities for improvement. A high-level summary of these outputs is provided in this document.

MACROLOGISTICS SUPPLY CHAIN SEGMENTATION
Distinct macrologistics supply chains are derived from the economy's basic value chain and its related logistics requirements, as illustrated in Figure 1.

Freight flows take place from the place of extraction or manufacturing to the place of utilisation or consumption. Volumes are skewed towards the extraction stages of value chains, and costs towards the consumption stages. Figure 2 illustrates the volume and cost distribution between the two extraction sectors of the economy (mining and agriculture), semi-beneficiated products and final products ready for consumption.
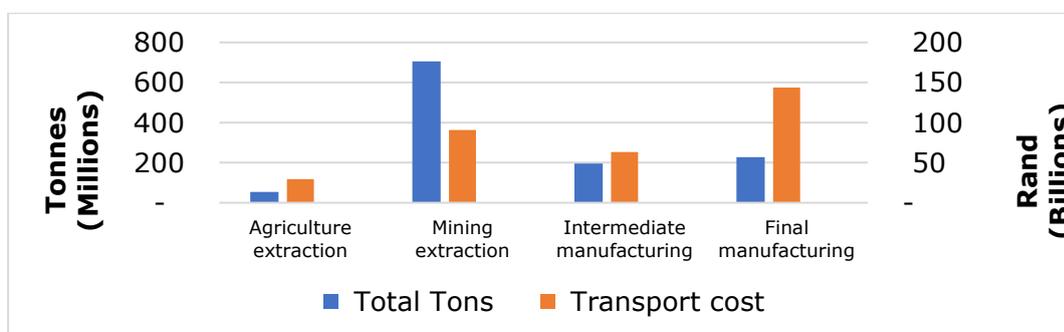
Figure2. Volume and logistics cost distribution for South Africa's macrologistics supply chains based on 2019 data from the FDM™ (Havenga, de Bod, Simpson, Swarts & Witthöft, 2021:18)

The extraction stages of value chains require bulk handling facilities and large volume transport solutions that cost less per ton relative to solutions for higher-value commodities. However, due to the lower value of mining and agricultural commodities, transport and logistics add relatively more value, i.e. contributing a larger portion of the delivered cost of commodities. (The transport cost of one ton of coal is significantly less than the transport cost of a one-ton car, but the transport cost portion of the delivered cost of one ton of coal is significantly higher). This phenomenon has an important effect on how these supply chains develop. Cost pressures in extraction supply chains are high, but so are volumes; high-volume solutions that drive cost down are attractive. In the ultimate case, for very simple bulk solutions, like the conveyor-belt type flows of commodities from a mine to an export port, such as for coal, iron ore or manganese, logistics costs can be relatively low, but cost pressures very high. In general, most of these supply chains are relatively straightforward and it is often possible to complete the supply-and-demand pair with a single solution and mode.

Volumes decline towards the beneficiation and consumption stages of value chains, yet matching supply and demand pairs often require more complex solutions involving many different shipments. Service providers along this chain can be either a creator of a complete chain or compete to be inserted as a contributor to this chain. Where a total chain is created (such as with a 3PL) by what could be called a "channel captain", the creator can subcontract portions of this chain to 2PL's.

The supply chain view could take various perspectives. It could be a modal view where, for instance, the same supply-and-demand pair requires a first-mile leg, long haul and a last-mile leg utilising different modes for the various legs. Road and rail

are common in South Africa for domestic freight, but in some countries, this could include waterway and coastal shipping. (Some coastal shipping in South Africa does take place, as well as flows where the long-haul portion of the supply-and-demand pair is in pipelines). The supply chains can also be company-specific where large portions of the chain are occupied by a single business, such as Sasol, which holds positions in extraction, conversion, manufacturing and even retailing in energy and chemical supply chains. Supply chains can also be industry-specific where industry associations or loose combinations of industry players organise these supply chains. The basic macroeconomic value chain depicted in Figure 1 gives rise to five distinct supply chains in the South African context:

1. Large-volume export mining flows: Exports of coal, iron ore and manganese.
2. Domestic mining flows: Movement of local minerals to domestic beneficiation centres.
3. Beneficiation (intermediate manufacturing) flows (siding-to-siding for rail, or dedicated road-handling facilities at different plants): Flow of semi-beneficiated commodities between intermediate and final processing facilities.
4. Consumption value chains: The flow of FMCG commodities of higher value between manufacturing facilities, distribution centres and retailers.
5. Rural extraction and delivery: The flow of agricultural bulk from rural areas and delivery of consumer goods to these areas

In the next section, a summary of the salient characteristics, logistics costs and improvement opportunities of each macrologistics supply chain is provided. Macrologistics costs are comprised of transport costs, storage, handling and road distribution costs (last-mile

CHARACTERISTICS OF SOUTH AFRICA'S OVERARCHING MACROLOGISTICS SUPPLY CHAINS

As mentioned, South Africa's supply and demand pairs total 865 million tonnes, comprising 83 million tonnes agriculture, 551 million tonnes mining and 231 million tonnes manufacturing.

Large volume export mining supply chains

South Africa's volumetric freight flows are dominated by three export mining commodities, namely coal, iron ore and manganese, amounting to 156 million tonnes (i.e. 18% of total supply and demand pairs and 88% of the total export mining flows of 178 million tonnes). Export coal and iron ore use dedicated "conveyor belt" type rail lines with dedicated sidings and dedicated loading-offloading equipment (most export coal uses the coal line between Ermelo and Richards Bay and export iron ore the iron ore line between Sishen and Saldanha).
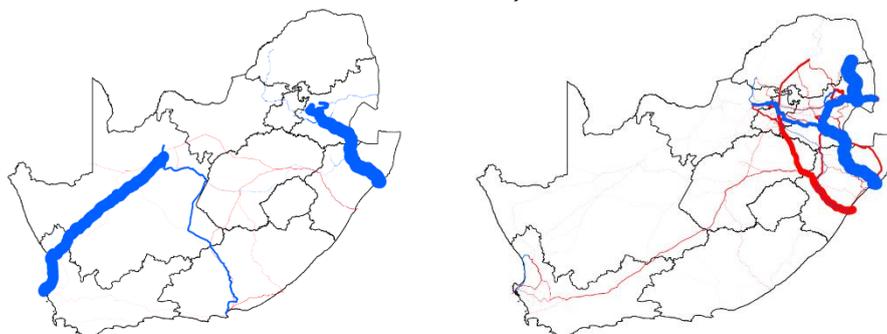
Figure 3. Large volume export commodity flows (on the left) and other export commodity flows (on the right) and in South Africa (i.e., coal, iron and manganese; road freight in red and rail freight in blue) based on 2019 data from the FDM™

The use of the rail mode is only limited by available capacity; in fact, customers match volumes to rail capacity to avoid additional supply chain costs to maintain the competitiveness of these primary commodities on global markets. Manganese flows are typically on the general freight rail network between Kuruman and the dedicated

terminal in Port Elizabeth. However, due to the higher market value of manganese, road transport is utilised when rail capacity is insufficient, and other rail routes to export ports have also been developed, such as utilizing the iron ore export line and developing a road and rail route to Luderitz in Namibia. Large volume export commodity flows are depicted in Figure 3.

Other export mining commodities often behave similarly to manganese with a mixed modal split favouring rail where capacity is available to facilitate the lowest cost logistics solutions. In some instances, such as for the 13 million tonnes of chrome exports in 2019, mines jointly own and operate common-use facilities, resulting in a first-mile move from the various mines to the common-use facility. Some logistics solutions consider this, and rail, though dominant, now have to consider that an additional transfer is necessary and plan for this. Other export mining commodity flows in South Africa is depicted in Figure 3.

Within large volume export mining supply chains, the logistics costs component differential between the dominant bulk export commodities and smaller mining commodities with slightly more complex flows is already evident. For the dominant export mining commodities of coal, iron ore and manganese, transport costs typically comprise almost 100% of logistics costs and focusing on providing and maintaining adequate conveyor-belt type infrastructure is the key logistics requirement. For the bulk other mining exports on NatCor (which represent the majority of other export mining flows on road) 2019 road logistics costs are distributed between transport (75%), handling (13%), storage (8%) and last mile (4%), highlighting that the management of other logistics cost components require more attention.

Domestic mining supply chains
Rail's competency in the movement of domestic mining commodities to beneficiation centres is relatively well-established, especially in the domestic coal and manganese segment. The challenge is that these flows do not follow typical freight corridors, but often rural routes, e.g. iron ore from Sishen to Newcastle, manganese from Kuruman to VanderBijl, or coal from coal mines to power stations. This freight is clearly rail economical (Havenga et. al. 2021, p. 14 – 15) and it is challenging for road infrastructure in rural areas to entertain a large number of heavy road vehicles. Rail capacity failures in this regard should therefore be of concern. The rail gap in the transport of domestic mining is mostly around the coalfields, although there are also sizeable amounts of coal on the N1 and some manganese flows that require attention.

Manganese is a high-value commodity, therefore less cost-sensitive than coal and iron ore and shifts to road even more easily during rail capacity challenges. Figure 4 illustrates domestic mining commodity flows in South Africa.
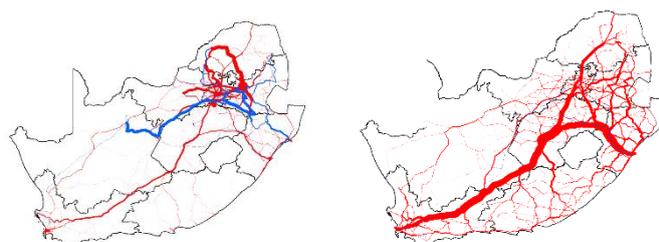
Figure 4. Domestic mining (left) and agricultural (right) commodity flows in South Africa (road freight in red and rail freight in blue) based on 2019 data from the FDM™

The first portion of this supply chain is the same as for export mining (dedicated sidings with some common use facilities), but these supply chains usually end up at a production siding or road receiving facility. As an example of the cost structure for

domestic mining bulk, on NatCor the 2019 road logistics costs are distributed between transport (69%), handling (10%), storage (8%) and last mile (13%).

Agricultural supply chains

Agricultural supply chains are similar to that of domestic mining with dedicated sidings, but common-use facilities, such as silos are often utilised.

As an example, beef production in South Africa has become more vertically integrated as many large commercial feedlots also own their own abattoirs. These feedlots also sell directly to consumers at their own retail locations. Abattoirs are also expanding downwards in the value chain and starting to enter the wholesale market.[1] In the milk segment, farmers store milk in cooling tanks until it is bought by a milk buyer and transported to their processing facility[2].

In contrast, most grain farmers do not have their own on-site storage facility. This is mostly due to needing the revenue from the current year's harvest to prepare for the next year's crop. They, therefore, store their commodities in commercial grain silos of which the large majority (95%) are on the rail network. Due to changes in the grain commodity landscape, more grain processors are willing to buy directly from farmers which could see an increase in on-farm storage in the coming years.

Agricultural or rural freight typically exhibit low-density flows and dispersed collection points, making rail economics more challenging. Figure 4 illustrates all agricultural flows. However, once consolidated at e.g., silos, and provided there are sufficient volumes, the same approach as with domestic minerals can be followed. Rail-friendly characteristics are also improved if the cargo has to be moved over long distances to production centres and begin to follow corridors. A sizeable portion of this freight could therefore potentially be classified as rail-friendly and a road-to-rail strategy must also consider service offerings here to support the development of rural economies.

For domestic agricultural bulk supply chains, transport currently remains the major road logistics costs component (the majority of this segment is on road). Compared to domestic mining, however, the shift in road logistics costs towards the last mile is evident (2019 data):
- The Cape Town corridor – Transport 67%, handling 5%, storage 5% and last mile 23%;
- The Natal corridor – Transport 63%, handling 8%, storage 8% and last mile 21%.

Beneficiation supply chains

Beneficiation or intermediate manufacturing flows refer to large industrial value chains where an intermediate step is required before a final product is manufactured (refer Figure 5). These flows follow corridors much more than mining and agricultural flows, and mostly use dedicated sidings or road receiving/dispatching facilities, sometimes with common-use facilities. An example is the manufacturing of steel coils at Mittal Steel Vanderbijl that is subsequently shipped to Volkswagen for car manufacturing. Usually, the two centra (in this case Mittal and Volkswagen) should have rail sidings and can easily be connected by a rail service. With large consignments (as is often the case), block trains or at least rakes can economically be used, with smaller wagon loads these wagons have to be collected from sidings in an area, taken to a shunting yard, built into a train and follow the same process on

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[1] A Profile of the South African Beef Market Value chain 2019, Department: Agriculture, Forestry and Fisheries
[2] The Milk SA guide to dairy farming in South Africa, 2nd edition, Milk SA

the other side, which is obviously less economical. However, once again, large volumes of the same commodities over long distances can here be defined as rail-friendly. A revitalisation of industrial sidings, and the re-insertion of rail in industrial value chains, is a critical component of any road-to-rail strategy.
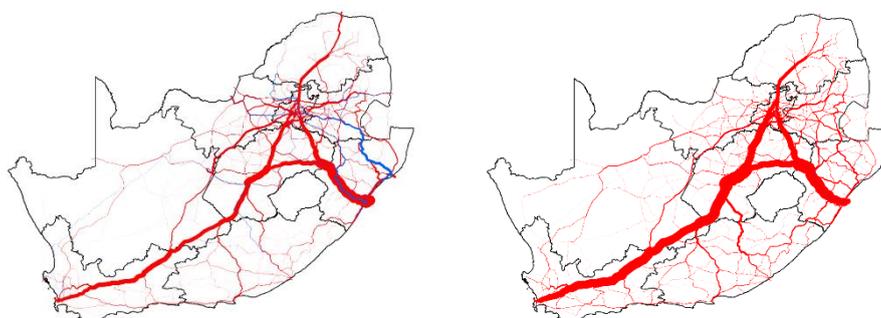
Figure 5. Beneficiation (left) and consumption (right) flows in South Africa (road freight in red and rail freight in blue) based on 2019 data from the FDM™

In 2019, road logistics costs for domestic heavy break bulk on the various corridors were as follows:
- NatCor: transport 56%, handling 13%, storage 13% and last mile 17%.
- CapeCor: transport 58%, handling 10%, storage 10% and last mile 22%.
- SouthCor: transport 56%, handling 10%, storage 10% and last mile 23%.

If dedicated supply chains can be developed where commodities can be transported from a rail siding or a dedicated road transport facility from the initial point of beneficiation to the point of final intermediate input, i.e., without the need for redistribution or a last-mile leg, logistics costs can be reduced.

Consumption supply chains
Large volumes of finished palletised commodities (in South Africa mostly packaged food with some textiles, toiletries, pharmaceuticals and beverages) are moved between distribution centres on a core network connecting three predominant centra, Gauteng, Cape Town and Durban, and several other large peripheral centra such as Port Elizabeth, East London, Bloemfontein, Kimberley and Nelspruit. This freight is higher in value, follows main commercial corridors such as the N1 and N3, and is often transported over long distances on road, frequently in a pallet-friendly curtain-side interlink (refer to Figure 5).

Road line haul costs remain the largest cost contributor for both light break bulk and palletised goods on the two major domestic freight corridors (refer to Table 1).

Table 7. Road cost components for consumption value chains on South Africa's two main general freight corridors based on 2019 data from the FDM™

ROAD COST COMPONENTS	Transport	Handling	Storage	Last mile
Domestic light break bulk				
Capecor	65%	6%	6%	22%
Natcor	57%	11%	11%	20%
Domestic palletised				
Capecor	56%	10%	10%	24%
NatCor	46%	17%	17%	19%

In contrast to beneficiation chains (such as intermediate inputs into automotive manufacturing, where more specialised equipment is required for loading and

offloading), manufactured goods can be unitised and more standardised handling is possible. In these chains however feeder and distribution services will always be required. In the case of South Africa, the line haul cost is the core element where significant cost reduction opportunities can be engineered through domestic intermodal solutions. A modal shift objective, where road long-haul is replaced by rail, should consider the total supply chain, including the terminals, links, consolidation and distribution functions, the unitisation of freight and more complex commercial arrangements. It is not as simple as only providing a rail solution in isolation.

In South Africa, rail however does not have a service offering for palletised long-distance freight despite this freight complying with all the aspects of rail economics i.e.:

- It is unitised onto pallets and can be easily unitised into pallet-friendly containers making the resulting 'commodity' uniform,
- It follows highly densified routes, and
- It has dense origin and destination points.

(also refer to the textbox earlier in the document).

In the developed world this type of freight is often transported via rail between distribution centres, with the first and last mile on road. A domestic intermodal solution must be developed for this freight in South Africa – typically rail for long, dense flows, with road providing feeder services at both ends (refer to Figure 6).
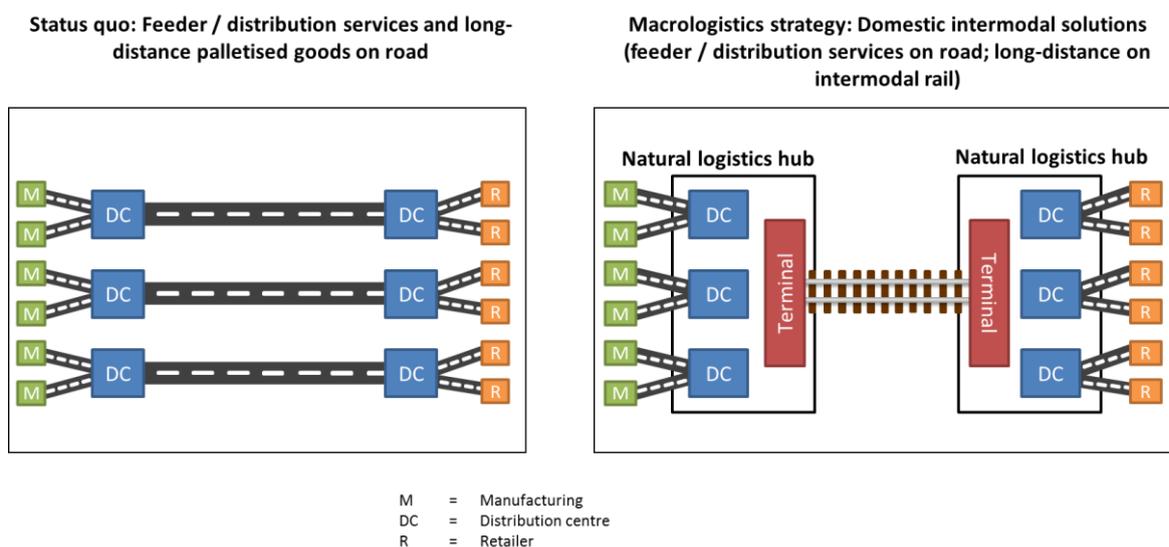
Figure 6. Freight consolidation opportunities enabled by domestic intermodal solutions (Simpson, De Bod, Havenga, Van Dyk & Meyer, 2021:194)

CONCLUSION
Transport costs as a percentage of road logistics costs decline as supply chains become more complex. Consider the example of NatCor (refer to *Table 8*).

Table 8: Natal corridor road logistics cost distribution based on 2019 data from the FDM™

ROAD LOGISTICS COSTS	Linehaul	Storage	Handling	Distribution
Export mining (excluding export lines)	75%	8%	13%	4%
Domestic mining	69%	8%	10%	13%
Agriculture	63%	8%	8%	21%
Beneficiation	56%	13%	13%	17%
Consumption - light break bulk	57%	11%	11%	20%
Consumption – palletised	46%	17%	17%	19%

Within beneficiation and consumption supply chains, transport costs are still important but transporters must consider their effect on other supply chain elements which become increasingly important. As an example, when modal shift is considered, rail line haul does not only compete with road line haul but also has to consider the fact that the rail mode will have significant impacts on storage, handling and distribution. For instance, storage costs and handling costs might be negatively impacted. This impact could be negated by lower rail transport costs, but also more seamless and effective transfer between rail, storage and distribution.

This analysis emphasises the importance of a nuanced macrologistics approach informed by detailed market segmentation based on *inter alia* supply chain types and modes.

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MAPPING THE TERRAIN FOR THE LEAN SUPPLY CHAIN 4.0

Olivia McDermott
National University of Ireland, Galway, Ireland
E-mail: Olivia.McDermott@nuigalway.ie
Jiju Antony
Dept of Industrial & Systems Engineering, Khalifa University, United Arab Emirates
Michael Sony
WITS Business School, University of Witwatersrand, Johannesburg, South Africa

Vikas Swarnakar
Department of Mechanical Engineering, National Institute of Technology Raipur, India

ABSTRACT

Purpose of the Paper: This study aims to carry out a systematic literature review on the integration of Lean, Industry 4.0 and the Supply Chain or the Lean Supply Chain 4.0. The research analyses the current research on the Lean Supply Chain 4.0 concept in an increasingly digitalised world. We present the benefits, motivations, critical success factors, and challenges of integrating the Lean Supply Chain with Industry 4.0 technologies within this emerging area of research.

Design/methodology/approach: A systematic literature review is carried out on how Lean can be integrated with Supply Chain 4.0. Using the search strings of "Lean Supply Chain 4.0" and "Lean Supply Chain Management 4.0", a review of published literature was carried out via searches on academic search engines.

Value/Originality: This study adds to state of the art around the Lean Supply Chain 4.0 and future directions in this nascent research area. This area of research is evolving, and this study will aid organisations in understanding how Lean, Supply Chain Management and Industry 4.0 can be integrated.

Practical Implications and Findings: Organisations can use this study to understand what the Lean Supply Chain 4.0 means to industry, the benefits and motivating factors for implementation, the Critical Success Factors to implementation, the challenges and the organisational readiness factors for implementation and the role of leadership in the Lean Supply Chain 4.0 deployment. Industry 4.0 has a synergistic effect on the Lean Supply Chain and, depending on the technology and sector applied in, can complement and enhance the Lean Supply Chain.

Keywords: Lean, Supply Chain, Industry 4.0, digitalisation, Lean Supply Chain 4.0

INTRODUCTION

With the dawn of the first Industrial Revolution, production evolved from craft production into mass production and ultimately into Lean production and supply chains. Lean Management (LM) is an operational excellence methodology to eliminate any source of waste and non-value-add activity in a value stream (Womack and Jones, 1996). The concept of SCM was put forward in the mid-1980s, incorporating a definition based on inter-organisational operations management, system integration, and information sharing (Cooper et al.,1997). The incorporation of Lean principles has evolved to what has become known as the Lean Supply Chain (LSC). LSC consists of stakeholder organisations and functions linked by flows of products, services and monies and information combined to improve profits and reduce waste by pulling what is required to meet the customer's needs (Núñez-Merino et al., 2020).

Thus, the LSC concept refers to the integration of LM principles in the supply chain to reduce costs and eliminate waste by utilising Lean to establish flow and pull processes to meet the needs of individual customers (Reyes, Mula and Diaz-Madronero, 2021). However, the application of Lean practices at the supply chain level is much more complex than LM application internally within the company as it requires more coordination and management of physical, information, and financial flows between the various stockholders involved (Moyano-Fuentes, Bruque-Cámara and Maqueira-Marín, 2018).

The concept of LM and I4.0 integration has not been widely studied (Tortorella et al., 2020; Antony et al., 2021). However, the area as a research theme and integration into practice has been evolving in recent years (Antony et al., 2022) and indeed has shown a "synergistic" effect between LM and I4.0 (Snee and Hoerl, 2018; Calabrese, Ghiron and Tiburzi, 2021). In terms of the concept of Supply Chain 4.0 or SCM 4.0 - this concept has also not been widely studied. Frazzon et al.(2019) found that the term has only started to increasingly appear in the literature (more than 10 yearly publications on the concept) since 2016.

Frazzon et al. (2019) defined SCM 4.0 as "the integration and synchronisation of the product's entire value chain across different companies, using smart technologies (IoT, IoS and others) to build an interconnected and transparent system with real-time communication that can manage flows and optimise itself, leading to an autonomous, adaptive, intelligent, agile, and dynamic network that focuses on customers' requirements".

However, as traditional manufacturing and supply chains are now transitioning into increased digitalisation with the implementation and evolution of Industry 4.0 (I4.0) technologies, the LSC has become digitally ready(Calabrese, Ghiron and Tiburzi, 2021). Thus, there is a new evolution of the LSC or LSC 4.0 digitalisation.

Hence the tripartite relationship between Lean, the supply chain and Industry 4.0 is represented in Figure
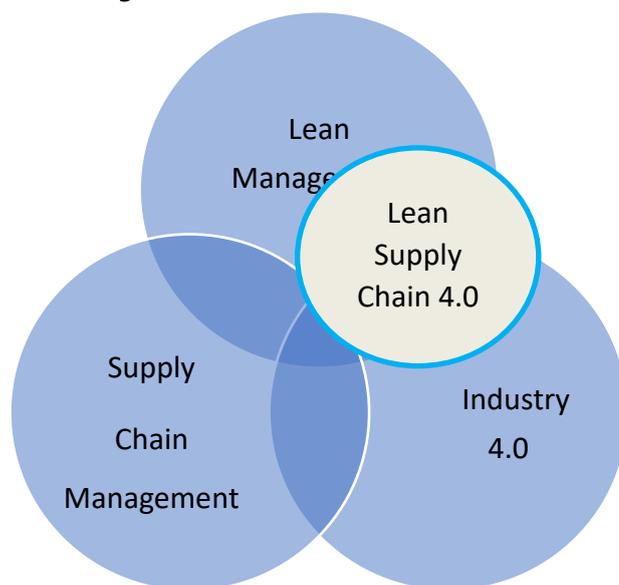
Figure 1: The Lean Supply Chain 4.0 trilogy- Authors own derivation.

However, the integrated effect of Industry 4.0 technology and Lean manufacturing practice on the SC has not been empirically investigated. Hence, the question arises

if and how these developments can possibly support each other. Thus, this paper aims to contribute to this research area.

The research questions in this study are:

> RQ1: What is the current research on the LSC integrated with I4.0?
>
> RQ2: What are the motivations for integrating the LSC and I4?
>
> RQ3: What are the benefits of integrating the LSC & I4.0?
>
> RQ4: What are the critical success factors (CSF's) and challenges to integrating the LSC and I4.0?

METHODOLOGY

To aid understanding of the LSC 4.0, a systematic literature review (SLR) was utilised. In addition, systematic research was carried out for articles published between 2012 and 2022 using the academic databases Web of Science and Scopus. The body of literature was synthesised using Tranfield, Denyer and Smart's (2003) approach to systematic literature research.

A benefit of SLR is that large quantities of information can be reduced into digestible segments (Mulrow, 1994). The systematic approach also aids scientific voracity as the process is structured and, therefore, replicable (Yang, Khoo-Lattimore and Arcodia, 2017)

A systematic literature review was carried out in stages following Webster and Watson (2002), identifying the literature that was relevant to the RQ's, a structured process of review and one that can be followed by future researchers through a research process flow.

The research was only within the academic databases to publications that contain research, or models specific to the LSC 4.0 published between 2012 to 2022 (to date) due to the nascency of the topic. Therefore, a search string was applied to search all the above databases: "Lean Supply Chain 4.0" and "Lean Supply Chain Management 4.0". Table 1 provides a detailed listing of the inclusion/exclusion criteria.

The references from the selected studies were checked manually to identify any other relevant studies that were missed in the database search. In addition, grey literature was excluded.

The first search resulted in a total of 3177 articles (928 in Scopus, 2249 in Web of Science) which were stored in the reference management software "Zotero" to aid the screening process. Once duplicates were removed in Zotero, the list resulted in 3138 papers which were then future screened in two stages.

Stage 1: Within the 3138 screened articles, a search was conducted of the titles, abstracts and keywords of the articles to identify their relevance to the RQ's. The main criteria reviewed at this stage were whether the articles specifically referred to the LSC 4.0. Many articles referred to the LSC and SC 4.0 but not to the integration of the LSC and I4.0 and thus were disregarded at this stage. The four authors of this research reviewed and independently assessed whether the studies matched the criteria for inclusion based on the search criteria (Parameswaran, Ozawa-Kirk and Latendresse, 2020). The agreement as to whether to include was reached by discussions and consensus among reviewers. This stage concluded with a total of 35 articles.

Stage 2: In this stage of the screening procedure, the 35 articles that remained were next thoroughly evaluated for their relation to the research themes (LSC 4.0 or LSCM 4.0). The second review stage concluded with 12 articles to be included in the main analysis. The articles that were selected from the second stage were then used in the results and discussion section of the paper.

Inclusion criteria	Exclusion criteria
Academic peer-reviewed journal articles, books, magazine-related articles, etc.) related to "Lean Supply Chain 4.0" or "Lean Supply Chain Management 4.0". Articles published in high-quality journals Articles published from 2012 to 2022	Grey literature (conference proceedings, dissertations, magazines, workshops, editorials, books, prefaces). Articles published in languages other than English Articles published before 2012 as the term Industry 4.0 was only coined in 2011, and thus LSC 4.0 is a nascent area. Articles published in non-refereed journals

Table 1. Inclusion & Exclusion criteria for the SLR

A flowchart aided the illustration of the SLR steps (Figure 2). The analysis then was started using various themes in response to the research questions, for example the year of publication, authors, journals, research methods, the benefits of LSC & I4 integration, motivations for LSC & I4 integration, challenges of LSC & I4 integration, and finally the CSFs for LSC & I4 integration. The insights from these publications were summarised through the review of any patterns and themes therein.
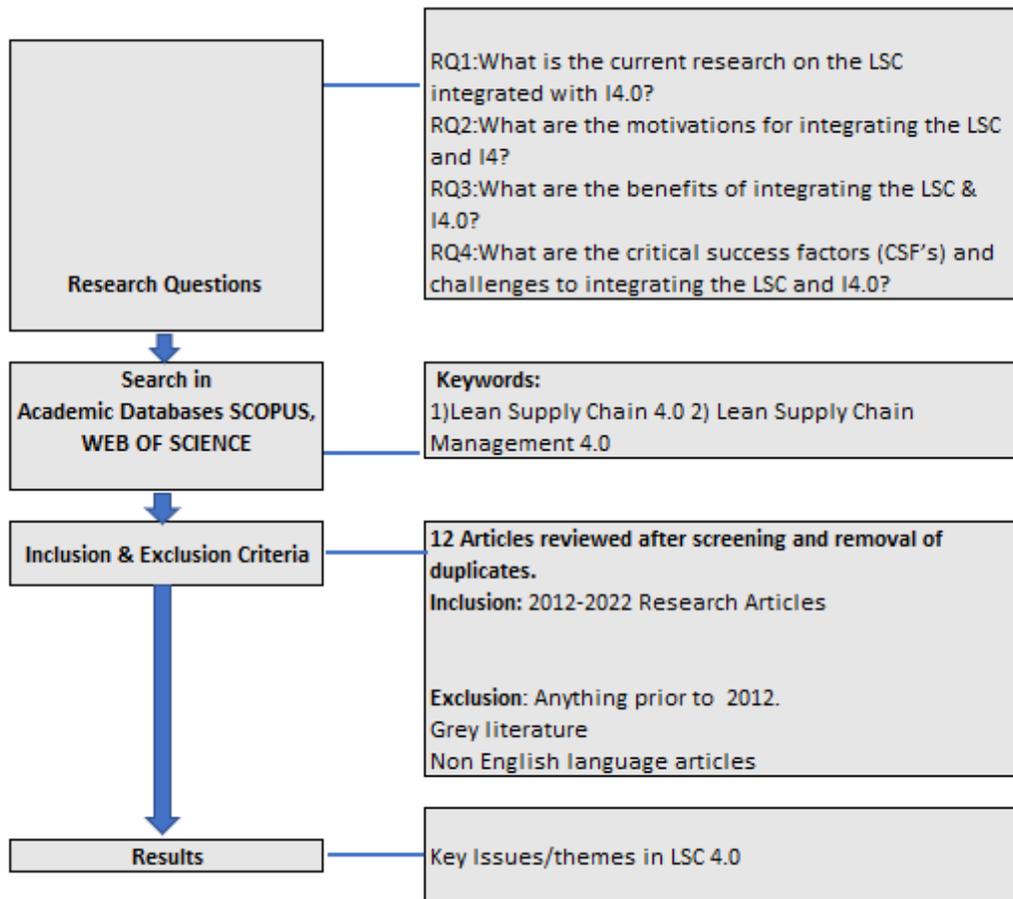
Figure 2. A summary of the SLR process flow followed by the researchers

RESULTS

The resulting journals from the final selection were subsequently analysed based on the journal type and when published. The LSC and I4.0 is an evolving research area, as demonstrated by the relatively few remaining 12 articles in the final selection (Table 2).

Table 2: Final Selection of articles from SLR review

Year	Authors	Title	Journal

2019	Tortorella, G; Miorando, R; Francisco, A; Cawley, M	The moderating effect of Industry 4.0 on the relationship between lean supply chain management and performance improvement	INTERNATIONAL JOURNAL OF OPERATIONS & PRODUCTION MANAGEMENT
2020	Tiep, NC; Oanh, TTK; Thuan, TD; Tien, DV; Ha, TV	Industry 4.0, Lean Management and Organisational support: A case of supply chain operations	POLISH JOURNAL OF MANAGEMENT STUDIES
2020	Haddud, A; Khare, A	Digitalising supply chains potential benefits and impact on lean operations	INTERNATIONAL JOURNAL OF LEAN SIX SIGMA
2020	Nunez-Merino, M; Maqueira-Marin, JM; Moyano-Fuentes, J; Martinez-Jurado, PJ	Information and digital technologies of Industry 4.0 and Lean supply chain management: a systematic literature review	INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH
2020	Bag, S; Wood, LC; Xu, L; Dhamija, P; Kayikci, Y	Big data analytics as an operational excellence approach to enhance sustainable supply chain performance	RESOURCES CONSERVATION AND RECYCLING
2020	Frontoni, E; Rosetti, R; Paolanti, M; Alves, AC	HATS project for lean and smart global logistic: A shipping company case study	MANUFACTURING LETTERS
2021	Raji, IO; Shevtshenko, E; Rossi, T; Strozzi, F	Industry 4.0 technologies as enablers of lean and agile supply chain strategies: an exploratory investigation	INTERNATIONAL JOURNAL OF LOGISTICS MANAGEMENT
2021	De Giovanni, P; Cariola, A	Process innovation through industry 4.0 technologies, lean practices and green supply chains	RESEARCH IN TRANSPORTATION ECONOMICS
2021	Reyes, J; Mula, J; Diaz-Madronero, M	Development of a conceptual model for lean supply chain planning in industry 4.0: multidimensional analysis for operations management	PRODUCTION PLANNING & CONTROL
2021	Ciliberto, C; Szopik-Depczynska, K; Tarczynska-Luniewska, M; Ruggieri, A; Ioppolo, G	Enabling the Circular Economy transition: a sustainable lean manufacturing recipe for Industry 4.0	BUSINESS STRATEGY AND THE ENVIRONMENT
2022	Mahdavisharif, M; Cagliano, AC; Rafele, C	Investigating the Integration of Industry 4.0 and Lean Principles on Supply Chain: A Multi-Perspective Systematic Literature Review	APPLIED SCIENCES-BASEL

2022	Tay, HL; Loh, HS	Digital transformations and supply chain management: a Lean Six Sigma perspective	JOURNAL OF ASIA BUSINESS STUDIES

Most of the "limited" final selection came from 12 journals -one article each from 12 different journal titles. As demonstrated in Figure 3 – the theme of LSC 4.0 is a current theme of researcher interest, first appearing as recently as 2019 and with a very low steady stream of research since then. As LSC 4.0 is a recent evolving area of research several authors who have written about the topic have commented on the sparse literature on the concept (Frazzon *et al.*, 2019; Tay and Loh, 2022; Marodin *et al.*, 2019).

While there are numerous articles about Industry 4.0 and digitalisation of the supply chain, a recent SLR study by Antony et al. (2021, 2022) on the integration of *Lean Six Sigma* and Industry 4.0 found similar results with the theme of *LSS* 4.0 only appearing since 2017 and with a corresponding low quantity of publications. The LSC 4.0 as a concept is still very much in its infancy.
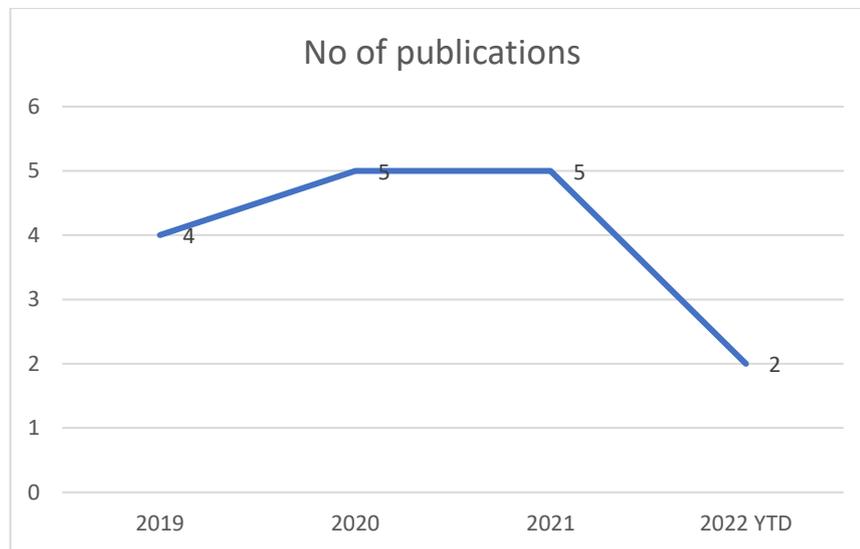
Figure 3 –Publications by year related to the LSC & I4 area

The final selection of articles were screened for themes related to the benefits of the LSC & I4 integration, the motivations for the LSC & I4 integration, the challenges of the LSC & I4 integration, and the CSFs for the LSC & I4 integration. These articles were screened to ascertain their alignment with the RQ's and research themes and summarised in table 3. All authors of the selected articles were supportive of the benefits of integrating the LSC and Industry 4.0. However, few articles discussed the CSF's and the challenge of integrating the LSC and Industry 4.0 as this is still an evolving research area lacking longitudinal studies.

Table 3: Themes discussed related to the Lean Supply Chain 4.0 within the final selected articles

Cited Article	Benefits of Integrating the Lean Supply Chain with Industry 4.0	Motivations for Integrating the Lean Supply Chain with Industry 4.0	Challenges for Integrating the Lean Supply Chain with Industry 4.0	Critical Success Factors for Integrating the Lean Supply Chain with Industry 4.0
Tortorella, G; Miorando, R; Francisco, A; Cawley, M (2019)	X	X	X	X
Tiep, NC; Oanh, TTK; Thuan, TD; Tien, DV; Ha, TV (2020)	X	X	X	X
Haddud, A; Khare, A (2020)	X	X	X	
Nunez-Merino, M; Maqueira-Marin, JM; Moyano-Fuentes, J; Martinez-Jurado, PJ (2020)	X	X	X	X
Bag, S; Wood, LC; Xu, L; Dhamija, P; Kayikci, Y (2020)	X	X	X	X
Frontoni, E; Rosetti, R; Paolanti, M; Alves, AC (2020)	X	X		
Raji, IO; Shevtshenko, E; Rossi, T; Strozzi, F (2021)	X	X	X	
De Giovanni, P; Cariola, A (2021)	X	X	X	
Reyes, J; Mula, J; Diaz-Madronero, M (2021)	X	X	X	X
Ciliberto, C; Szopik-Depczynska, K; Tarczynska-Luniewska, M; Ruggieri, A;	X	X		X

Author				
Ioppolo, G (2021)			▨	
Mahdavisharif, M; Cagliano, AC; Rafele, C (2022)	X	X	X	X
Tay, HL; Loh, HS (2022)	X	X	X	▨

DISCUSSION

RQ1:What is the current research on the LSC integrated with I4.0?

The literature reviewed in the SLR had a common theme of the benefits for integrating the LSC and I4.0. The challenges to the integration and CSF's to integrating the LSC and I4.0 were also very evident in the literature. As outlined in the previous section, this area is understudied at the moment, and very few research papers are devoted specifically to the LSC 4.0 or LSCM 4.0 in the literature (Tay and Loh, 2022). Lean and supply chain practices are positively aligned with Industry 4.0 technologies, and the concurrent implementation results in performance improvements (Chiarini, 2020). I4.0 and Lean practices are complementary to I4.0 technologies (Snee and Hoerl, 2018), and there is a synergistic relationship between both to increase operational excellence and supply chain improvement (Calabrese et al., 2020).

While there are many benefits and motivations to the LSC 4.0, many unknowns exist. For instance, there is importance to understand the technology being implemented in terms of what it can due for the LSC and look at one process and the applicability of that technology at a time(Mahdavisharif, Cagliano and Rafele, 2022).

A common thread across the literature around digital transformation and LM methodology are that both seek to continuously improve SC operational visibility and process performance and that I4.0 can enable a stronger LSC (Tay and Loh, 2022).

RQ2:What are the motivations the LSC and I4 integration?

The studies reviewed to discuss the interactive, symbiotic, and synergistic nature of Lean with SCM and complemented and enhanced by the technologies of I4.0 (Bag et al., 2020; Raji et al., 2021; Tay and Loh, 2022). According to (Tortorella and Fettermann, 2018; Tortorella, Miorando and Mac Cawley, 2019), the adoption of Industry 4.0 technologies moderate the relationship between LSC practices and supply chain performance in organisations. Furthermore, Tortorella, Miorando and Mac Cawley (2019) emphasised that integrating product and service-related Industry 4.0 technologies into flow practices can lead to significant operational and supplier chain performance improvement.

There is a structured relationship among lean, agile, sustainable, resilient and flexible principles to enhance SC performance by the implementing of digitisation technologies (Mahdavisharif, Cagliano and Rafele, 2022). Mahdavisharif, Cagliano and Rafele (2022) proposed a conceptual model, or LSCP 4.0, which they piloted with a case study in a large footwear company and had associated supply chain operations improvements (Mahdavisharif, Cagliano and Rafele, 2022)

Currently, Industry 4.0 is considered the essential improvement of business processes that could improve lean management, high organisational support, and effective supply chain practices (Tiep et al., 2020). Moreover, the synergistic effect between I4.0 and LSCM is high and impacts results positively (with benefits including agility, data sharing, increased synchronicity and partnerships, more speed, improved profits, on time deliveries, defect

reduction, better inventory management and control, a pull system, enhanced, traceability, better risk management, improved quality of services, and higher levels of customer satisfaction)(Bag *et al.*, 2020).

Haddud and Khare (2020) examined the impact of digitalising supply chains on lean operations practices and found the explored lean operations practices were improved as were the overall supply chain and business performance

Trust, and information sharing among supply chain partners and members can be improved by using Industry 4.0 technologies to enable data sharing and transparent (Mahdavisharif, Cagliano and Rafele, 2022).

RQ3:What are the benefits of integrating the LSC & I4.0?
All of the selected authors in this SLR research were unanimous in their conclusions that there were benefits to integrating the LSC and I4.0.

Frontoni *et al.* (2020) demonstrated the application of Lean and smart technology in a global shipping logistics company to deliver lead time improvements, reduced costs, higher inventory security levels and enhanced real-time data sharing. Lean and agile are important SCM strategies that improve organisations performance, and combining with I4/0 technologies offers the means to optimise and enhance processes (Raji *et al.*, 2021). De Giovanni and Cariola (2021) found in a study that Lean facilitates improved supplier partnerships on environmental projects and contributes in a positive manner to environmental and operational performance and profitability. They also posited that integrating I4.0 technologies enhances the benefits of Lean on operational performance.

A positive association had been found between connecting Industry 4.0 and business processes and LM (Tiep *et al.*, 2020). Tiep et al. studied how the Supply Chain Operations Reference Model (SCORM) interacted with Lean and I4.0. SCORM was found to positively mediate the connecting of the role of I4.0 into business processes and LM. Digitalising supply chains have been found to positively impact the adoption of JIT, VSM, TPM, CI, and error proofing lean methods (Haddud and Khare, 2020).

RQ4:What are the challenges and CSF's of integrating the LSC & I4.0?

Adapting Lean principles outside of manufacturing and into the LSC is not straightforward (Hines, Holweg and Rich, 2004) because waste at the production floor level is more straightforward to identify and quantify than at the SCM level. Tortorella, Miorando, and Mac Cawley's (2019) research emphasised that integrating Industry 4.0 technologies for products and services into Lean flow principles can result in significant improvements, but only if integrated cautiously and in a structured manner. They also found that organisational size and the length of the duration of LM deployment were highly positively correlated but that the duration of LM deployment was highly negatively correlated with increasing technology.

As many organisations have struggled with implementing Lean in the SC due to a lack of understanding and poor implementation approaches – similarly, it is important to understand how Cloud Computing, Big-Data, IoT, and AI affect the LSC results at both the operations level of flexibility, improving quality, achieving delivery and service levels as well as its impact on the financial results of revenue, profits and increased market share (Bag *et al.*, 2020). Organisational support and leadership are important for the LSC 4.0 success – as they positively moderated the nexus of SCORM and LM (Tiep *et al.*, 2020).

It is important to understand how different lean tools interact and impact the SC operations when integrated with I4.0 technologies to not make the wrong investment decisions. For example, lean tools, such as Kanban, Just in time (JIT) and Value Stream Mapping (VSM),

can enhance SC operations management when integrated with I4.0. On the other hand, simulation can lead to more collaborative management between suppliers and manufacturers and aid risk management and risk contingency planning (Mahdavisharif, Cagliano and Rafele, 2022).

CONCLUSION

With the dawn of the fourth industrial revolution and future increased digitalisation, the researchers find that the technologies of Industry 4.0 will enhance the LSC. However, it is very important to reap the benefits from this increased digitalisation and wide availability of process-enhancing technologies to review and integrate these right technologies to enhance the LSC. A limitation of the study is the limited research in this area as it is an evolving area. Also, the researchers excluded from this SLR research and may offered further research related to the LSC and Industry 4.0 integration. Future research opportunities could include more longitudinal studies on organisations aiming to integrate their LSC's with the technologies of Industry 4.0 to understand further and benchmark the learnings in narration to the integration of the LSC and I4.0. In addition, further mixed methods studies with SC professionals working on the LSC and organisational digitalisation programs would be an opportunity to leverage further learnings around this new evolving area of the LSC 4.0.

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A Study of reverse logistics in the retail sector: A Mauritian Case Study

Callychurn Devkumar S

Mechanical & Production Engineering Department, Faculty of Engineering, University of Mauritius

Purpose of this paper

This paper ponders in finding out whether Mauritian companies, in particular those in the retail business are aware of the concepts of reverse logistics. Most companies strive to offer the best customer experience and satisfaction to their customers. Much emphasis is laid on offering product varieties and quality so that the customers have a hassle-free shopping experience. However, one particular and very important segment, often ignored by businesses in the retails business is product returns. This research work aims to find out how far supermarkets are apprised of the reverse logistics concept. The end result is the development of a framework on reverse logistics which can be critically used by retailers for identifying causes/sources of defective products which at the end will lead towards optimal logistics performance.

Design/methodology/approach

The use of both exploratory and descriptive research in analysing current practices in the retail business with regards to Reverse Logistics. Following discussions and meetings with experts in the retail sector, it was decided to conduct the study in supermarket outlets in the country. The main rationale behind was that these offer mostly all categories of products to customers, among all other retail outlets considered. Also, the supermarkets in Mauritius were under the control of 6 major group of companies which made up the industry. A questionnaire was developed to conduct the study on the extent to which supermarkets had cognizance of the concept of reverse logistics. The results obtained from the study were conducive in developing the Reverse Logistics framework for the supermarkets in Mauritius.

Findings

While conducting the study on the awareness of the Reverse Logistics concept, the main elements which were examined were: **Products and services, Customer Retention, Return Policies, Products Returned Rate, Customer Complaints**. It was observed that many respondents were quite reluctant to respond to the survey, at the beginning. This mind-set subsequently changed, following face-to-face meetings, where the rationales of the study were clearly explained to them. From the results, it was deducted that only 1 out of the 6 supermarkets group was aware and has implemented the concept Reverse Logistics in its activities. A Reverse Logistics framework was worked and developed for the Mauritian Supermarket industry. The aim of this frame of reference was mainly to help supermarkets having a better control on the returns of products and its processing in a more structured manner.

Value

Through this research, it became obvious that supermarkets had other priorities in terms of the elements that were under study. This piece of work, not only made us realise this, but also were also useful to prompt supermarkets to initiate appropriate actions towards sustainable consumption. The resulting framework will not only be helpful in indulging a better control on the returns in this industry, but also will be quite significant in getting more accurate data with regards to the costs of this returns.

Practical implications
Though the study produced a resulting framework which is based on Reverse Logistics performance, overall success of this schema will be guaranteed only if stakeholders of the industry are ready to participate in this endeavour. Last but not the least, the Government of Mauritius should take initiatives towards implementing and enforcing laws related to disposal of waste and quantity of wastes produced. We are not there yet in terms of paying taxes for amount of wastes produced or even more down the line, having a Sustainability Index for the retail sector.

1.0 INTRODUCTION
Over the years, there has been a drastic change in the retailing sector, which has a vital position in the value chain. The retail sector can be defined as the intermediate point between producers, customers and consumers. Scheffer et al. (2013) posits that retail, over and above its traditional role, can contribute to the proper disposal of defective or post-consumer products, and their packaging by enabling the return of these material to their manufacturers. It is deemed important that retail companies adapt their strategies to the current changes in the business environment. In fact, it has been descried that only those who have been flexible enough to adapt to this new shift have been able to sustain while the rest have ultimately failed and disappeared from the retail scenery. One of the major changes that have occurred in the market is its propensity to a customer-driven one, with the latter being considered as the 'King'. Sam Walton, the founder of Walmart confirms all that in his statement *'There is only one boss. The Customer. And he can fire everybody in the company from the chairman on down, simply by spending his money somewhere else.'* This adds in the increase of pressure on retail companies, who have been obliged to adapt their strategies, taking into consideration the customer satisfaction and retention as their main focus.

The retail sector in Mauritius
Mauritius being a small island in the Indian Ocean has done a lot of development and today it consists of multiple sectors including the wholesale and retail sector. Goods are distributed through the standard channels of importers, wholesalers, retailers and supermarkets. Mauritius has a wide range of retail outlets, ranging from high-end shopping centres to family-run corner stores. Distribution of goods is relatively uncomplicated once goods arrive on the island given its size. The responsibility of the retail industry is to distribute the final and finished product to the general public and it should be noted that in the supply chain the retailer is the means to which the final product reaches the customer. The Mauritian retail sector, when compared, to the other sectors is very small. However, there is a continual increase in the development of this sector. The trend over the past years has shown that the wholesale and retail sector in Mauritius has been experiencing a growth of around 3% as exhibited in figure 1.
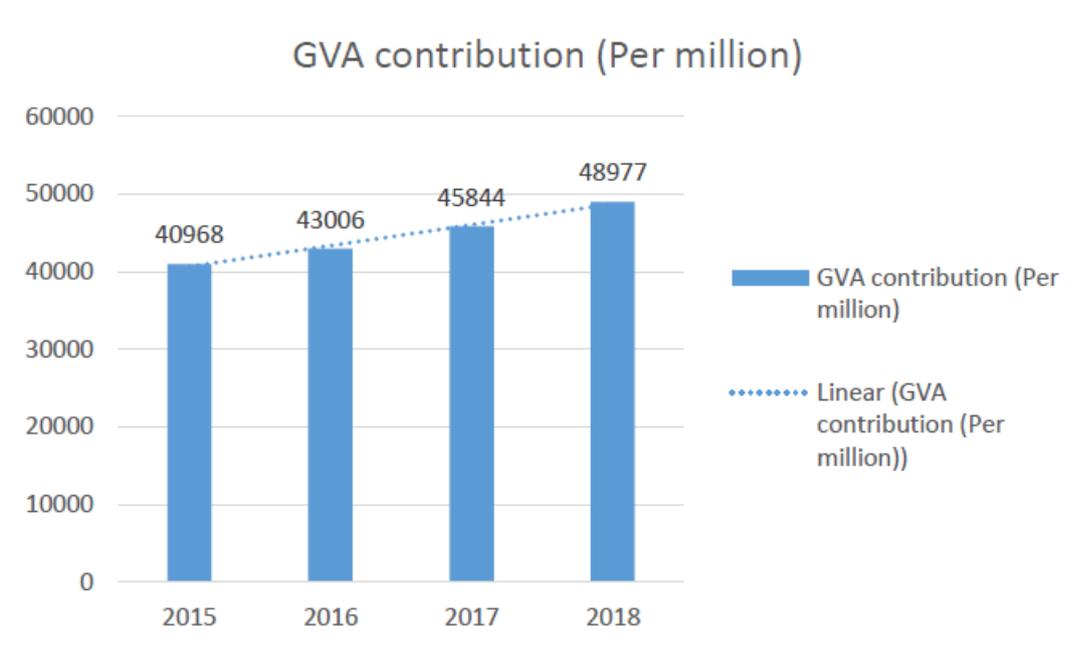
Figure 1: GVA Contribution of the wholesale and retail sector for the year 2015-2018

The growth in the GVA provides a good indication that this sector has been expanding and this enhancement continues even today. The contribution of this sector in the Mauritian economy is non negligible, another reason why businesses need to re-adapt their strategy to be more competitive in the future. The Mauritian retail sector mainly comprised of supermarkets, grocery stores, corner shops and hypermarkets, amongst others. However, the biggest chunk of the retail market is dominated by supermarkets/hypermarkets that have been more present over the recent years. With fierce competition in this particular segment, now is the time for these supermarkets to adapt to this new era of customer-driven and competitive market.

One of the main concerns of supermarkets, given the significant amount of products bargained for on a day to day basis, is the returns of goods. Hawks (2006) declared that the profitability of the retailers can be reduced by up to 4.3% because of returns. Hence, in order to be able to survive and be competitive in this sector, not only have to deal and accept with returns, but most importantly there need to be a worthy strategy about managing these returns. This piece of research work will not only look into this aspect, but will also try to find appropriate answers to the following questions:

- What are the main reasons customers return the products once purchased?
- What is the rate to which products are being returned?
- How are the products returned processed?
- To what extent are supermarkets in Mauritius aware of the concept of 'Reverse Logistics'?
- What is the relationship between 'Reverse Logistics' and quality?

2.0 LITERATURE REVIEW
Reverse Logistics (RL)
Business logistics activities both integrated (downstream) and reverse (upstream), are important players of the supply chain. Beh et al. (2016) posits that the first one is responsible for planning, implementation and controlling the flow of storage goods,

services and information from the origin to the consumption spot. Whereas the second one, in turn, consists of planning the reverse flow of products and packaging, starting from the consumption spot to the put back into the productive chain, as by-product or as raw materials for the productive chains (Dias and Braga Jr.,2016). Rogers and Tibben-Lemke (1998) defined RL as the cost effective planning, implementation and control process, efficient flow of raw materials, inventory processes, finished products and related information from point of consumption to point of origin, in order to recapture value or environmentally sound disposal, and remanufacturing and reconditioning activities may be included in its process.

At present, product returns are being experienced by a vast majority of organisations. The challenge rests in how and what these companies are dealing with these (reverse logistics). This definitely affects the revenue/sales of the company. According to Marchesini and Alcantara (2016), reverse logistics activities are directly related to return management, which consists of one of the eight key business processes, that forms part of the supply chain management. The Global Supply Chain Forum defined these processes, which cover both upstream and downstream flows include: customer relationship management; customer service management; demand management; order fulfilment; management flow management; supplier relationship management; product development and marketing; returns management (Dias et al.,2019). Reverse logistics can crystallize in a series of perceived advantages in the environmental, economic, social scopes and competitive (Hernandez et al.,2012).

Importance of Reverse Logistics
Rogers and Tibben-Lemke (1999) rightly stated that the US is losing millions of dollars simply because of the lack of a well-managed and systemized approach framework. Even though it is not the case right now in Mauritius, the same scenario might be repeated here in the upcoming years, since customers demand are being put quite high on the agenda of retailers. Hence embarking on a reverse logistics strategy will greatly help in creating this customer-driven philosophy. Over and above all this, the retails will also reap the following benefits:

- If well managed, reverse logistics provides a competitive advantage to companies as it will massively contribute towards customer retention.
- Products returned by customers can easily be reprocessed which in return will lead to recapturing the value of the products.
- Defective products or scraps can be collected by the company and sell to recycling companies which will generate scrap values.
- By doing all these activities, the companies would be taking initiative towards sustainability, hence enhancing the organisation's image and reputation in the society.

Drivers of Reverse Logistics
Many studies conducted on reverse logistics suggest that there are numerous factors that can impede on the former, both internal and external. Internal factors include top management commitment and support, and the existence of any sort of incentive system that rewards employees and managers for their involvement with reverse logistics activities (Routroy,2009). External circumstances include pressures from the government and regulatory bodies, customers, suppliers and competitors (Eltayeb and Zailani,2011). Ploughing through the plethora of literatures reveals that the main internal drivers fall

under three main categories: economic, competitive and operational performance and those external ones are: legal, environmental and social. The summary of the findings from the literature are depicted in table 1 below.

External Drivers	
Legal drivers	There are different laws set up by different governments of different countries concerning the amount of wastes being produced, the types of wastes being disposed. These laws are the driving forces of RL (Zhang et al, 2013)
Environmental drivers	This is an important issue in which emphasis must be laid on. It can be observed that the amount of wastes in the landfills are increasing. Reusing, reprocessing and recycling can help in contributing towards the reduction of those wastes to the landfills (Arrieta, 2015)
Social responsibility	Governments and the society have made demands for every organization to have aspects of sustainability (Lamsali, 2013). Not only this creates a good image of the company but also it improves the environmental sustainability (Rahman & Post, 2012)
Internal Drivers	
Economic drivers	Focusing into the closed loop supply chain instead of the open loop supply chain may allow opportunities for revenues (Das & Dutta, 2013). Practices such as reuse and recycling of returned products can recapture their value and it is also a source of revenue for the company (Govindan et al., 2013)
Competitive drivers	A company can remain competitive through the means of RL as it helps to have a control and reduce the inventory level through the reprocessing of the products (Barcos et al, 2013). Using this practice and other ones like recycling will enhance the company's image with respect to sustainability (Chan et al, 2012) and also customer prefer organizations with sustainable practices.

Operational performance drivers	Re-integrating product returns in the forward flow can help the company to reduce its operations cost and minimizing disposal of defective products (Dues, Tan & Lim 2013). This helps in increasing operational performance of the company and hence making it to gain competitive advantage (Rahman & Subramanian, 2012).

Table 1: Drivers of Reverse Logistics (adapted from drivers and barriers of logistics practices, Journal of transport and SCM, Meyer,2017)

Reverse Logistics in the Retail Industry
It is a fact that the practice of reverse logistics has gained much popularity over the past years. Reverse logistics in the retail industry for reversing the supply chain to correctly identify and categorise returned products for disposition, so that it can offer additional revenue instead of simply focusing on defective items returned by the customers (Panigrahi et al.,2014). In the retail industry, the ability of capitalizing on demand is pivotal for boosting profitability and customer satisfaction (Partridge,2005). The overall firm's operations can be highly impacted by the strategic reverse logistics network management. Lindgreen et al. (2009) ascertains that managing the supply of products from the point of order and redesigning the retail distribution system can be quite complex. However, this new system endows the work with the customer's order management system and at the same time improving the visibility of the products throughout the supply chain process.

The organizations concerned are responsible in managing and handling the customer's reverse logistics and this includes both collecting and returning the defective or recalled items. Chang and Zheng (2014) posits that if both transportation costs and uncertainty are not reduced, this means that the reverse logistics practices are not effective enough. This leads to the belief that it is vital to establish an effective reverse logistics network that are representative of a compelling portion of the supply chain cost. In this case, reverse logistics can be used to recover value from assets to increase revenue and reduce expenses. By establishing an appropriate reverse logistics strategy, the efficiency of the traditional supply chain can be boosted, just by separating the operations. It is withal to note that less than 20 per cent of the products are returned due to defects in the retails industry (Rubio at al.,2008). The most relevant items of concern in the retail industry are recalled products, end of life products, season returns and disposal. Reverse logistics will help to fulfil the product lifecycle to support reuse and repurposing of products and materials. Their value can be recaptured simply be reselling the items as refurbished, or even selling them at a discounted rate. Last but not the least, some materials can be recycled or sent for final disposal in an environmentally responsible way.

4.0 METHODOLOGY
In order to have an idea where the supermarkets/hypermarkets stand with regards to reverse logistics the leading organisations were selected. This was done mainly on the basis of number of customers visiting these supermarkets. A more qualitative approach

was utilized to conduct the research with the supermarkets. Qualitative research has been criticised due to a small sample, lack of scientific rigour and non-replicable efforts (Goodyear, 1990). However as per Knemeyer et al. (2002), qualitative research plays an influential role in generating discussions with the key practitioners and organizational decision makers. A semi structured interview was conducted using a well-designed questionnaire with a series of open-ended questions. The main content of the questionnaire was divided in five sections as shown in table 2 below.

Section A: Products and Services	This section deals with type of products and services that the supermarket is offering to its customers.
Section B: Customer Retention	In this section, there are the different factors that lead to customer retention
Section C: Return Policies	This section deals with how much emphasis the companies lay on return policies
Section D: Product Returned by customers	This section includes questions concerning the different types of products that have been returned by the customers and the various reasons behind these returns.
Section E: Customer complaints	In this last section of the questionnaire, there will be questions that will relate customer complaints and Reverse Logistics

Table 2: Content of the survey questionnaire

Six retail outlets were selected with the people responsible of the operations, supply chain, stores or logistics as interviewee. Due to confidentiality purposes, the names of the supermarkets cannot be revealed and are referred to as Supermarket A-Supermarket F in this article. After analysing all the results, one of the six supermarkets was agreeable to be used a case study for this research for the implementation and testing of the proposed Reverse Logistics Framework developed. What also encourages this decision was the simple fact that it was only supermarket which were actually using a reverse logistics system and they also granted access to the supermarkets as well as to some confidential data.

5.0 RESULTS AND DISCUSSIONS

From the interviews and regular meetings/discussions with the stakeholders from the six supermarkets, it was quite surprising to note that only 33.3% of the outlets were aware of the reverse logistics concept. As such, not much attention was given to this concept and that elements such as return goods were managed on an ad hoc basis and that no appropriate systems were put in place, to say the least. As mentioned in table 2, the questionnaire had six sections and some of the results obtained per category are depicted below.

Products and Services

Based on the data collected, it was observed that the supermarkets concerned provided mostly the same category products. Table 3 gives an indication of the different range of products offered.

		Responses		Percent of
		N	Percent	Cases
Categories of products	Perishable Products	5	8.9%	83.3%
	Frozen Products	6	10.7%	100.0%
	Groceries	6	10.7%	100.0%
	Drinks	6	10.7%	100.0%
	Health and beauty Products	6	10.7%	100.0%
	Accessories	5	8.9%	83.3%
	Sanitary Products	6	10.7%	100.0%
	Furniture Products	4	7.1%	66.7%
	House Maintenance products	6	10.7%	100.0%
	Babies Products	6	10.7%	100.0%
Total		56	100.0%	933.3%

Table 3: Product Categories (Dichotomy group tabulated at value 1)

Customer Retention

According to the White House of Consumer Affairs, it costs 6 to 7 times more to acquire a new customer than it is to retain existing ones. Customer retention is an important parameter on which retailers need to put more emphasis. The factors that were considered during the research were: price of products, quality of service, delivery of products, availability of products and quality and variety of products, among others. The interviewees were asked rate different factors, with the scale of 1 to 5. Among the factors listed above, the supermarkets did realise that most of them were paramount to retain the customers. The element where most supermarkets were more or less agreeable was on the availability of products on their shelves, as shown in figure 2 below. There is a belief, rightly so, that if products are unavailable, customers will end up going to another, given the number of options that they have nowadays. However, one important point was also raised on the fact that if a customer is loyal, he/she will end up coming to the same supermarket every time required.
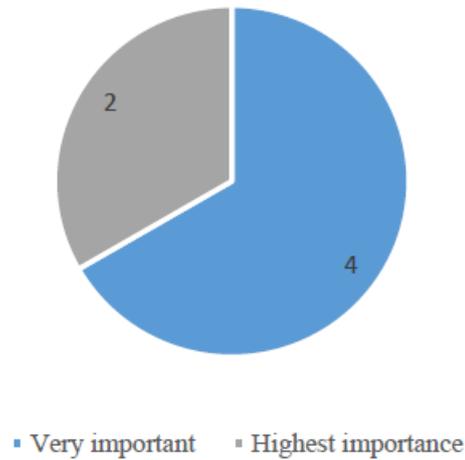
Figure 2: Availability of products

Return Policies

From the research, it was quite peculiarly noted that none of the supermarkets cared and laid emphasis on return policies. It's not that they do not have one, but no customers are made aware of these. According to them, this will make customers more uncomfortable and make them feel that they supermarkets do not trust their loyalty. This is quite contradictory to what is mentioned in the literature where mention is made that customer satisfaction and loyalty indeed increases with a proper return policy in place.

Products returned by customers

Supermarkets were asked about the reasons for the return of products, the majority of them mentioned about the following factors: defective products, change of mind of customers, products not as expected, products not as per catalogue, missing product parts, expired products, product sold at cheaper price, products not up to customer's expectations, wrong products received. It is quite normal that, in this customer-driven society, supermarkets must exceed what the customers are looking for, in terms of both availability and quality. A further analysis was done using the Pareto chart to determine those main reasons for product returns, as shown in figure 3 below:
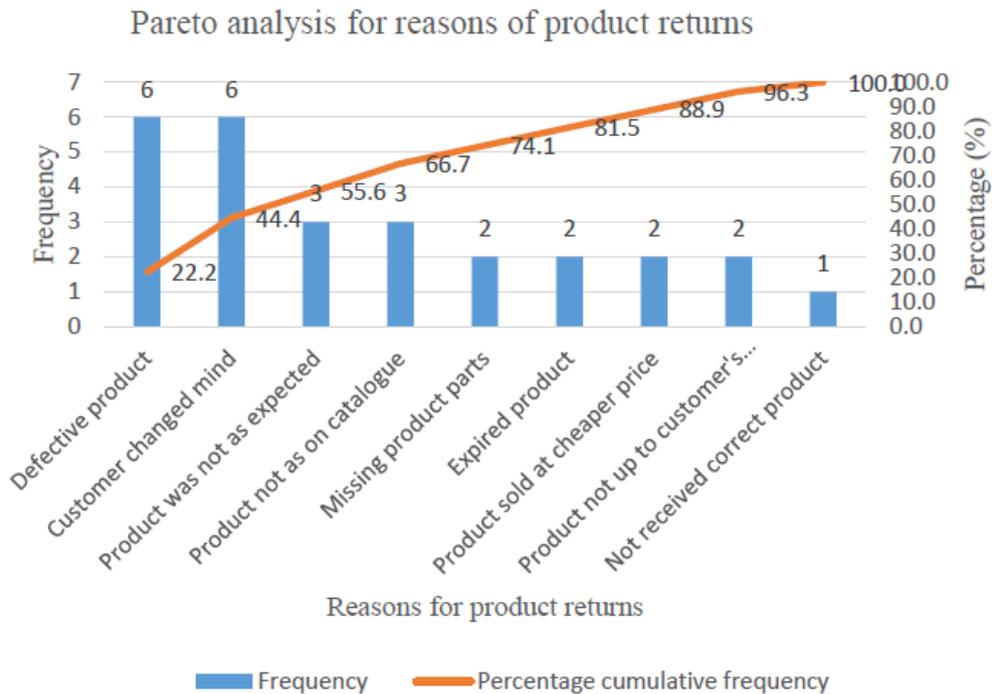
Figure 3: Pareto analysis for returned products

Based on the above analysis, the main reasons for products returns in the supermarkets, on which supermarkets need to devise appropriate strategies, were observed to be as follows:

- Defective products
- Customer changed their minds after purchasing a specific product
- The product was not as it was expected to be
- The product was not as shown on catalogue
- Some of the product parts are missing
- Expired products

Reverse Logistics Framework

Based on various discussions held with the stakeholders, a reverse logistics framework was proposed in this research work. The system developed made sure that the following benefits were obtained by supermarkets implementing it:

- Involvement of employees in the process.
- RL ensures a better quality assurance and quality control of the products and services.
- There is less wastage and the amounts of wastes produced were controlled
- Customer loyalty was build up in the process
- There is a positive word of mouth which in return is of great power since it is believed that one happy customer will bring along many others.

The resultant framework is shown in figure 4.
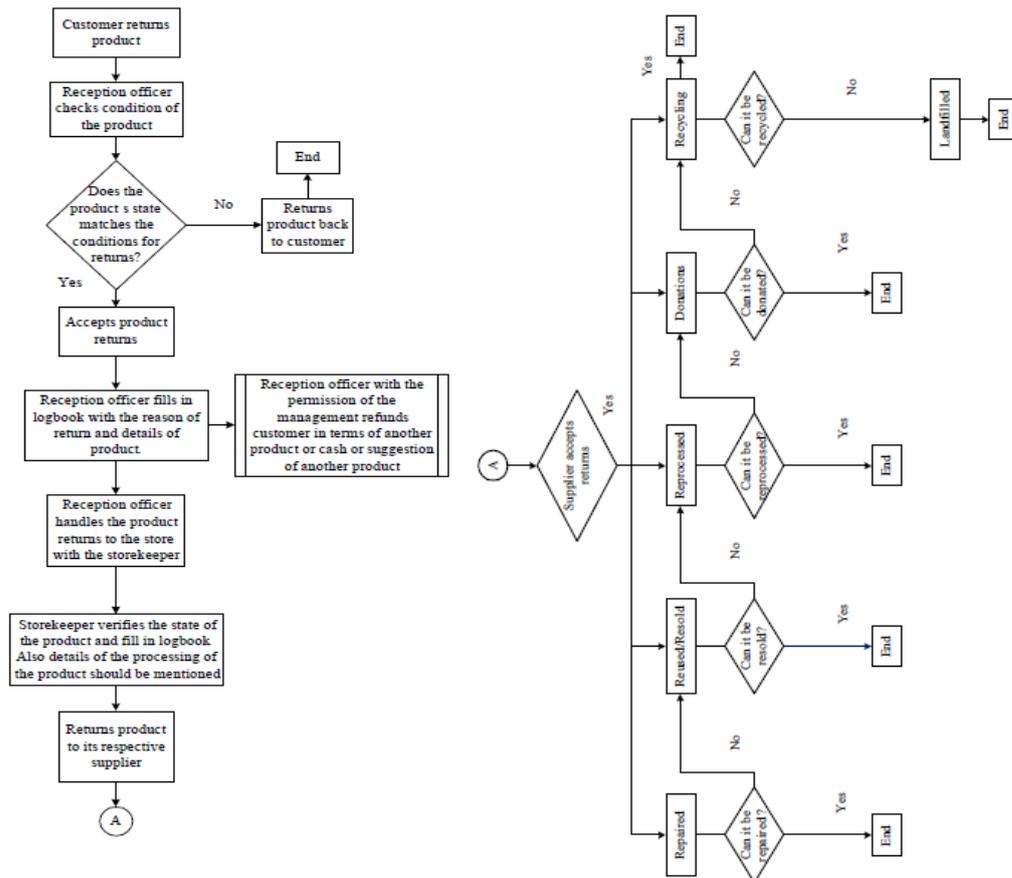
Figure 4: The proposed RL framework for the supermarkets in Mauritius

This framework shall enable supermarkets to have a better control on the returns of products and its processing as it more structured and there is a better flow in the process. The costs of the products returned can be more easily and accurately calculated. One important aspect of the proposed framework is the possibility for the supermarkets to include recycling activities within their operations, which were missing. Even though, the investment to have such a facility can be quite expensive, it being recommended that the least they can do is to work in affiliation with a recycling company. For instance, plastics and plastics products can be collected to be sold to companies doing recycling, instead of dumping them in the landfills. This will largely help in increasing the brand image of the supermarkets as well as encourage them to align themselves with environmental sustainability.

6.0 CONCLUSIONS

The concept of reverse logistics applied to retail, especially in the Mauritian context, can be treated as immature and still in the developing stage. However, it is expected to gain relevance mainly due to the effective contributions with regards to returns management processes that can be adopted. This will in return generate improvements in the management of the activities of the supermarkets. Often referred as 'necessary evil', reverse logistics has to be accepted as part and parcel of the operations in the retail sector. It is important to accept its implications and find the positive contributions RL brings to the company through customer satisfaction which eventually leads to customer loyalty. Another perk from reverse logistics is the ability to recapture the value of returned

products. This research aims at determining how far the Mauritian retail sector- mainly supermarkets- were aware of the concept of RL. Quite surprising that the vast majority of these businesses were unfamiliar with this approach.

The process of reverse logistics is initiated at supermarkets, but stops only at the level of accepting the returns which were either sent to the suppliers or directly to the landfills. No further processing or investigation was done after that. The proposed framework for reverse logistics for the Mauritian supermarkets however went beyond that and included aspects relevant to sustainability: reuse, resell, repair, reprocesses and recycling. It is hoped that supermarkets will henceforth realise the importance of RL and consider same as part of the future strategies. This will provide the supermarkets with more opportunities to provide quality products and services to their customers, based on results and observations made from product returns. Improved and tighter quality control will become a must for these institutions such that all defective products are removed from their shelves and help them to have a greater competitive advantage.

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Resilient Supply Chains

Supply Chain Resilience: Strategies and Impact on Sustainable Operations Among Ghanaian Manufacturers

Joshua Ofori-Amanfo[1], Juliet Ohenewa Siaw[2], Prosper Konlan[3], Florence Adwoa Newman[4]

1: University Of Ghana, Ghana; 2: University of Ghana, Ghana; 3: University of Ghana, Ghana; 4: University of Ghana, Ghana

1. Introduction

The business world is ever-changing and managing this change is a critical success factor for businesses and a key concern for management (Agarwal and Seth, 2020). The increasing uncertainties and risks characterising business activities make the supply chain vulnerable. Businesses are faced with uncertainties such as terrorist attacks, political instability, stiff competitions, risks caused by disasters, and pandemics such as COVID-19, all of which have the potential to disrupt the supply chain. Supply chain disruptions have major economic impact. Each year, it is projected that almost three quarters of organisations in the world experience a supply chain disruption of some kind (BCI, 2018). Managing supply chain disruptions require some degree of resilience to be developed by firms. Firms need to build some capabilities across their value chains to prepare for and quickly recover from such disruptions when they occur (Ponomarov and Holcomb, 2009).

Supply chain resilience refers to the capability to counter risks from supply chain disruptions (Ali and Gölgeci, 2019). Supply chain resilience is considered essential in business continuity (Linnenluecke, 2017). Resilience, is concerned with reducing the impact of disruptions by identifying resilience strategies that allow supply chains to respond and recover quickly to at least its original state (Zsidisin *et al.*, 2016). The literature has identified strategies flexibility and agility as a strategies for developing resilience in supply chain (Yang, 2014).

Despite the emerging criticality of managing supply chain disruptions, relatively little empirical research has been conducted on supply chain resilience strategies. Ganbold and Matsui (2017) examined the impact of different types of environmental uncertainties on supply chain integration with the purpose of discovering the role of supply chain integration in environmental uncertainty reduction. Beckman *et al.* (2004) also proposed two types of uncertainties based on uncertainty level: firm specific and market based. Models have also been developed to assess supply chain resilience (Cardoso *et al.*, 2014). However, less literature attention has been paid to exploring influential resilience strategies which the current study examines. Further, studies on supply chain resilience have received less attention in the literature within the context of developing countries.

The relationship between supply chain resilience and sustainable operations has also not been sufficiently explored. Although there are related studies, their focus is not developing understanding of the extent to which resilience influences sustainable operations. The supply chain resilience strategies being examined in this study include agility, information sharing, redundancy and collaboration. Subsequently, this study aims at exploring the relationships between supply chain resilience strategies and firms' sustainable operations.

2. Literature review and hypothesis development

2.1 Supply chain resilience strategies

Resilience strategies are employed by firms to prepare for, respond and recover quickly from supply chain disruptions and any environmental uncertainties (Ali *et al.,* 2017). Many scholars have identified flexibility, redundancy, agility, supply chain reengineering, supply chain risk management culture, information sharing, strategic risk planning, integration, operational capabilities, and transparency as strategies for supply chain resilience (Christopher and Peck, 2004; Agarwal and Seth, 2020; Ponomarov and Holcomb, 2009). The current study focuses on agility, redundancy, collaboration and information sharing as these particularly important in manufacturing.

2.2.1 Agility. Agility refers to the capability of firms to respond appropriately to changing customer needs (Tukamuhabwa *et al.*, 2015). Agility helps firms to be proactive in their

businesses. Agility is considered to be among the dominant strategies enabling resilience in supply chains to be built. Agility, also, serve as a risk management strategy that aid firms to deal with actual or potential supply chain disruption rapidly (Sodhi, 2014). It can be argued that firms' that adopt agility financially perform better than their peers (Musa and Nyoman Pujawan, 2018). Also, agility indirectly influences firm's performance through risk management performance (Liu, 2018) and cost efficiency (Yang, 2014). Agile practices are perceived to have higher impact on sustainability. Also, Goldman *et al.* (1993) as cited in (El-Khalil and Mezher, 2020) suggest that an agile manufacturing entail acknowledging the significance of employees in firms by developing their education skills, training and proper workplace. Agile practices aim at effectively and efficiently utilising resources to improve performance (Chen, 2017). Practicing sustainability leads to reduction of waste in raw materials. Hence, agile practices in firms are perceived to influence sustainability. Therefore, the following hypotheses are proposed.

$H_{1a:}$ *Agility in supply chains influences a firm's financial performance.*

$H_{1b:}$ *Agility in supply chains influences a firm's employee wellbeing.*

$H_{1c:}$ *Agility in supply chains influences a firm's raw material consumption.*

2.2.2 Redundancy. Redundancy may be employed as a strategy for improving supply chain resilience. Christopher and Peck (2004) posit that redundancy encompasses the tactical and selective use of inventory and additional capacity that is needed in time of crisis be it shortage of supply or increase in demand. Kamalahmadi *et al.* (2021) indicate that firms can deal with disruptions and increase their responsiveness in times of crisis by creating redundancies across their supply chains. Every firm aims at achieving a high financial performance; hence strategies are adopted to realize this goal. The wellbeing of employees contributes to the survival and growth of businesses. Hence, measures need to be in place to see to its manifestation. Considering redundancy as one of the resilience strategies to reduce disruption will in turn create a conducive and stable atmosphere for employees to thrive. The adoption of the redundancy strategy requires the utilisation of resources to create buffer for the firm's operations. Redundancy may be used for minimising uncertainties resulting in sustainability in operations offering better employee wellbeing as well as improved financial performance. Firms' demand for raw materials implies that redundancy can influence raw material consumption. It is therefore hypothesised that:

$H_{2a:}$ *Redundancy in supply chains influences a firm's financial performance.*

$H_{2b:}$ *Redundancy in supply chains influences a firm's employee wellbeing.*

$H_{2c:}$ *Redundancy in supply chains influences a firm's raw material consumption.*

2.2.3 Collaboration. Collaboration is considered as an important strategy in building resilience (Ahmed and Sobuz, 2019). Collaboration in supply chain relates to two or more separate firms working diligently together to plan and execute supply chain operations toward a common goal than can be achieve in isolation (Cao *et al*., 2011). Zacharia and Mentzer (2004) maintain that firms are dependent on external suppliers for some of their resources hence, firms need to collaborate with other partners of the supply chain to get their needs met. Collaboration as a strategy is needed because its absence have adverse effect on togetherness of partners and development of other strategies as well (Cao and Zhang, 2011). Lee and Ha (2020) examined the influence of supply-chain collaboration on sustainable supply chain performance and concluded that collaboration has a positive impact on sustainable performance. Musa and Nyoman (2018) concludes that there is a significant correlation between collaboration and firms' financial performance. On the contrary Blome *et al*. (2014) suggest that supply chain collaboration does not have direct impact on sustainability as well as the financial performance of firms. Firms are currently increasingly focusing economic performance primarily with regards to achieving success in overall market strength and assets, bring into attention, financial performance, employee well-being and addressing environmental concerns. Attention has subsequently been shifted to environmental and social performance while achieving economic

performance in order to attain a higher level of sustainability performance (Carter and Rogers, 2008). Thus, the following hypotheses are proposed:

$H_{3a:}$ *Collaboration between supply chain partners influences a firm's financial performance.*

$H_{3b:}$ *Collaboration between supply chain partners influences a firm's employee wellbeing.*

$H_{3c:}$ *Collaboration between supply chain partners influences a firm's raw material consumption.*

2.2.4 Information Sharing. Information sharing is an important instrument for the continuity of every business and key strategy to dealing with supply chain disruptions. Christopher and Peck (2004) assert that, in reducing risk and disruption in supply chains, members of the chain should exchange information to aid in building resilient supply chains. Information sharing enables the identification of potential problems in the supply chain (Macdonald *et al*., 2018). Information sharing is among the most important element of coordination between supply chain partners. Efficiency of the supply chain can be increased through the application of information sharing by balancing production (Lee and Whang, 2000). Information sharing is seen as an instrument that benefit employees and firms as a whole (Campbell *et al.*, 2014). Shared information among partners and employees improves overall business performance. More so, accurate and timely information sharing among partners enhances their raw material utilisation effectiveness. Thus, information sharing is seen as a tool in managing firms' resources. The higher the level of accuracy in information shared among partners, the higher the efficient use of resources hence the hypothesis:

$H_{4a:}$ *Information sharing between supply chain partners influences a firm's financial performance.*

$H_{4b:}$ *Information sharing between supply chain partners influences a firm's employee wellbeing.*

H_{4c} *Information sharing between supply chain partners influences a firm's raw material consumption.*

2.3 Sustainable operations

The term sustainability is defined by many scholars (Ben-Eli, 2015; Basiago, 1998) but, the most used definition was developed in 1987 by the Brundtland Commission formally known as the World Commission on Environment and Development (WCED) and it states that "sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs" (Miller and Engemann, 2019, p. 252). Sustainability has three pillars: economic, social and environmental. The economic dimension of sustainability helps to save money by reducing waste. Economic performance relates to the capability of the firm to perform its operations effectively as well as the market value of the firm. Indicators of economic performance are productivity, order fill lead time, market value and product defect rate. Social dimension on the other hand, relates to sustainable behaviour that benefits stakeholders of a company including its workers, hence, promotion of employee wellbeing. Sloan (2010) categorised performance indicators of social sustainability into workplace, community and institutions/systems. Workplace deals with the internal human capital. Community refers to people outside the firm whilst institutions/systems refer to the procedures and systems that relate to the social dimension. The environmental dimension entails the reduction of waste (Miller and Engemann, 2019). This includes reducing a firm's carbon footprint, improving the surrounding environment of the workplace, improving the basic needs such as water and air in the working environment as well as the surrounding community (Rezaee *et al,* 2019).

SCR Strategies

Agility

Redundancy

Collaboration

Information sharing

Sustainable Operations

Financial Performance

Employee Wellbeing

Raw Material Consumption

H1a H2a H3a H1b H2b H3b H4a H4b H4c H3c H2c H1c
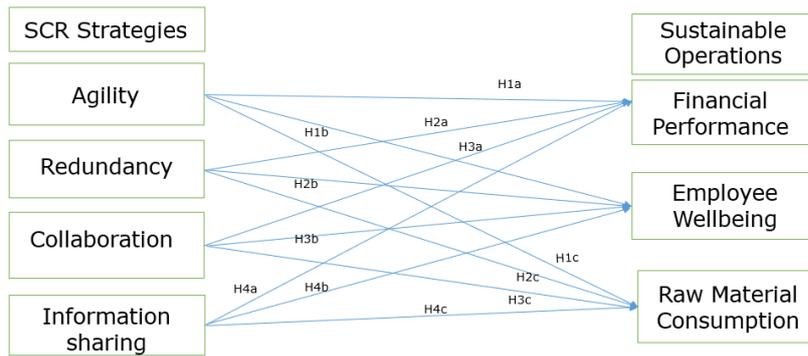
Figure 1: Conceptual framework

3. Research methods

The study adopts the quantitative approach to gather data from 269 manufacturing firms in industry in Ghana using survey questionnaires. Pharmaceutical, textiles and clothing, food processing and soap and detergent were the manufacturing subsectors considered for the study. The purposive sampling technique is employed in this study to select single respondents from each firm who held key managerial positions (owners /managers, general managers, operations managers, supply chain and procurement managers). The research variables were measured using a 5-point Likert scale with the measurement items being largely adapted from literature. Out of the 296 questionnaires distributed, 186 responses were valid for analysis representing 69% response rate. This response rate is acceptable as Baruch and Holtom (2008) posits that, a response rate that is above 50% is considered to be good for data analysis. The Partial Least Square Structural Equation Modelling (PLS-SEM) was employed in the analysis of the relationships amongst the research variables.

4. Analysis and results

The analysis of the relationships involved two steps: first, the evaluation of the measurement model and second, the structural model assessment (Hair *et al.,* 2017). The measurement model was evaluated to know the reliability and validity of the study constructs' measures. The internal consistency of the variables was measured using indicator reliability. The rule of thumb says that, an indicator is reliable if the outer loadings estimated is 0.70 and above. However, loadings between 0.40 and 0.70 should be maintained if their removal will bring about a reduction in the composite reliability and the average variance extracted of the corresponding construct (Hair *et al*., 2017). Subsequently, indicators that did not meet the threshold of 0.70 were deleted from the model, however, item RMC3 (0.654) was maintained as its removal would have affected the composite reliability. The Cronbach Alpha and composite reliability for all the study constructs were above 0.70. The analysis therefore established that, all the constructs achieved the acceptable levels of internal consistency indicating acceptable levels of reliability.

In testing the validity of the study constructs, convergent validity and discriminant validity were considered. The convergent validity was evaluated using the Average Variance Extracted (AVE) of the constructs. The rule of thumb with respect to evaluation of convergent validity is that, the AVE should be above 0.50 (Hair *et al*., 2017) to be acceptable and this is because the constructs should be capable to explain more than 50% of variations of the various indicators. All the study constructs met the threshold with the AVE values ranging between 0.599 and 0.804. The discriminant validity of the constructs were assessed by employing the Fornell-Larcker criterion. The threshold for Fornell-Larcker criterion is the values being equal to 0.50 or greater. The square root of the AVEs of the constructs are higher than all of the diagonal AVEs of the other constructs and the AVE values were all greater than 0.50 depicting that all the constructs met the criterion.

The evaluation of the structural model involved assessment of multicollinearity, significance of path, coefficient of determination, effect size, predictive relevance and model fitness all of which met the minimum threshold requirement. Emphasis in this paper is placed on the path significance which describes the relationships between the research variables. Table 1 shows the assessment of the path significance.

Table 9: Assessment of Path Significance

		Path Coefficient	T-Statistics	P-Values	Decision
H1$_a$	Ag->EWB	0.229	1.550	0.122	Not supported
H1$_b$	Ag-> FP	0.265	2.078	0.038	Supported
H1$_c$	Ag->RMC	0.032	0.232	0.817	Not supported
H2$_a$	Col ->EWB	0.053	0.455	0.649	Not supported
H2$_b$	Col ->FP	-0.057	0.518	0.604	Not supported
H2$_c$	Col ->RMC	0.231	2.359	0.019	Supported
H3$_a$	IS->EWB	0.032	0.393	0.694	Not supported
H3$_b$	IS->FP	0.438	4.828	0.000	Supported
H3$_c$	IS->RMC	0.252	1.707	0.088	Not supported
H4$_a$	Red->EWB	0.330	2.704	0.007	Supported
H4$_b$	Red->FP	0.242	2.031	0.043	Supported
H4$_c$	Red->RMC	0.243	2.064	0.040	Supported

Significant at 5% level, two-tailed test. (Ag=Agility; EWB=Employee wellbeing; FP=Financial Performance; Coll.=Collaboration; RMC=Raw Material Consumption; IS=Information Sharing; Red=Redundancy)

The hypothesised relationship between agility financial performance (H1$_a$) was supported. However, there was no statistically significant relationship between agility and employee wellbeing as well as agility and raw material consumption. Thus, hypotheses H1$_b$ and H1$_c$ were not supported. Also, the findings show that there is a positive statistically significant relationship between collaboration and raw material consumption whiles there exists insignificant relationship between collaboration and both financial performance and employee wellbeing. Thus, whereas hypothesis H2$_c$ was supported hypotheses H2$_a$ and H2$_b$ were not supported. With regards to information sharing and the dimensions of sustainability, there exist an insignificant relationship between information sharing and both employee wellbeing and raw material consumption. However, a statistically significant relationship was established between information sharing and financial performance. This results therefore confirms H3$_b$ whilst hypotheses H3$_a$ H3$_c$ were rejected. Finally, the path relationship hypothesised for redundancy and employee wellbeing, redundancy and raw material consumption and, redundancy financial performance show a statistically significant relationships, hence H4$_a$, H4$_b$ and H4$_c$ were all supported.

5. Findings and implications of the study
The study established the significant impact of agility on a firm's financial performance. This finding is consistent with the previous studies which established that the relationship between agility and financial performance is significant and positive (Musa and Nyoman Pujawan, 2018). On the other hand, the relationship between agility and employee wellbeing is not statistically significant, contrasting previous finding suggesting that agility practices have positive effect on the three dimensions of sustainability (El-Khalil and Mezher, 2020). The relationship between agility and raw material consumption is statistically insignificant and contradicts previous research (Altay *et al*. (2018) which found agility practices to have a higher positive impact on sustainability practices. The study established a significant relationship between redundancy and financial performance hence, corroborating Musa and Nyoman Pujawan (2018) finding that, redundancy has a

direct impact on the financial performance of firms. The result further reveals that redundancy directly influences both employee wellbeing and raw material consumption.

The hypothesis that collaboration between supply chain partners influences a firm's financial performance was not confirmed. This is in contrast with previous studies (Min *et al*., 2005; Pujawan, 2018) which established a positive significant relationship between collaboration and financial performance. The finding however supports Blome *et al*. (2014) claim that collaboration does not directly impact firms' financial performance. Collaboration again did not influence employee wellbeing. Perhaps, this is because firms collaborate to gain knowledge and acquire skills which may not directly affect employee wellbeing (Cao *et al.*, 2010). The result further confirmed the influence collaboration on raw material consumption.

Information sharing between supply chain partners was hypothesized to influence a firm's financial performance. The result demonstrates a significant positive relationship between information sharing and financial performance as has been widely reported in the literature (Sahin and Topal, 2019: Baihaqi and Sohal, 20139). The hypothesized relationship between information sharing and employee wellbeing was not supported which contradicts the findings of Lotfi *et al*. (2013) who found information sharing among supply chain partners to influence performance of firms. No significant relationship was found between information sharing and raw material consumption hence the hypothesis was unsupported.

The insights emerging from the study have significant theoretical, practice and policy implications. To theory, the study provides empirical evidence on the relationship existing between supply chain resilience strategies and sustainability of firms. To practice, the findings that information sharing, agility and redundancy are resilience strategies with significant impact on the financial performance of firms, may inform managerial decisions on the selection resilience strategies to improve their financial performance. The study also provides insights to policy makers and players in the manufacturing sector such as the government, Association of Ghana Industries and other professional associations with respect to developing appropriate policies that will promote sustainable operations among manufacturers.

Limitations of study

The study focused on manufacturing firms in Ghana and therefore the findings may be generalised with caution to other geographic contexts which may possess different operating conditions. Again, the findings may not be generalised to the industry populations other than the manufacturing sector. The study limited supply chain resilience strategies to agility, redundancy, collaboration and information sharing. Future research may explore the relevance and significance of other resilience strategies available in the literature.

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PRIORITIZING MACROLOGISTICS INTERVENTIONS: THE CASE FOR MONGOLIAN INFRASTRUCTURE INVESTMENTS

Jan Havenga, **Zane Simpson, Stefaan Swarts, Anneke De Bod**
University of StellenboschSouth Africa, South Africa
E-mail: zane@sun.ac.za

1.   INTRODUCTION

In this paper, macrologistics is defined and the principles that it relates to are then used to guide national logistics research to prioritize infrastructure investments.

2.   THE ROLE OF MACROLOGISTICS

2.1.   What is macrologistics?

Even though logistics has military origins (Hesse, 2020:1) with a revived focus to improve business operations and optimize production factors (Cowen, 2014:50-51; Hesse, 2020:1), i.e., microeconomics, logistics' relationship with macroeconomics is quite new. Relating to macroeconomics logistics optimizes the time and place discrepancy at a national level (Havenga, Witthöft, de Bod & Simpson, 2020) and can be conceptualized as an accumulation of all the value chains in an economy. This approach will position inventory optimally across all economic value chains for the benefit of society, with a strategic goal of "reducing the total cost of ownership of goods on a macroeconomic scale to improve societal wellbeing and ecological sustainability, implemented through balanced logistics policy, appropriate infrastructure provision and systemic management" (Havenga *et al*., 2020).

2.2.   Policy, infrastructure, and spatial planning as macroeconomic tools

Key macrologistics policy elements include sustainability, market and user access, land use, economic and safety regulation, congestion, and the management of a nation's truck and maritime fleet, and strategies aimed at improved macrologistics performance should address these (Havenga *et al*., 2020).

Sustainability policies related to emissions are gaining traction. The effect of emissions taxes on both internal and external costs can be measured; emissions taxes could increase the internal cost of transport, but the internalization of external costs can have direct benefits. (Havenga *et al*., 2020).

Market access is facilitated through infrastructure, especially the links between the primary, secondary and consumption portions of value chains. It requires policy that guides connections, network planning, land use policies and especially equitable access in the developing world.

The policy areas outlined here are embodied in the development of infrastructure. There is a significant positive link between guided infrastructure investments and growth in the developing world (Straub, 2008), for example, the development of transport corridors could increase trade within a region or facilitate exports, especially for landlocked countries (OECD/WTO, 2013). This background points towards Mongolia, in many respects, being a landlocked developing world country with growth and infrastructure challenges.

2.3.   Mongolia's macrologistics landscape

Mongolia is a landlocked, lower-middle-income country with unique geospatial and demographic challenges. Just over 3.2 million people inhabit a territory of 1.564 million square kilometres, for a density of 2.1 people per square kilometre. About half the population (some 1.4 million people) reside in the capital city Ulaanbaatar, with the remainder in small urban centres and vast steppes.

Some economic activities, such as livestock herding, mining, or renewable energy generation, take place in rural areas. More than 66 million livestock (goats, horses, cattle, yaks, and camels) are owned and raised by 230,000 households. Traditional nomadic pastoralists constitute about 30 percent of the population, with livestock often their only source of income. Appropriate infrastructure development for the instance of the meat supply chain could unlock around US$800 million from meat export (World Bank, 2020a). Mongolia has significant quantities of proven diverse mineral resources (including coking coal, copper, iron, and gold) and once fully developed, will be among the largest mines in the world.

Economic diversification and development, and specifically infrastructure investment, are challenged by the country's territorial expanse and low population density (World Bank, 2020b). A combination of infrastructure gaps and inefficient institutions result in poor connectivity. Mongolia's roads connect only a small fraction of the country, making travel costly, lengthy, and hazardous.

Several macro-level indicators confirm Mongolia's transport connectivity and infrastructure challenges (World Bank, 2020b). For example, the World Economic Forum's (WEF) 2019 *Global Competitiveness Index* ranked Mongolia at 102 out of 141 countries, while its 2019 transport infrastructure rating was 119 out of 141. The World Bank's *Logistics Performance Index* ranked Mongolia's overall at 130, with lower ratings for infrastructure (135), customs procedures (127), and logistics services (140). In the *Global Connectedness Index* produced by DHL, Mongolia ranked 85 out of 169 countries.

Despite significant road and rail infrastructure investments over the past 15 years, infrastructure asset management practices remain inadequate, resulting in substantial deferred maintenance and loss of investment value due to shortened life of physical assets (World Bank, 2020b).

Mongolia's unique geographic location between China and Russia holds potential for access to large markets. The proximity to China provides a ready outlet for exports, in particular minerals. Russia has strong historical links with Mongolia's economy through significant investment holdings in various sectors. The route through Mongolia is a potentially attractive transit corridor between the Beijing-Tianjin-Hebei economic cluster and Siberia, connecting with the significantly shorter Trans-Siberian railway link and on towards Europe, compared with the route to Vladivostok.

Against this background, Mongolia could undertake some actions to significantly increase its expected benefits from infrastructure development, but funds are limited, requiring careful consideration of opportunities.

3.   MONGOLIA'S MACROECONOMIC OPPORTUNITIES

Mongolia's GDP of $13.11 56% tertiary, but 'with significant mining and agricultural contributions (see Table 1).

Table 1. Relative size and contribution of industry sectors (Created by the authors)

Industry	Contribution to GDP (USD billion)	Percentage contribution to GDP	Volume (tonne)
Mining & quarrying	3.05	23%	58 361 567
Agriculture, forestry & fishing	1.70	13%	2 842 157
Manufacturing	1.02	8%	5 781 612

Tertiary	7.34	56%	
Total	13.11	100%	

Possible opportunities exist in agro-processing, mineral beneficiation, tourism and exploiting transit traffic opportunities. To rank these opportunities a freight flow model for Mongolia was developed to quantify distance, volumes, cost and contribution of the various alternatives to the economy of Mongolia.

3.1. Agriculture and mineral beneficiation

3.1.1. Agriculture (Meat, Milk, Leather, Cashmere)

Mongolia has a significant national herd, leading to meat, milk, cashmere, and leather value chain opportunities.

Meat

It is estimated that Mongolia could earn up to $800 million annually from meat exports given the huge demand in China alone. However, to date it has proved difficult to supply the quality, quantity and consistency demanded. The meat industry faces multiple challenges including but not limited to animal health and the perishing of meat in the absence of a well functioning cold chain. The industry in Mongolia is still unsophisticated and primarily driven by herder households which are spread across the country. In the existing supply chain, merchants serve as intermediaries in the local supply chain between the households, small slaughterhouses, and wholesalers who supply urban areas. The main challenge for the Mongolian meat sector is that the current structure cannot produce the quantities and quality required for the export markets and there is a lot of spoilage in the supply chain.
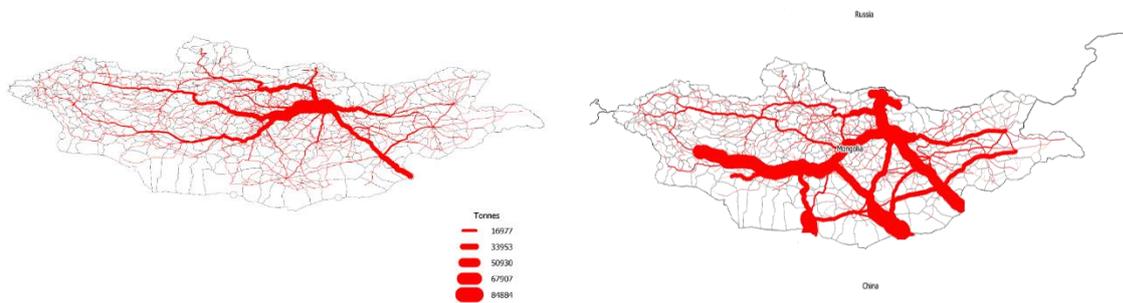
Figure 1. Meat (left) and total (right) freight flows (Created by the authors)

As shown in the freight flows, most of the meat is sourced in various locations and then transported to the capital city Ulaanbaatar through a very inefficient logistics system. Considering the long distances and poor infrastructure, a large volume and value is lost along the supply chain and export potential is not realized. By comparison, all successful meat exporting countries have a tightly aligned supply chain that aims to reduce loss of value at each stage from farm to ultimate market. For example, the New Zealand and Australian meat supply chain consolidates its operations using commercial farming, feedlots and sales yards which serve as a market mechanism through which livestock is optimally distributed. Processing abattoirs are supplied via the sales yard with livestock which will yield sufficient conditions that are required by both the domestic as well as the export market. However, this might be incompatible with the current state of the Mongolian meat industry caused by the social structure of the herder households and their reliance on their livestock.

The key to exploiting the potential in the meat value chain is to identify where value is lost along the chain and address in an integrated and comprehensively manner the gaps – including infrastructure bottlenecks. It is not realistic to transform the structure for heading from household to large commercial farming as is the case with the large meat producers, however, the supply can be reorganized to reduce loss of value and increase the possibility of producing consistent quality, quantity, and reliability of supply.

Milk, Cashmere, and Leather
The relatively large urban areas of Darkhan, Ulaanbaatar, Erdenet, and Zuunkharaa are supplied with milk by herder households who live within a radius of 50—100 km. The existing supply chain involves a middleman or farmers in small 1- to 2-ton trucks. The milk is then either taken to a milk cooling centre or a milk processing plant. The milk processing plants supply bakeries and restaurants, schools (according to the government lunch program) and retail stores and shops. A small portion of the milk is delivered directly to canteens, kindergartens, hospitals, sanatoriums, or kiosks near compounds. The transport of milk in other Aimags often involves horses or motorbikes and the milk is distributed similarly to that of the urban centres. Like the meat and animal by-product supply chains, the milk supply chain is inefficient. Mongolia is currently a net importer of milk and milk products—driven by the demand in urban areas.

There is a significant untapped potential for expanding wool and cashmere exports. Given its unique natural environment, Mongolia is well suited to sustaining large herds of sheep and cashmere goats and producing high-quality wool and cashmere for the global markets. With almost 30 million goats that produce one of the finest quality cashmere, the country is the second-largest producer of cashmere with a global market share of almost 40 percent.

The cashmere-wool sector plays an eminent role in diversifying Mongolia's economy and the products offer the highest value density compared to the other agricultural outputs. The producers in the cashmere-wool industry tend to be better organized in terms of their supply of inputs, value-added production, and distribution channels. They have more control over their inbound and outbound supply chains and are increasing their control over the production and supply of inputs. Their major challenge for the farmers is to expand their distribution channels while continuing to increase the value of their products (World Bank, 2019).

As far as leather is concerned Mongolia exports mostly intermediate commodities rather than finished leather goods. The nomadic style of animal husbandry practised in Mongolia limits the year-round availability of inputs and places an upper bound on the economic viability of more sophisticated manufacturing. Mongolia's leather industry also constitutes a small fraction of global trade.

3.1.2. Raw mineral exports and mineral beneficiation

Direct Reduction Iron (RDI)
Since Mongolia is very well endowed with coking coal and has iron ore, the opportunity to develop a steel value chain has been of interest to both the Government and some project proponents. In fact, considerable effort has gone into evaluating the techno-economic foundation for developing steel-making capacity to take advantage of raw materials availability. Much of this has focused on the existing small-scale steelworks in Darkhan which relies on scrap metal feed, rather than iron ore.

Iron Ore Value Chain
The continued and accelerated of un-beneficiated Iron Ore is also a possibility. Mongolia has a few medium size deposits of iron ore (reserves >30 million tons of ore) and numerous small magnetite deposits which vary significantly in the quality of ore. Until the

early part of the century, little interest was shown in these – the first iron ore mine was started in the 1990s. Interest grew when the rapid growth of demand for iron ore in China's steel sector drove prices up. This prompted a scramble to convert known iron ore deposits into mines.

Coal Value Chain
Mongolia has abundant coal resources, sufficient at current levels of exploitation, to last many decades. In the past, most coal produced was thermal coal for domestic use in power generation from mines developed in the 1980s and 1990s such as Baganuu and Shivee Ovoor. Supplies were some 5 million tons annually. But from around 2008 coal production increased to meet the fast-growing demand for coking and thermal coal in the neighbouring industrial regions of northern China. Several new mines were brought into operation, especially in the Tavan Tolgoi and Nariin Suhait coal complexes in the South Gobi Region, which are rich in coking coal.

3.2.   Development of the tourism sector
Mongolia has a rich cultural heritage and breath-taking landscapes that attract 500,000 visitors annually, contributing revenue of over US$590 million to the state budget as of 2018. Capitalizing on the country's unique natural landscapes and rich cultural heritage, Mongolia could further unlock the potential in the tourism sector as one of the key pillars of the economic diversification agenda. Mongolia has a relatively short tourism season between May to September. However, the Ministry of Environment and Tourism of Mongolia estimates that the domestic tourism industry has a capacity of receiving up to 1.2 million visitors during this period of the year, or 72,000 a day. In 2018 and 2019, there was an increase in tourist numbers and international tourist arrivals peaked at 577,000. To unlock the full potential of tourism, Mongolia needs to have the transportation infrastructure and system in place. At a minimum, this will include links between the new Ulaanbaatar international airport in the Khushig Valley some 52 km south of the capital and Ulaanbaatar. The links via a six-lane, 30.4-km-long highway and the airport rail express are in various stages of implementation. The transportation infrastructure should link international tourists to hotels and various sites.

4.   METHODOLOGY
Given that Mongolia's transport and logistics costs are equal to approximately 25% of its GDP, various industry sectors were analysed to determine how much their development would contribute to a growth in GDP and a reduction in logistics cost as a percentage of GDP. The developed freight demand model describes freight flows for 84 commodities across 339 soums and 10 border crossings. Supply and demand were modelled using a gravity flow methodology.

4.1.   Calculating transport and logistics costs
Using the freight demand model, a bottom-up approach was used to quantify the effect of macrologistics interventions (see Section 2.1) for different industry sectors. Transport costs were calculated by using origin-destination (OD) flows per commodity in tandem with the quality of the transport infrastructure network. For the road network, a relative increase in road costs was extrapolated based on an average current cost of transportation in Mongolia. Rail tariffs for additional freight were calculated assuming that there will be a positive return to cost as density on the main line increases based on the Harris curve (De Bod & Havenga, 2010).

For each commodity $n \in N$, the set of all commodities, and each OD pair $r \in R_n$, the set of all OD pairs for commodity n, with associated distances on transport infrastructure for mode m of quality q, d_{rmq} and tonnes for mode m, t_{rm}, the tonne-km, k_{nmq} is obtained by

$$k_{nmq} = \sum_r d_{rmq} t_{rm}$$

Given a commodity n, the annual tonne-km per commodity being transported on mode m over infrastructure of quality q, k_{nmq}, with cost per tonne-km, c_{nmq}, the total transportation cost for a commodity C_n is calculated by

$$C_n = \sum_m \sum_q c_{nmq} k_{nmq}$$

It is further assumed that the total logistics cost associated with a commodity n, L_n, is some multiple a of total transport cost

$$L_n = aC_n$$

The total transport and logistics costs C and L, respectively, are therefore obtained through

$$C = \sum_n C_n \text{ and } L = aC$$

4.2.   Quantifying the effect of macrologistics interventions

It is anticipated that macrologistics interventions would enable an increase in industrial output. The total additional tonnes for commodity n, t_n^* and its average annual value per tonne, p_n, as well as die GDP multiplier for the sector to which the commodity belongs, g_e, are used to calculate the increase in GDP, G_n:

$$G_n = t_n^* p_n g_e$$

The increase in logistics cost, L^+ is attained through subtracting the total logistics cost before additional production, L, from the total logistics cost including additional production L^*

$$L^+ = L^* - L$$

which is obtained by including the additional tonnes between the corresponding OD pairs and taking account of the associated transport infrastructure quality in the tonne-km calculation.

The results in Table 2 show that the livestock (meat products) value chain and iron ore beneficiation will provide the largest contributions to GDP growth and savings in logistics costs. The entries in Table 2 were calculated by assuming an increase in output for each of the industry sectors. The GDP growth was calculated by using a GDP multiplier on the estimated value of the final additional goods. The multipliers for the primary, secondary and tertiary sectors were assumed to be 3, 4 and 1.5, respectively.

Table 2. Contribution to GDP growth and reduction in logistics costs for various industry sectors (Created by the authors)

Sector	Industry	% GDP growth	National Logistics cost as % of GDP, will reduce from 24.7% to:
Primary	Coal export	13.8%	21.9%
	Iron ore export	3.5%	24.1%
Secondary	Meat products	26.5%	19.7%

	Other animal products	10.5%	22.9%
	Direct reduced iron	31.0%	20.1%
Tertiary	Tourism	0.4%	24.6%
	Transit traffic	2.9%	24.1%

For coal and iron ore exports increases of 4 million and 1 million tonnes, respectively, were assumed, both at US$ 150 per tonne, exported via road on trucks. These are increases of approximately an eighth of the 2019 export values. It was further assumed that two-thirds of the coal exports would be coking coal, resulting in a weighted price of US$ 150 per tonne for coal exports.

Additional meat production of 250 000 tonnes at US$ 344 per tonne is based on a 25% culling rate of cattle and sheep around eight logistics hubs in a 272 km catchment area. Other animal products comprise 160 000 tonnes of milk at US$ 750 per tonne, 5 000 tonnes of leather at US$ 10 000 per tonne as well as an increase of US$ 100 million in cashmere production. The calculation of direct reduced iron export is based on additional production of 2 million tonnes per annum at a proposed new plant, valued at US$ 3 440 per tonne and exported via rail.

A 10% increase in tourism (50 000 additional tourists annually) was assumed, each contributing US$ 500 to GDP, before the multiplier. Transit traffic was increased by 4 billion tonne-km at an average transit rail rate of US 5 cents per tonne-km.

The saving in road transport cost was calculated as the difference between the rate for travelling on bad roads and the rate for travelling on good roads. The saving in rail transport cost was based on the Harris curve, which describes the reduction in rail transport cost as the volume of rail freight, and therefore the utilisation of infrastructure, increases (De Bod & Havenga, 2010).

Proposed macrologistics interventions for Mongolia's meat and mining value chains are therefore indicated by this research. The meat value chain improvement was prioritized first (although both were attractive) because a wider pool (400 000 herder households) of the population would be immediately impacted

5.   UNIQUE INFRASTRUCTURE INTERVENTIONS
The meat industry proposal hinges on the development of 7 hubs and a central freight village close to the capital, connected by upgraded or new roads (see Figure 2).

Figure 2. Location of the identified agro-processing freight villages (Created by the authors)

Connecting these hubs with an unbroken cold chain can minimize losses and maximize bulk transport opportunities (see Figure 3).

The implementation of an alternative, integrated supply chain requires infrastructure that extends beyond the physical infrastructure, as summarised in Figure 3, showing physical infrastructure requirements at the top, their specifications in the middle, and the soft infrastructure at the bottom. Certification will be used to facilitate trusted access to export markets, and validate ethical standards and sustainable practices, to protect animals as well as herder households.
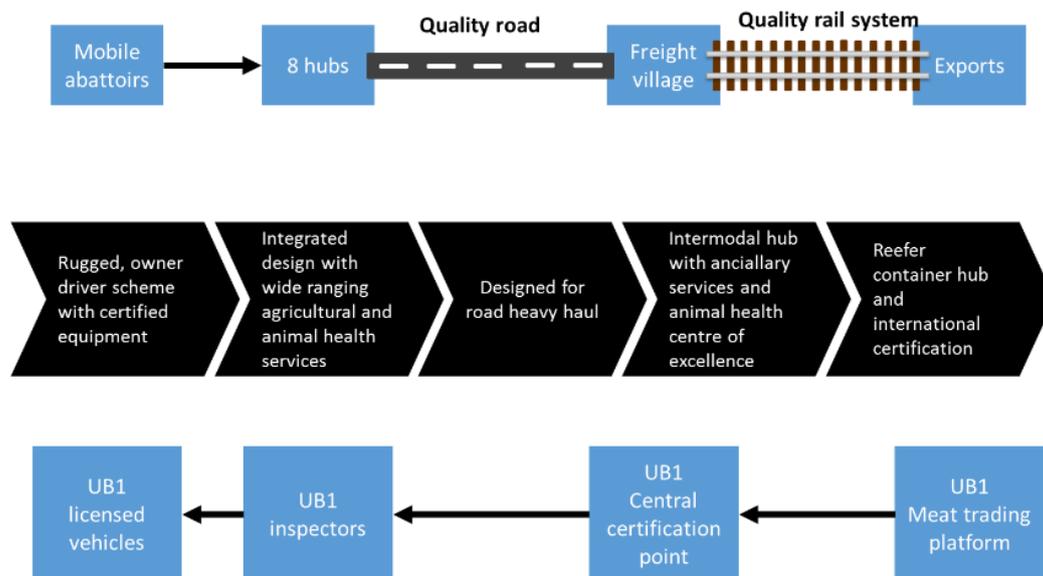
Figure 3. Supply chain design to facilitate the additionality meat scenario

The branded meat can be marketed as disease-free, organic, and free-range, in addition to conforming to UB1 standards and practices.

6.   CONCLUSION

The research has since led to a detailed analysis of the hubs and a proposal to borrow $150 million from the World Bank to develop the hubs, freight village and roads. The research approach successfully illustrated how a macrologistics infrastructure prioritization approach could be used.

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RESILIENCE OF SMALL-SERIES PRODUCTION MODELS: INSIGHTS FROM EU APPAREL INDUSTRY DURING COVID-19

Sara Harper, **Rudrajeet Pal**

University of Borås, Sweden

INTRODUCTION

With COVID-19 pandemic preparing our global economy for the next normal, there is an obvious resurgence in focus on designing more resilient supply chains (Handfield et al., 2020, van Hoek, 2020), in order to reduce risk exposure, and better adapt to impending supply chain disruptions caused by global uncertainties (Um and Han, 2021). While building resilient supply chains is pre-emptive across all industrial value chains (Lund et al, 2020), research should take into consideration industry-specific vulnerabilities and capabilities (Pettit et al. 2019), and thus recipes for building industry-specific supply chain resilience.

Of particular importance in this study is the textile and apparel (T&A) industry which is particularly vulnerable to supply chain shocks due to its globally dispersed and complex structure with heavy reliance on exports and high labour-intensity (Lund and Krishnan, 2020). Even before COVID-19, 25-50% of production was estimated to be relocated near-shore in the next five years for improving resilience, and in a study (Andersson et al. 2018), it was found that 66% of supply chain managers considered new business models (e.g., on-demand production) to be a major future growth driver. Pandemic impacts have further made such heavily traded labour-intensive T&A supply chains highly exposed to global risks, and in response trends towards increasing nearshoring, digitalization, environmental sustainability and small order volumes will likely accelerate (Andersson et al., 2018; Lund et al., 2020). McKinsey and BoF (2021) suggested while such near-shored, small-series production models are expected to reduce risks of overproduction and markdowns; however, these are fraught with other internal supply chain risks like limited available manufacturing competences and riskiness in investing to support such relocation (Andersson et al., 2018).

While research has stressed that supply network configuration is a key source of resilience due to its potential to improve supply chain flexibility (Christopher and Holweg, 2017; Srai and Gregory, 2008), there is a dearth of studies exploring the relationship between such reconfigurations and resilience (Al Naimi et al. 2021). Research has suggested resilience enablers related to capabilities, network structures, and reconfigurations (e.g. Al Naimi et al., 2021; Handfield et al. 2020, Um and Han, 2021), in high-risk supply chain environments, for example through production models focused on innovative and customized products (Um and Han, 2021). Further studies (e.g. McMaster et al., 2020; Pearson et al., 2010) have shown how shortening product life cycles, enhancing product variety, and increasing focus on high margin products increase could help in combating unpredictable demand. However, flexible production for enhanced customer value can conflict with supply chain costs (Mirzaei et al., 2021; van Hoek and Dobbrzykowski, 2021), while reducing exposure to disruption (Ellram et al., 2013; van Hoek, 2020). Thus, resilience building costs must be balanced carefully with risk reduction activities (Christopher and Holweg, 2017). Thus, for understanding such reconfigurations of small-series production models, and their influence on resilience further study is necessary.

The purpose of the paper is *to understand the how supply chain configuration related to small-series production models influence its resilience, in EU's textile and apparel industry.*

FRAME OF REFERENCE

From a holistic perspective, resilience refers to the ability to avoid disruption through anticipation, withstand through absorption, adapt to through reconfiguration, or recover from through restoration (Madni and Jackson, 2009). Although supply chain resilience is distinguishable from risk management (Madni and Jackson, 2009), to understand resilience, internal and external risk factors (vulnerabilities) must be considered, in order

to better explain supply chain resilience, and build upon knowledge regarding internal supply chain risks (Um and Han, 2021).

While resilience is associated with (cost) trade-offs (e.g., Christopher and Holweg, 2017), due to COVID-19 disruptions, supply chain designs are expected to evolve to focus more on metrics like resilience and sustainability (e.g., Handfield et al., 2020; van Hoek, 2020). Thus, the role of supply chain design decision, structures, and reconfigurations, i.e. structural flexibility, to mitigate risks and adapt to volatility (Christopher and Holweg, 2017) is essential for building resilience capabilities such as flexibility, agility, adaptive supply chain structures, visibility, collaboration, and risk management culture (Christopher and Holweg, 2017; Christopher and Peck, 2004; Madni and Jackson, 2009; Um and Han, 2021). Innovativeness (new product development) and internal social capital (geographic and relational proximity) also distinctively contribute to resilience of medium-sized firms (Polyviou et al., 2020; Pettit et al., 2019). Overall, this makes supply chain resilience depend on multi-dimensional configuration; however, fewer studies have addressed the correlations between resilience and reconfiguration (Al Naimi et al. 2021).

Based on the literature, small-series production is expected to increase exposure to internal risks, due to high-risk supply chain environments, but this in turn demands development of resilience capabilities, e.g., agility, collaboration, information sharing, trust, etc. (Um and Han, 2021). These capabilities will likely reduce exposure to external risks. Thus, to understand how resilience correlates with supply chain design (Christopher and Holweg, 2017) for such small-series production models, a holistic approach is required. This is enabled by the supply network configuration (SNC) framework proposed by Srai and Gregory (2008), encompassing network structures, products, operations, and relationships. The framework supported organization of the related literature, is summarized in Table 1.

Table 1 – Risk framework structured according to SNC (Srai and Gregory, 2008)

Small-series SNC (resilience enablers +/challenges -)	Internal risks	External risks
Structures		
SS+/SS- SNC+ Localization	• Decreased risk exposure from proximity (Um and Han, 2021); Increased risk exposure with local production due to cost trade-offs with knowledge and flexibility (Mirzaei et al., 2021)	• Decreased risk exposure from relocation and proximity (Ellram et al., 2013; van Hoek, 2020)
SNC+ Structural flexibility	• Decreased risk exposure due to structural flexibility (Christopher and Holweg, 2011;2017)	
Products		
SS+ Small volumes	• Decreased risk exposure through demand-driven production and increased agility (Um and Han, 2021)	• Decreased risk exposure from custom/small batch products (Christopher and Holweg, 2011)
Operations		
SS+ Flexible manufacturing	• Decreased risk exposure to manufacturing risks (e.g., operations breakdowns, etc.) due to flexible capacity (Um and Han, 2021)	• Decreased risk exposure through flexible capacity, knowledge, and process postponement (Christopher and Holweg, 2011; 2017)

| SNC+ Supply chain relationships | • Decreased risk exposure through supplier/customer relationships, information sharing, supplier selection, etc. (Christopher and Holweg, 2017) |

Notes: Resilience enablers/challenges (**+/-**) = decreased/increased risk exposure: (**SS+/-**=Small-series production in high-cost; **SNC+/-**=Configuration/Reconfiguration)

METHODOLOGY

Multiple case study was adopted to seek maximum variation in terms of supply network configuration, i.e. in terms of combination of small-series production models, company sizes, and business models, as detailed in Table 2. In total seven company cases constituting the study were purposefully sampled to seek deeper understanding of the risks related to the COVID-19 pandemic and each case's strategic reaction.

Table 2 – Overview of cases

Case #	Country x	Size +	Small-series production model	Value chain position/product	Interviewees (number of interviews)
Case 1	Belgium	Micro	**Custom/on-demand**: Focus on high variety MTM products with proximity sourcing (~100%)	**Brand**: Customer-driven digital business model for MTM woven fashion products	CEO (1, pre-interview and follow-up)
Case 2	Denmark	Small	**Custom/on-demand**: Focus on MTM product sustainability with proximity sourcing (~100%)	**Brand**: Customer-driven digital business model for sustainable MTM jersey/knit products	CEO (1)
Case 3	Italy	Large	**Small volume**: Implementation of proximity sourcing to test small-series production (5-10%)	**Brand**: Physical retail stores, multiple brands, apparel and accessories, including high-tech sportswear	Internal R&D/project manager (*.5); Two internal R&D/project managers (*.5)
Case 4	Sweden	Large	**Small volume**: Growing proportion (~12% of apparel) of 300-600 piece orders with proximity sourcing	**Brand**: E-commerce retailer of fashion products, e.g. trend and never out of stock apparel and shoes	Sourcing manager (1, and follow-up)
Case 5	Italy	Large	**Small volume**: Focus on fabric production and small volume product sustainability (100% of apparel)	**Producer/brand**: Complex fashion products with sustainable high-technology fabrics and innovative processes	Internal project manager (1, and follow-up)
Case 6	Sweden	Micro	**Small volume**: Core focus on flexible/small volume production; Implementation of on-demand brand (~100% small-series)	**Producer**: CMT manufacturing for all products and sustainable denim brand	Owner (1, and follow-up)

Case 7	Italy	Medium	**Small volume**: Focus on small volume products using classic and innovative technologies (100%)	**Producer**: Full-package fashion garment production	Two internal product/project managers (1, and follow-up)

Notes: [X] Headquarters; [+] Size defined by employee numbers, in line with European Commission (2003); *Interview took place over two occasions

The interviews were semi-structured and included two sections; first, regarding the small-series production model, while the next focused on recent experiences related to risk and resilience, i.e. what risks were experienced, what were the impacts, how were these impacts monitored and managed, and if the companies perceived any benefits/challenges with small volume, local production, flexible manufacturing, etc. Overall, the guidance came from the risk framework presented in Table 1. All interviews were conducted between February-March 2021 via video conferencing, and each lasted between 35 and 60 minutes. The interviews were later recorded and transcribed, and sought clarification if required to seek updates.

Within each case data were analysed for understanding the exposure to internal supply chain risks from delivery, manufacturing and sourcing, and external risks stemming from political and trade challenges, along with the risk impacts, and capabilities required to respond. The capabilities were organized along the four SNC elements (Srai and Gregory, 2008), for holistic analysis of small-series production models. Case write-ups were confirmed by respondents within follow-up interviews and over email. Table 3 presents the cross-case analysis, only including the aspects found with at least two case companies.

RESULTS AND ANALYSIS
All the case companies faced disruptions due to COVID-19 albeit their small-series production model faced different levels of risk due to it. Simultaneously, BREXIT also posed a major location-specific risk to some of the companies if they had market or supplier presence in UK. When it comes to more internal supply chain-related risks, some of the companies faced high relational risks at the buyer-supplier level, due to either lack of sustainability and transparency, or supplier dependence. Regarding small-series apparel production, our findings reveal that it both enables and impedes supply chain resilience in a number of ways, due to its configuration and priorities/performance goals (Table 3). While supply network configurational aspects related to product and operations (e.g. learning and process improvement, product variety and production scale) mainly reduce the risk exposure, our cases reveal some not-so-obvious results regarding how performance goals, supply chain structures and relationships can actually impede resilience (i.e. increase risk exposure).

Table 3 – Summary of cross-case analysis

Small-series production (Priorities & SNC)		Risk exposure (Int/Ext)	Case: 1	2	3	4	5	6	7
Priorities	**G1** Differentiation priorities (Innovation, Sustainability, Quality, Delivery)	*Low/Medium (Ext-COVID-19)*	X	X	X	X	X		X
	G2 Innovation (New product/ projects)*	***High** (Ext-COVID-19)*	**X**	**X***	*	**X**	*	**X**	**X**
	G3 Delivery performance (delays)	***High** (Ext-COVID-19)*	**X**	**X**		**X**			**X**
	G4 Sustainability performance (costs/logistics)	***High** (Ext-COVID-19)*	**X**			**X**			

SNC: Structure		Risk (Int/Ext)	1	2	3	4	5	6	7
SNC: Structure	**S1a** *Local supply chain/Location* ˣ*	*Low/Medium (Ext-COVID-19)*	X*			X	X		X
	S1b *Local supply chain/Location* ˣ	***High*** *(Ext-BREXIT)*	**X**			**X**			
	S2 *Supply chain/ Competence reconfiguration* ˣ*	***High*** *(Ext-COVID-19)*		**X**		**X**	*		
Products	**P1** Product type/variety	*Low/Medium (Ext-COVID-19)*	X			X	X	X	
	P2 *Small volume production* ˣ	*Low/Medium (Ext-COVID-19)*				X		X	
Small-series production (Priorities & SNC)		**Risk (Int/Ext)**	**Case: 1**	**2**	**3**	**4**	**5**	**6**	**7**
Operations	**O1** *Learning and process improvements* ˣ	*Low/Medium (Ext-COVID-19)*	X			X	X		X
	O2 Digital supply chain (E-commerce/ On-demand)	*Low/Medium (Ext-COVID-19)*	X	X		X			
	O3 Facility size (Small/Large)	*Low/Medium (Ext-COVID-19)*					X		X
	O4 Material sourcing (Higher prices/delays)	***High*** *(Ext-COVID-19)*	**X**			**X**			**X**
Relationships	**R1a** Buyer-Supplier relationships	*Low/Medium (Ext-COVID-19)*		X		X	X		
	R1b Buyer-Supplier relationships	***High*** *(Int-SC)*					**X**	**X**	**X**

Notes: ˣ*Reconfiguration;* *Contrasting evidence

Supply chain priorities in small-series production and resilience

Cases with small-series production models that enabled balancing different supply chain priorities, such as offering sustainability, innovation, and delivery speed, could develop a resilient supply chain. Such balancing enabled differentiation (G1) thus competitiveness during COVID-19. For instance, producers with specialized competence and innovative production could attract customers (in Case 7) or render innovative products with technical functionalities (in Case 5). On the other hand, some cases faced significant delivery delays, and challenges with sustainability improvements and innovation in response to COVID-19 (G3-G5). Delivery delay was described as particularly challenging for made-to-measure brands (in Case 1) due to customers being made to wait longer, and as such delays can be associated with difficulties in sourcing fabrics (O4). Such delays and added costs with material sourcing additionally contributed to difficulties in achieving sustainability performance, for instance it demanded relying on air freight for delivery (in Case 1). Amidst these sustainability-related challenges, while improvements were prioritized, e.g. sustainable material development (in Case 4), disruptions somewhat meant postponing other innovation efforts, such as digitalization projects which further hindered supply chain reconfiguration suited to small-series production models.

Supply network configuration in small-series production and resilience

Right supply chain location is crucial for enabling resilience; particularly in terms of being local or regional in set-up amid COVID-19 (S1a), as it leads to lower risk exposure. In particular, such locational characteristics (influencing supply chain structure) were beneficial as European sourcing or production was increasingly in demand for developing innovative fabrics and products (in Case 5), for delivering consistent product quality (in

Case 7), and for implementation of high-value manufacturing in small volumes (in Case 3). However, for on-demand production models such local production models showed both benefits, due to transportation ease, and challenges, as key fabric brands situated in a single nearshore location led to higher risk exposure to delays in material sourcing (in Case 1). Amidst COVID-19, those case companies having significant market in UK also faced BREXIT-related supply risks, i.e. they had to absorb added costs e.g. related to searching for replacements for UK-based suppliers (in Cases 1, 4). For Case 4 this demanded supply chain reconfiguration, which led to accessing better and sustainable supply options available in rest of Europe. Building competence in-house and with suppliers was difficult for Case 2, due to COVID-related travel restrictions (in Cases 2, 4), which hinders the collaborative development required to overcome limited production competence.

When it comes to inherent product-related features in small-series production models; these were particularly suited to enable resilience in COVID-19. For instance, suitable for small-series production are low volume-high variety products (P2), which were specifically suited to meet the demand uncertainties during COVID-19. For instance, Case 4 could adjust its product variety-volume in line with changing demands in its product portfolio. Another company (Case 6) described themselves as being used to offering many different types of products, "because we are working with so many different customers and projects (…) maybe it is a little bit easier to adapt and survive because of that". Other companies' products were particularly high-value, such as Case 5's speciality fabrics, or Case 7's made-to-measure fashion clothes, and did not face significant demand reduction. This highlights the adaptability of such small-series production models to be particularly enabling resilience. Beyond confirming the link between high-variety, high-value manufacturing and resilience (Um and Han, 2021), our findings additionally show that (product) innovativeness is a key enabler for resilience (Polyviou et al. 2019) of small-series production models in response to external risks. Notably, the medium-sized producer (Case 7) was not found to leverage such capability due to its offering of a narrow range of fashion products, thus resulting in facing more significant demand disruptions during COVID-19. However, large company cases were better geared towards adopting or strengthening their small volume production models.

In general, configuration of operations aspects, such as through learning and process improvements (O1), adoption of digital features in the supply chain channel (O2), and changing facility capacity (O3), were found as enablers of resilience. For instance, Case 5's long history of improvements for process efficiency, using digital tracking technologies, was valuable during the pandemic, while Case 7 showed increased opportunities to learn, improve and develop processes in response to COVID disruptions. Similarly, in order to react to long delivery lead times, Case 1 introduced a new digital sales feature to offer transparent information and greater control to customers over delivery decisions. In COVID-19 context, most of the case companies further acknowledged the benefit of having e-commerce and on-demand production systems (O2). Case 1 highlighted how being online only allowed better management of demand disruptions, while Case 2 highlighted the benefit of having no finished goods inventory when facing fluctuating demand, thus confirming the benefit of e-commerce and postponement to reduced risk exposure (Um and Han, 2021). Despite operational benefits related to small-series production, material sourcing (O4) posed a significant challenge to building resilience due to increased costs and delivery delays, e.g. for sustainable materials. This reveals a key vulnerability to such production models in T&A; while such risk exposure can speed up transitions to supply chain co-location for producing sustainable materials (Culot et al., 2020), this could only be achieved by building up necessary manufacturing competence in Europe (Andersson et al., 2018).

Finally, configuring supply chain relationships in small-series production models can have either enabling or impeding impact on resilience. While close buyer/supplier relationships were necessary for brands to hedge the risks related to demand disruptions (R1a), such

relationships can be a source of risks for producers too. Close supplier relationships (R1a) are described as key for resilience in the face of higher risks related to delivery delays - one of the company (case 4) highlighted *"It's just natural to work even more close now to survive this COVID situation (…) through long term cooperation, with suppliers that work well and that have a very smooth communication, stable financial situation, and good sustainable fabrics"*. However, production companies faced high exposure regarding buyer-supplier relationships (R1b), due to sustainability/transparency goals and high levels of supplier dependence on customers. For instance, Case 5 highlighted how its material suppliers in Asia were the source of previously unknown social sustainability risks that were untenable to its customers, despite the expected control associated with a joint venture. Thus, Case 5 reconfigured its upstream supply chain through partnership with an Italian company. However, another producer (Case 7) faced high risks due to its high degree of dependence on customers for orders in the absence of its own brand. This was described as a key problem for the apparel producers. While brands could minimize sourcing risks by reducing dependence on single supplier/location or by increasing supplier closeness (McMaster et al., 2020), as a producer, reducing customer dependence could only be done by integrating forward in the value chain, however such investments are high-risk (G2). Thus, the findings show buyer-supplier relationships offer significant benefits to brand resilience in the face of external risks, although producers face several risks related to such relationships.

DISCUSSION AND CONCLUSION

The study offers four main contributions; first, the SNC framework (Srai and Gregory, 2008) enabled holistic understanding of the risk exposure and resilience of small-series apparel production models, through investigating a high-risk period within the EU context. Second, the findings show external risks to be highly relevant, as expected due to the widespread impacts of COVID-19, and suggest such risks can be mitigated by small volume production supported by flexible (digital) processes and supply chains with emphasis on digital supply chains/e-commerce, and the ability to adapt product varieties, learn and improve processes. This indicates such production models can support adapting to and withstanding risks in line with suggestions from previous research. Third, enabling and challenging effects are found with: priorities and performance (innovation, sustainability and delivery) due to high exposure to COVID-19 disruptions e.g., sustainable material sourcing; location (because of BREXIT impacts), and supply chain relationships due to relational dependence and sustainability risks. Fourth, location reconfigurations were found with sustainability and BREXIT-related risks upstream and the opportunity to enhance small-series production, e.g., through implementation or improvements and learning. These findings regarding (re)configuration enablers and challenges can support companies to reconfigure structures for small-series production to adapt to increasing risks, by highlighting various complexities and challenges that must be managed.

The industry specificity and the holistic view of network configurations during the time of COVID-19 are key benefits of the research; however, as with all research there are certain limitations. While the qualitative approach supports a holistic understanding of risk exposure that is sensitive to the perspectives of the decision-makers, the lack of quantitative measures of resilience can be considered a limitation of the study. Thus, follow-up research could strengthen the findings by addressing these issues using a large-scale survey to compare outcomes in different industries and location contexts. Additionally, future case study research can focus on gaining in-depth understandings of how companies balance the positive and negative impacts of different facets of small-series production on resilience as indicated, e.g., through enhanced structural flexibility and dynamic capabilities.

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Applying System Dynamics in Banks' Operational Risk Management: A Systematic Literature Review

Ajjima Jiravichai, Ruth Banomyong
Thammasat Business School, Thammasat University
E-mail: ajjima.jir@dome.tu.ac.th

INTRODUCTION

Operational risk in the banking industry is defined as "the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events." It includes legal risk but excludes strategic and reputational risk (BCBS, 2003). It is considered one of the most pernicious forms of risk that can contribute to numerous failures with extensive impacts to financial institutions and global stability (Jorion, 2007). From the annual banking loss report of the Operational Riskdata eXchange Association (ORX), one of the world's leading operational loss data associations for banks and insurance companies, operational risk loss reported by the member banks in 2020 was Euro 16.7 billion with a cumulative total gross loss of Euro 513 billion since 2002 (ORX, 2021).

According to McKinsey & Company, operational risk management (ORM) is a relatively young field and have become an independent discipline in the early 2000. Banks have been aware of risks associated with operations or employee activities for a while, while the Basel Committee on Banking Supervision (BCBS), in a series of papers published between 1999 and 2001, elevated operational risk to a distinct and controllable risk category requiring its own tools and organization (Eceiza et al., 2020). According to Bain & Company, banks have developed sophisticated systems for controlling financial risk, nonetheless they have struggled to deal effectively with operational risk (Huber & Funaro, 2018).

In academia, banking ORM is "truly a controversial topic" providing ample opportunity for future studies (Moosa, 2007). Studies in this field also contain major gaps that are possibly resolved by an interdisciplinary approach (Green et al., 2000).

This paper aims to report the use of system dynamics (SD) in banking operational risk management (ORM) research and propose SD as a methodology to expand future research in this area.

The paper is separated into three sections. The first section will present major gaps in the banking ORM literature. It will also discuss the dynamic complexity and uncertainty of the system. The second section will report the systematic literature review (SLR) of SD applications in banking ORM. The third section will provide conclusions, including contributions and limitations.

MAJOR GAPS IN THE BANKING ORM LITERATURE

Usefulness of measurement models in effectively managing operational risk is one of the most controversial topics in the field of banking ORM. From the study of Pakhchanyan (2016), almost 60% of 279 studies published between 1998 and 2014 dealt with capital adequacy requirements. We further observed that the majority of studies in this discipline focused specifically on the development of measurement models that yield minimum capital charge (Mizgier et al., 2015; Li et al., 2014; Fantazzini et al., 2008; Dalla Valle & Giudici, 2008; Brechmann et al., 2014) rather than explain how these models can cover adequate level of loss from pervasive and enormous operational risk (Goodhart, 2001; Herring, 2002, Sands et al., 2018).

In academia, shortage and bias of operational loss data are widely recognized as a serious problem in modelling operational risk and conducting empirical studies (Power, 2005).

Internal loss data, in general, lack reliability (Moosa, 2007) while external public and pooled loss data are restricted only to large losses (Chapelle et al., 2008) and only accessible to subscribers of specialized databases (Power, 2005). BCBS allows banks to define and justify thresholds for operational risk data collection (BCBS, 2016). Therefore, in practice, threshold for internal loss data collection varies between banks. External database vendors also set different thresholds for operational loss reporting. For example, SAS OpRisk Global Data, one of the existing public loss databases, set the minimum reporting threshold for operational risk loss at USD 100,000 (SAS Institute Inc., 2015) while the threshold of ORX is set at Euro 20,000 (ORX, 2019). Although BCBS requires that these thresholds must be qualified as "appropriate de minimis gross loss threshold" (BCBS, 2016), the fact that operational loss data below the thresholds will not be reported but accumulated remains. In practice, these thresholds cause bias in underreporting loss (Aldasoro et al., 2020). External data is also inherently biased due to the focus on larger, more remarkable losses (BCBS, 2011). Furthermore, in practice, an accumulation of operational loss data before reaching the threshold for reporting causes fluctuation in internal and external loss databases. In addition to bias from underreporting loss, protracted legal proceedings may cause delays in the acknowledgement of loss accumulation (Aldasoro et al., 2020).

The new Standardised Approach (SA) that will be effective on 1 January 2023 requires only internal data source for operational risk capital calculation (BCBS, 2016). As researchers, our concern is on the reliability of capital reserve. Logically, the quality of input determines the quality of output, in what level can researchers rely on capital reserve provided by existing measurement model that uses data with potential bias? In addition, if the forward-looking operational risk data are not considered in the reserve calculation, how can banks be sure that they have enough capital for operational risk events incurred as a result of banks' operations?

We further observed that there have been attempts from academics in this field at developing measurement models from various techniques in solving data problem in banking ORM. These techniques are, for example, the calibration process in merging between internal and external operational loss data (Frachot & Roncalli, 2002), and the use of Bayesian Network in integrating between forward-looking and backward-looking data (Giudici & Bilotta, 2004; Cowell et al., 2007). However, the models from these techniques can neither prevent the occurrence of operational risk nor incentivise management in effectively managing operational risk (Goodhart, 2001; Herring, 2002; Chapelle, et al., 2008; Sands et al., 2018).

Major gaps in the literature and general problems in ORM described in the preceding paragraphs require a different methodology. Apart from the use of measurement models, it is important for banking ORM research to investigate and propose how operational risk can be effectively managed.

Operational risk incidents can be so costly that society and the responsible bank cannot afford them. Therefore, it is important that the newly identified methodology employs a forward-look and preventive strategy in managing risks by controls that address its root causes, rather than its consequences or symptoms (Vaughan, 2005; Cowell et al., 2007). In addition, to support the reliability of measurement models, the new methodology should be able to resolve the poor and scarce data problem of ORM.

Furthermore, the methodology should be able to capture both dynamic complexity and uncertainty derived from interactions between multiple stakeholders in the ORM system. Unlike market and credit risk management, ORM requires all staff within banks to be responsible for managing operational risk along the three lines of defense model (BCBS, 2011). Interactions among staff make ORM a dynamic complex system. Collaboration of staff, including reporting of operational risk data, can create time delays and feedback loops. These time delays are, for example, delays in loss reporting after its occurrence,

delays in implementing ORM policy after its design, and delays in learning after training. Besides banking staffs, ORM involves multiple stakeholders, including central banks, regulators, shareholders, rival banks, and the media. These multiple stakeholders create spillover effects, which cause uncertainty in banking ORM. For instance, operational risk event in one bank can cause regulatory sanction, loss of shareholders' trusts, and negative press coverage for all industry participants (Deloitte Development LLC, 2018). Technological advancement, including financial technology, also creates new complex environment for ORM. They introduce new operational risk exposures, expand the scope of ORM, and require even more capabilities from operational risk managers.

A SLR ON THE APPLICATIONS OF SD IN BANKING ORM

Founded by Jay Forrester in the late of 1950s, SD is widely recognized as the approach for learning and understanding the behaviour of complex systems (Homer & Oliva, 2001). Its powerful toolset has the capacity to provide insight into managerial systems issues (Wolstenholme, 1999). SD qualitative and quantitative models can capture the dynamic complexity of ORM system from feedbacks, multiple interconnections, nonlinearities, time delays, and accumulations (Sterman, 2000). A causal loop diagram, which is a qualitative model of SD, describes a system by portraying the relationships between entities and identifying the existence of feedback loops (Wolstenholme, 1999; Coyle, 2000; Coyle, 2001). Simulations, which run from the quantitative model, not only help a modeler in discovering the flaws in a model but also explain system behaviour resulting from an application of policy or strategy (Homer & Oliva, 2001).

We followed the SLR methodology suggested by Banomyong et al. (2019) to identify where SD was applied when studying ORM in banks, and to evaluate how, to what extent, and for what purpose SD was used in these studies,

     a.   Selection of the database

We selected both Scopus and ProQuest to search for articles applying SD. Each of them has coverages of titles more than 7,000 academic publishers worldwide (Elsevier, n.d.; ProQuest, n.d.). These numbers are sufficient to understand and assess as well as to form a conclusion.

     b.   Collection of articles

We used a combination of three keywords and one equivalent keyword in all fields. These three keywords are: (1) operational risk, (2) system dynamics, and (3) bank. Financial institution, which is the equivalent keyword of bank, was also used for collecting all relevant articles.

We focused only on studies that employed SD in banking ORM. Therefore, we included only full text and peer review journal articles while excluded book and book chapter, conference paper and conference review, and non-English articles. The search results are provided in Table 2.

Table 2: Number of banking ORM studies applying SD identified from a SLR

Keywords and equivalent keywords	Number of articles	
	Scopus	ProQuest
Operational risk	4,037	6,270
Bank or financial institution	7	135
System dynamics	1	55

Source: The Authors

     c.   Elimination of articles based on the inclusion and exclusion criteria

We initially screened titles and abstracts of the articles, and excluded (1) redundant articles, (2) literature review, bibliography, and the similar, (3) annotation, book review,

and the similar, and (4) studies in the fields outside the banking industry. There were numerous occasions where we had to screen the full articles to decide whether the studies employed SD and the unit of analysis of the studies was ORM in the banking industry. Studies that only mentioned the term "system dynamics" but neither used it in their studies nor meant the SD approach were excluded. Examples of these studies are those that mentioned system dynamics in their references or in the author's bibliographic note. Likewise, studies that mentioned bank or financial institution in their references or in the author's bibliographic note were excluded. Finally, studies where the unit of analysis was not ORM in the banking industry were excluded.

By applying the inclusion and exclusion criteria, only three relevant articles were left from 56 articles. They are presented in Table 3.

Table 3: Banking ORM studies applying SD

Author	Year	Title	Source
Ramanujam and Goodman	2003	Latent errors and adverse organizational consequences: A conceptualization	ProQuest
Yan and Wood	2017	A structural model for estimating losses associated with the mis-selling of retail banking products	Scopus
Farhan and Alam	2019	Operational Risk Management in Islamic Banking; a System Thinking Approach	ProQuest

Source: The Authors

> d. Classification of articles

From the three banking ORM studies that used SD, we sorted them into 1) qualitative studies; and (2) quantitative studies. We examined how these studies used SD in managing operational risk of banks.

By following the approach taken by Besiou and Van Wassenhove (2021), we evaluated whether the use of SD by these studies was appropriate. Table 4 summarized how these studies used SD in capturing dynamic interactions between variables that affected banks' ORM. The three studies used causal loop diagrams in presenting complexity of the systems under study. Ramanujam and Goodman (2003) developed a conceptual model of latent errors and used it in explaining the dynamic interactions between variables in their model. Farhan and Alam (2019) also used the qualitative model of SD to gain an understanding of the dynamic behaviour of variables in ORM system of Islamic banks. Yan and Wood (2017) collected and used operational loss data from ORX, one of public loss databases, to simulate losses from the quantitative model of the mis-selling complaints of banking products.

Table 4: Types of SD models used by banking ORM studies

Author (Year)	Conceptual model	Causal loop diagram	Simulation model	Real data	Hypothetical data
Ramanujam and Goodman (2003)	X	X		X	
Yan and Wood (2017)	X	X	X		X
Farhan and Alam (2019)	X	X		X	

Source: Adopted the table template from Besiou and Van Wassenhove (2021)

Ramanujam and Goodman (2003) developed the concept of latent errors and examined the complex relationships between latent errors, their antecedents, and consequences. Latent errors were defined as activities, events, or conditions that deviate from organizational expectations, and may cause adverse consequences. According to the authors' concept of latent errors, latent errors can be classified into two types that are routine and non-routine latent errors. Routine errors are, for example, a deviation from standard operating procedures, a noncompliance with transaction limits, and an omission in executing monitoring activities. Routine errors can be subclassified into execution, monitoring, and infrastructure. Non-routine latent errors are, for example, errors in strategic decision making. The study focused only on latent errors from routine operations. They are, for example, The authors built a conceptual model depicting the positive and negative feedback loops of interactions between routine latent errors themselves and between latent errors and trigger events. The construct validity is from the authors' analysis of different types of routine latent errors collected from different business units of a large financial institution. We evaluated that SD is an adequate methodological approach for this study. These authors appropriately used the conceptual diagram in explaining an acceleration of routine latent errors and ineffective corrective actions that caused the collapse of Baring Bank However, we observed that the diagram does not include other mechanisms that also cause the adverse consequences. These mechanisms are, for example, errors from strategic decision-making and fraud. According to Bhalla (1995), information failure, including delays in Barings management decisions, was mainly accountable for the collapse of the bank. In addition, we observed that there is a need to quantify the effects of latent errors in the conceptual model in order to gain important insight into the dynamics of the system (Sterman, 2000).

Yan and Wood (2017) proposed a structural model to estimate losses associated with the mis-selling of retail banking products. According to the authors, the structural model, which was built on key risks of loss generating processes, provides greater accuracy in the estimation of capital for operational risk than do other approaches relying on backward-looking and incomplete operational loss data. The model used both Bayesian Network to determine the frequency distribution and SD to estimate the severity distribution of loss from mis-selling complaints.

The authors developed a stock and flow diagram to track the accumulations of complaints as they moved through the system. A queueing system was incorporated into the model under the assumption that the complaints will not be investigated before the trigger event. The severity model of mis-selling complaints was constructed and simulated to investigate losses attributable to redress, resourcing, and financial penalty in the mis-selling event. By using SD, the researchers were able to quantify the delay effects, such as hiring, training, and dismissal of the temporary staff. Although the study of Yan and Wood (2017) was claimed to be the first published literature that applies SD in the estimation of operational risk loss, we viewed that the SD approach was not appropriate for the study with two main reasons. First, the study assumed that complaints from mis-selling products are homogenous. We argued that homogeneity is the condition of SD but complaints from mis-selling products are, indeed, distinct. Discrete-event simulation (DES) viewed a system as networks of queues and activities. Complaints in DES system are distinct individuals and investigation durations are sampled for each individual complaint from probability distributions. Second, the study assumed that the complaint will not be investigated before the trigger event, which is defined as when the number of awaiting complaints for investigation is materialized. This assumption does not align with the reality. In practice, banks do not wait until the number of awaiting complaints is materialized. In addition, according to Brailsford and Hilton (2001), one of the technical distinctions between DES and SD is whether the state changes occur at discrete points of time or they are continuous. SD is appropriate when the state changes are continuous, not at discrete points of time.

Farhan and Alam (2019) used SD to understand the interrelationships between variables affecting the noncompliance with legal and fiduciary duties of Pakistani Islamic banks. SD facilitated the collaboration between the researchers and the banks in modelling variables in the qualitative causal loop diagram. The authors performed three stages in the development of their causal loop diagram. The first stage was the development of the preliminary model from these authors' knowledge gained from relevant literatures. In the second stage, these authors confirmed and improved the preliminary model based on semi-structured interviews with selected practitioners. In the final stage, these authors refined and validated their model from interview data analysis. The qualitative model makes visible the importance of proactive ORM namely staff trainings, contingency plans, and adoption of advanced technology but it needs to be tested to uncover the flaws in the model. The model, which reflects the homogeneity assumption of SD, makes SD an appropriate methodology for their study. However, we observed that impacts of variables and their interactions in the model need to be quantified.

e.   Summary and mapping of knowledge structure within the research domain

From this SLR, we observed that SD is not used extensively among scholars in the field of banking ORM. Only three articles have been identified from this review.

Among the three studies, only Yan and Wood (2017) developed a simulation model that used the hypothetical loss data from one of the public operational risk loss databases, rather than empirical data. In contrast, Ramanujam and Goodman (2003) and Farhan and Alam (2019) collected empirical data to construct and validate their causal loop diagrams.

Case studies with empirical data help researchers develop both causal loop diagram and simulation model (Besiou & Van Wassenhove, 2021). Farhan and Alam (2019) conducted semi-structured interview to support their preliminary causal loop diagram, Ramanujam and Goodman (2003) collected data from 80 departments of a large financial institution to analyse the distribution of different types of routine latent errors across three business divisions.

According to Sterman (2000), our cognitive ability is limited. Therefore, we cannot simulate large and complex model by using our mental models, which are easily driven by ideology or unconscious bias. Computer can reliably simulate such large and complex conceptual model. Computer based simulation models can also compress time, thus speeding the test of hypotheses, learnings, and detection of model flaws. Furthermore, when real world experiment is not possible, simulation models enhance effective learning of dynamic and complex systems in virtual worlds. These are evidenced by the study of Yan and Wood (2017) whose simulation model not only facilitates the estimation of losses from mis-selling products but also enables the evaluation and optimization of risk management strategy.

CONCLUSIONS

In this paper, we identified the need for methodological approach, in addition to the existing measurement models, developed to address major issues in banking ORM. These issues include a controversy on the effectiveness of ORM measurement models and data problems. Future research needs to effectively manage operational risk in the banking industry.

SD was identified as a potential method for future banking ORM studies. It helps researchers not only gain insights into managerial system issues but also facilitate the communication and collaboration between researchers and practitioners. SD has a capacity to capture the dynamic interactions among risk drivers in the complex and uncertain ORM system. Its simulation model makes the analysis of large and complex models possible and in efficient manner (Sterman, 2000). A simple to understand and easy to use causal loop diagram supports researchers in the modelling process, including

data collection, model validation, and result explanation (Albin, 1997). In the case study method, SD enables understanding, trust, and data sharing between researchers and practitioners. Through group model-building techniques, engagement of stakeholders enhances quality of the model and the implementation (Vennix, 1996; Anderson et al., 1997; Sterman, 2000). In addition, because SD is well advocated and supported by scholars, its strengths are recognised over time, thereby providing researchers with confidence in the quality of toolset, including the SD models being developed.

To the extent of our knowledge, this paper is the first systematic review of SD applications in banking ORM. We identified three ORM studies that used SD. We observed that researchers of all three studies used SD models in capturing, examining, and validating the dynamic interactions between variables in the systems under their studies. Two studies collected from our SLR used qualitative diagrams in explaining the complexity of their systems. The causal loop diagram facilitated researchers in validating the preliminary map of variables and interconnections in the ORM system with the practitioners. One study constructed a quantitative severity model of operational risk to estimate the operational loss.

From our SLR, we pointed to shortcomings in the practice of SD modelling in the field of banking ORM. Specifically, we observed that the models need to be tested and the effects of interactions between variables in the models need to be quantified. Researchers also needed to be aware of the assumptions of SD in order to make sure that they align with reality and SD is suitable for their case studies. These shortcomings serve as extensive opportunities for future interdisciplinary researches in this field. We call for interdisciplinary research team of ORM academia, SD modelers, and risk and policy experts to contribute to the extended use of SD to understand and manage the problem of operational risk in the banking sector. Furthermore, we encourage the interdisciplinary team to construct a model of operational risk drivers derived from both forward-looking and backward-looking data to support a selection of effective ORM policies and strategies that resolve data problem in this discipline and support the effective ORM, in practice.

We assessed the limitation of our study to the extent that our SLR reviewed only full text and peer review journal articles while excluded non-English articles and conference or white papers. Generally, a SLR cannot guarantee but provides assurance on the quality of our literature review. The use of more than one academic databases like Scopus and ProQuest, which have material coverages of titles and publishers worldwide provides a sufficient number of articles for analysis and a formation of our conclusion.

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Can be furnished upon request

INFORMING MACROLOGISTICS CONNECTIVITY IN EMERGING ECONOMIES THROUGH A TRIANGULATED RESEARCH APPROACH: THE CASE OF UZBEKISTAN

Zane Simpson, Jan Havenga
University of Stellenbosch
E-mail: zane@sun.ac.za

INTRODUCTION

Uzbekistan is Central Asia's most populous country, with its 32 million citizens representing nearly half the region's total population. Tashkent, the capital, is Central Asia's biggest city. The government is exploring various initiatives for enhancing regional integration and connectivity, diversifying trade routes in the context of China's Belt and Road Initiative (BRI), and exploring maritime access options. The country has the potential to become a regional hub linking Southeast Asia, South Asia, the Commonwealth of Independent States, and Europe (World Bank, 2020), where logistics and especially logistics facilities can play a key role in the region, similar to Singapore's successful positioning as a hub for Southeast Asia (Yue & Lim, 2003). Uzbekistan's economic development goal is to move from a centrally planned, inward-oriented economy towards a more open, integrated, value-adding and export-driven economy (Tsereteli, 2018) supported through reforms to further improve the investment climate, the efficiency of public sector investments, and service delivery mechanisms in various sectors of the economy.

The country's ambitious New Development Strategy was launched in 2017 (Tashkent Times 2017) to support its transition to democracy, with the following key focus areas: state and judicial reform, economic liberalisation and growth, and social and cultural development and cohesion, including creating a foreign policy enabling regional cooperation. Economic liberalisation and growth include *inter alia* initiatives focused on the creation of industrial zones and techno parks, export facilitation and transport infrastructure development. These initiatives become even more pertinent given Uzbekistan's double-landlocked status (all neighbours are also landlocked), making the country reliant on both infrastructure and relationships with neighbouring countries to reach international markets (Qoraboyev 2018). It is therefore imperative for Uzbekistan to develop a clear understanding of its own national logistics needs and priorities to leverage opportunities for connectivity created by the opening of the country and initiatives in the Central Asian region.

However, within Uzbekistan the focus has been on physical planning of transport infrastructure assets without explicitly considering the demand for freight transport and intermodal competition (World Bank, 2020). Accurate, timely, and reliable information is the foundation of sound national and regional logistics sector policymaking and investment decisions (Asian Development Bank, 2007); the absence of which remains a critical barrier for the sector's sustainability and environmental performance, especially in emerging economies (Moon, 2013).

One tool to step out of this negative cycle is to have the ability to target the sectors and logistics facilities which would not only enable short term growth opportunities but would align with the economic development agendas of government and business over the long term. This is enabled through integrated data on the national transport and logistics industry with sufficient commodity and geographical disaggregation. Given the typical paucity of such data in emerging economies, this research describes the development of a freight-flow model for Uzbekistan – the Uzbekistan Freight-Flow Model (UFFM) – leveraging existing data sources. Both domestic flows within Uzbekistan, as well as freight-related movements beyond the borders of Uzbekistan, are included.

The UFFM was developed with support from the Government of Uzbekistan based on three drivers, i.e., the conviction that Special Economic Zones (SEZs) were required (Kuzieva,

2019); that the railway must improve (despite of its sizable network, the railway only shipped 68.4 million tonnes in 2018, albeit up from 61.5 million tonnes in 2012 (Sultanovich, 2019)); and that a data-driven transport strategy for Uzbekistan is required. However, from exploratory discussions, given the country's centrally planned economic history, it was clear that there would be challenges to readily obtain the detailed data required for the UFFM (further discussed in the methodology section). The primary aim was therefore to develop a freight-flow model with sufficiently detailed outputs to develop a cogent macrologistics narrative with evident application in the country's development strategies. The resulting secondary aim was to pique the interest of stakeholders to obtain wider access to data sources to refine the UFFM.

RESEARCH APPROACHES IN DATA-SCARCE ENVIRONMENTS
The United States Department of Transportation (2019) provides guidelines on data collection, compilation and refinement to support freight planning and forecasting (1) identify and assess available data sources and identify gaps; (2) collect, refine and clean existing data to create a base dataset of existing freight data; (3) collaborate with freight stakeholders to collect or estimate identified gaps; (4) process and combine existing and new data to create an integrated freight database; (5) create a process to maintain and update the freight database.

However, in emerging economies projects to improve data collection, accuracy and availability often fail because their goals are too ambitious, as the resources simply are not available to implement large-scale projects. This remains a key obstacle to the development of coherent national and regional transport policies and subsequent investments (Asian Development Bank, 2007).

To overcome the research limitations imposed by freight-flow data paucity, researchers often utilise the principle of data triangulation, i.e., the use of data from different sources to overcome the challenge of incomplete or conflicting datasets, to deepen understanding of the sector, and to cross-validate findings to increase the credibility of outputs (Mangan, Lalwani & Gardner 2004; Islam, 2005; Rahman, Mohammad, Rahim, Hassan, Ahmad & Kadir, 2017). The concept of triangulation refers to the trigonometric approach utilised in land surveying to determine unknown distances by measuring the angles in a triangle formed by three survey control points, i.e., two points on baseline with known distance and a distant third point in line-of-sight (Shafer, 1987). Through various iterations utilising the newly developed data a chain of triangles or triangulation network can be developed to describe the landscape under survey. Outputs of the triangulation network are strengthened by increasing the observations or inputs (Moose & Henriksen, 1976). The important principles are that known data points can be utilised to estimate unknown data points, that estimates can be improved by utilising more data inputs, and that this iterative process can eventually lead to a reliable description of the whole landscape under investigation if done diligently. A further approach to enhance triangulation is the Pareto principle in that significant commodities and regions were investigated in more detail.

In a model to estimate maritime carbon emissions from international trade, Schim van der Loeff, Godar and Prakash (2018) address the historical lack of data on this subject through linking and integrating many data sources, previously used in isolation. Even in the case of developed economies, Müller, Wolfermann and Huber (2012) refer to the 'scarcity of representative data' to build a large-scale freight-flow model for Germany, 'therefore, it is necessary to expand and specify the benefit of given data by skilful handling and combination' (although, naturally, much more data is available than in emerging economies). Islam (2005) combined research methods (a literature survey, a quantitative survey, and a two-round qualitative Delphi study) to analyse the extent to which the transformation of a fragmented freight transport system into an integrated multimodal transport system depends on the present state of the country. The integration of several data sources is therefore a relatively common practice in freight-flow modelling at various level of disaggregation due to the typical lack of data to address pressing macrologistics

issues. In addition to creative usage of available data, Chaberek and Mańkowski (2019) emphasise the need for "the right methods and tools" to develop a holistic map or model of the national logistics system for effective management of the sector. Schim van der Loeff *et al*. (2018) emphasise the value of spatially-explicit modelling to understand causality between demand for a commodity from a specific origin and its associated logistics need and impact, both direct and with regards to externalities. This increases the policy relevance of freight logistics modelling.

The literature therefore informs two principles for application in the freight-flow modelling approach for Uzbekistan. Firstly, the use of a combination of input data sources that is verified through an iterative process of triangulation and, secondly, the need for spatially and commodity explicit modelling inputs and outputs to increase the macrologistics relevance of the modelling outputs. A hybrid or triangulated research approach is therefore adopted for the UFFM, with a specific emphasis on developing spatial and commodity characteristics of freight flows. This approach is detailed in the next section.

METHODOLOGY
Uzbekistan freight flow model
The methodology for developing a freight flow model and related logistics costs model for Uzbekistan is a gravity model based on the supply of and demand for commodities within the economy (World Bank, 2020). Supply comprises local production and imports; while demand incorporates intermediate demand, final consumption, and exports. Due to the vast differences in the limited data available, the analysis aligned all the data to the major commodities in the customs data of UN Comtrade. 36 commodity groupings were then selected. Total supply and demand per commodity were then developed for each district. Total supply per district is depicted in Figure 1 and were developed for all commodities.
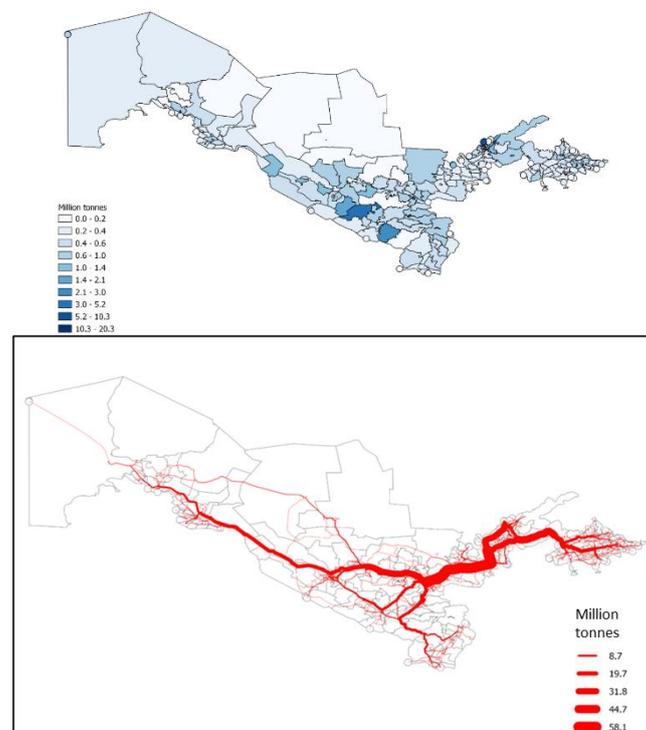
Figure 1. Total supply per district in Uzbekistan (left) and freight flows (right)

To obtain supply and demand data many different data sources from various local government and international agencies were triangulated. These included State Statistics data, road and rail data, customs and trade data, interviews and other sources.

Data limitations

As mentioned in the introduction, there were challenges to readily obtain the detailed data required for the UFFM. Firstly, not only is there a lack of data, but the legacies of the authoritarian structure of government remain a hindrance despite reforms (Omelicheva, 2016; Bowyer, 2018); data is often protected, and foreign involvement is questioned (Spechler, 2007). Secondly, Uzbekistan, being one of two only double-landlocked countries in the world, relies heavily on its central position in Central Asia, but at the same time many production factors are managed from outside the country. Landlocked countries normally face challenges to access world markets and lag neighbours in development and trade (Faye, McArthur, Sachs & Snow, 2004). For a double-landlocked country, where neighbours have similar problems, this situation is exacerbated. These factors further hinder the ability of researchers to gain access to relevant data.

KEY DESCRIPTORS OF THE UZBEKISTAN MACROLOGISTICS LANDSCAPE
Logistics Performance Index

The Logistics Performance Index (LPI) of a country is often quoted in transport industry reports and strategy documents as it is an acknowledged global dataset with improved methodology over time (Puertas & Garcia, 2014), and often in emerging economies it is one of the few comparative statistics available. It is however a stand-alone assessment, often without contextual links and importance weighting of its components (Rezaei, Van Roekel & Tavasszy, 2018). Limitations of the measure include, specifically, skewed measurements if a country is a 'victim' of outside control of its logistics system, exacerbated by being landlocked (Beysenbaev & Dus, 2020). The LPI alone cannot inform a macrologistics strategy, but if used as a springboard for research to follow can play a useful role.

In 2018, Uzbekistan's LPI position improved from number 118 to 99. Uzbekistan's overall score of 2.58 is on par with the lower-middle-income country's performance, with the country's score increasing on all but one LPI indicator between 2016 and 2018. Timeliness and consignment tracking improved markedly which can be traced back to improved regulation. The drop in the score of efficient customs and border management clearance ('customs' in Figure 1) is significant, given the country's dependence on freight outside of its borders (refer to Section 4.2). In 2018, the government took steps to reform these areas, including customs, and to open several border posts. The changes and impacts of these reforms might be captured in the 2020 LPI results. This problem is reflected in the reality of Uzbekistan's freight flows which put a sharp focus on border and trade issues in a double-landlocked country, as discussed below.

Total freight flows

Based on the UFFM, freight demand for Uzbekistan within the borders of the country is 194.6 million tonnes and 77.6 billion tonne-kilometres (refer to Figure 1). This includes all domestic freight flows and flows towards border posts for exports, as well as from border posts for imports. Transverse freight is excluded.

If the freight flows to and from final destinations in foreign countries are added, freight demand increases with 60 billion tonne-kilometres to 138 billion tonne-kilometres (due to the added distance) (refer to Figure 3). Simply put, to achieve Uzbekistan's final economic output 138 billion tonne-kilometres are required, 43% of which occurs outside of the country. This is exacerbated by the fact that cross border land operations don't have the very high efficiency possibilities as maritime trade, where a handful of global maritime merchant companies have developed inordinate coordination skills over the last few decades. Added to this problem is Uzbekistan's logistics service provider industry which is in its infancy and more or less all cross-border operations are by non-Uzbekistan companies. This effect is confirmed by Grafe, Raiser and Sakatsume (2008) who found that although regional market integration in Central Asia is quite high, borders do have a

significant effect on price dispersion and that this effect is at its worst for Uzbekistan. Uzbekistan therefore has the highest border 'friction' in Central Asia, but at the same time is more dependent on cross border land trade than all countries in Central Asia.

A second problem in Uzbekistan is the natural shape of the country which essentially splits the country in two parts: an Eastern portion east of Samarkand and a Western portion west of Samarkand. Freight-flow distribution is heavily skewed towards the East. The east has 65% of freight supply and 57% of freight demand, but only 13.5% of the land area (data from UFFM) (refer to Figure 2). At the same time the Gross Regional Product of regions to the West range from 23 to 36 thousand Soums per capita whereas the figure for the East ranges from 27 to 93 thousand Soums per capita in 1995 comparable prices (Qayumovna, 2021).
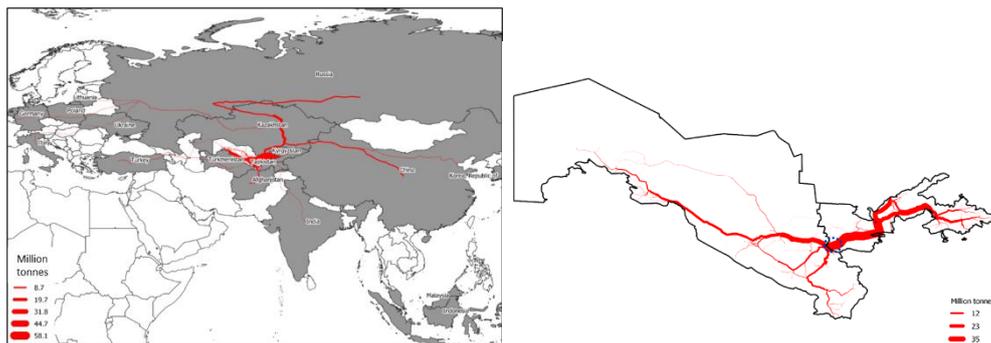
Figure 2. Uzbekistan freight outside of the border (left) and East West split (right)

From these observations clear overarching macrologistics objectives for Uzbekistan emerges. A logistics action plan should consider development objectives in the Western part of the country and strategies to streamline border crossings and exposure to freight risks beyond the borders due to the inordinate long distances of cross-border flows. This is therefore a spatial development problem and the absence of a powerful logistics hub to control logistics not only in the country, but in the region.

CONCEPT ANALYSIS – DOMESTIC OPPORTUNITIES FOR IMPROVING
Two key options were investigated, i.e., improved use of the railway, and the clustering of freight through the development of SEZs and, ultimately, freight villages. (1) The improved use of the railways can reduce transport costs, improve Uzbekistan's positioning in Central Asia and make it easier for the West to access markets; and (2) logistics centres (hubs or SEZs) can also through consolidation improve the locus of control of Uzbekistan to leverage the BRI. High-level outputs of these options are discussed below.

Improved use of the railway
Uzbekistan is relatively 'oversupplied' by rail if comparing the geographical and economic output size of the country with the rest of the world. Three avenues for improved use of the railway are considered namely modal shift, savings due to increased rail density, and savings due to improved rail efficiencies. Using the UFFM it is estimated that around 21.9 million tonnes of freight or 17.9 billion tonne-kilometres can shift to rail, resulting in a transport cost saving of US$ 430 million (due to lower rail costs). This shift will densify Uzbekistan's rail network which would result in a further decrease in costs of Uzbekistan rail freight by 17%.

Although not enough data is available for an accurate measurement, observations around margins and efficiency indicate that US$ 180 million could be saved by making the railway more efficient, cost effective and with more sustainable and fair margins.

Clustering freight

Clustering freight in SEZs and, ultimately, freight villages, will have an important effect on Uzbekistan's logistics costs. Freight villages shorten distances in the supply chain, enable more accurate delivery windows, consolidate long-distance freight which facilitates modal shift and decreases the unit cost of both road and rail transport. Investment in a refined freight-flow model will enable improved freight village positioning and design.

It seems as if only 5% of current freight flows will be affected by the current design (of logistics centres or logistics hubs), but an improved design where between 10% and 20% of freight could be captured, is potentially achievable and would improve the success of freight villages.

Dependence on trade routes and logistics outside of the country
Most importantly, however, is Uzbekistan's exposure to the regional freight network design. If tonne-kilometres of Uzbekistan freight outside of the country is added to domestic freight the volume grows with 60 billion tonne-kilometres from 78 to 138 billion tonne-kilometres. As a comparison, South Africa's 350 billion tonne-kilometres constitute only 20 billion tonne-kilometres added by overland or surface cross border freight. Countries such as South Africa require much more maritime freight for trade, but this freight is already, for the most part, efficiently consolidated, globally scheduled and part of an efficient global shipping line system. These conditions do not exist for a double-landlocked country and need to be created by a regional transport system that is run efficiently, similar to a global port and shipping line network. In terms of transport costs, also, this characteristic of the Uzbekistan freight system means that more money (52% of transport costs) is spent on freight transport costs outside of the country than within the country.

RECOMMENDATIONS AND ACTION PLAN
Olofin, Olubusoye and Salisu (2011) emphasise that an accurate, timely and systematic national statistical system is a prerequisite for national development (i.e., the fulfilment of a country's objectives), where this 'system' incorporates the people, procedures, data, and equipment to bring it to fruition. As one of the backbones of a globalised economy, the expansion of national statistical systems to include freight logistics intelligence, is long overdue. The research highlighted key principles to support both the development and application of such national statistical systems are: a culture of research-driven policy decisions; establishment of an active data users' forum; development of robust models; capacity building; and enactment of an appropriate legal frameworks.

The following recommendations and action plan for Uzbekistan support these principles and are informed by the outputs of the UFFM:

1. *Manage transport and logistics as a strategic commodity.* This means that the Transport Ministry should, on the one hand, be capacitated adequately and given enough powers to effectively develop strategic solutions while, on the other hand, integrative policy development with the ministry involved should receive attention.
2. *Firm up on data and statistics.* The poor state of statistics has many aspects. Data is not correctly captured, collated, and published, discrepancies are not questioned or cannot be explained, and data is often quoted without interpretation or context. A strategy is required to develop a set of reliable and useful statistics that allows for national policy development and decision making. An activity-based freight flow model for the country, building on the UFFM, will go a long way towards solving this problem. Importantly, this model should have a 30-year forecast component.
3. *Data-driven joint strategy development.* Policy makers should involve all stakeholders in development discussions, based on analysed statistics, to inform decision making. There are many suggestions on how to improve the freight-flow landscape, but a rough analysis points to different priorities for improvement. As an example, streamlining border crossings and the development of a domestic logistics industry that can work

across borders are often mentioned, but improving clustering and developing a regional intermodal strategy might be more important.

4. *Consolidation centres that are local- and region-critical.* Little evidence could be found that the positioning and design of the current SEZs will be optimal. This can only be determined by a freight-flow and related cost model. Evidence from other countries point towards this being one of the most important spatial and logistics strategies and should be informed by more in-depth freight-flow analysis and forecasts.

5. *Insert rail effectively into domestic and regional supply chains.* This relates to linkages with SEZs, design of the SEZs, rail's role in regional intermodal and the efficiency of the railway itself.

6. *Become more effectively involved in a regional freight-flow, clustering, and intermodal strategy.* Leadership in evidence-gathering (both from other nations and through proper development of its own statistics) will allow Uzbekistan to take a lead in a Central Asia freight strategy. Maritime nations have the advantage of a highly efficient, global water-based trade system. Uzbekistan's inordinate reliance on surface freight is a big risk.

7. *Develop a logistics strategy that specifically concentrates on the Western portion of the country.* Development ideals for the West must be confirmed and strengthened. This should be forecasted in terms of freight flows to align logistics strategies with freight flows.

CONCLUDING REMARKS

The concept UFFM is the starting point of a macrologistics decision-making tool and can be refined with access to outstanding data sources. Further refinement is advised to aid more detailed industry and regional analysis and scenario development for the identification of priorities to address modal, spatial and regional integration challenges which, in turn, will improve logistics costs and support the shift from fragmented to integrated multimodal planning.

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Humanitarian Logistics

Modelling resource optimisation for reconfiguring supply chains for reducing the impact of Covid-19 pandemic on infection

G. N. Patel* and C S Lalwani**

* Professor in Operations Research, Birla Institute of Management Technology, Knowledge Part II, Greater Noida, NCR, India
** Professor Emeritus University of Hull Business School, Hull, HU6 7RX, UK

Purpose

There has been considerable amount of research recently on the impact of Covid-19 infections on human life, businesses, economy, and education but there is limited research on how to identify the stakeholders and the key players who could assist in reconfiguring supply chains to make it possible to get the medical facilities on time for recovery of patients who have been infected. The purpose of this research is to in identifying the peers who can have direct impact in identifying the resources that will be required to minimise the infection cases and mortality in a pandemic and increase the recovery cases on daily basis.

Design/methodology/approach

To achieve the objectives of minimising infections and mortality a two-stage DEA model consisting of Phase-1 and Phase-2 is developed. For this research Covid-19 in India data for the application of data envelopment analysis (DEA) models have been collected mainly from published sources. Data sources include the government online data portals, published reports, WHO data portal, and the global data sets published by John Hopkins University. Most suitable DEA models are developed to get the highest values of good outputs, lowest values of bad outputs from both discretionary and non-discretionary inputs. Model developed is used to evaluate both contagion control and medical efficiency during non-vaccination period and fully vaccinated period.

Findings

For India, data was collected for 21 states with the population of over ten million. The results suggest that only three states were able to control the contagion in the non-vaccinated period of 2020. This changed to four states in the fully vaccinated period of the year 2021. Four states achieved the maximum medical efficiency '1' in non-vaccinated period which changed to eleven states in fully vaccinated period. This means that there is a need to provide required additional resources to inefficient states. The resource needs include the supply from production sites of vaccines, hospitals, doctors and other medical staff base. Required logistics including transport and distribution networks have to be integrated into supply chains.

Originality

A DEA model has been developed in this research to accommodate all discretionary, non-discretionary inputs and desirable, undesirable outputs. For this application as undesirable output 'infected cases' from Phase-1 needs to be decreased and from Phase-2, desirable output 'recovery cases' needs to be increased and at the same time undesirable output 'death' needs to be decreased. The combined models presented here are most suitable. The results of the combined model applications identified the states which had lower medical efficiency in pandemic period. Reconfiguring the supply chains at a short notice creating direct links with relevant suppliers for communication and logistics for transport and distribution is the best possible solution to improve this efficiency.

Introduction

There has been considerable research since beginning of 2020 on Covid-19 pandemic spread and infection globally and also specific to different countries (Danilo Rocha Dias et. al. (2022)). Researchers have looked at the impact of Covid infections on human life, businesses, economy, and education but there is limited research on how to identify the key players which can impact on supply chains that will make it possible to get the medical facilities on time for recovery of patients who have been infected. The aim of this research is to optimise the flow and relocation of resources including medical facilities to minimise the pandemic infection being diffused in the population of a country. For the analysis, the existing real-life data from India are analysed and modelled using a multi-method approach. Data envelopment analysis (DEA) models assist in identifying the variables (peers) which can have an impact in working out the resources that will be required to minimise the infection cases and mortality and increase the recovery cases on daily basis. What is critical here is the reconfiguration of supply chains for efficient mobilisation of resources such as medical personnel needed to minimise/treat the infection and the mortality due to pandemic. Reconfiguration of supply chains is required with the objective of making them more flexible, agile, and resilient.

Literature Review

There has been substantial growth in research publications on healthcare supply chain operations, management and planning over the past decade. Ali et al in their recent paper published an analysis of over 550 articles published until January 2022 identifying popular research topics including patient waiting time, COVID-19 pandemic and humanitarian logistics (Ali et. al., 2022).

Within the context of India, the government has done fairly well in the distribution of Covidshield and Covaxin vaccines across all the states but some states have faced challenges due to poor health infrastructure and other factors including logistics and supply chain issues. S. Kumar et.al (2022) and T.I. Meghla et.al (2021) have looked at the role of advanced technologies such as Internet of Things, Blockchain and Machine Learning on the impact on product supply, demand and adoption of these technologies within the context of vaccine supply and execution. There has also been research to develop decision support systems to assist in demand management in the healthcare supply chain to minimise the disruptions (K. Govindan et. al., 2020)

Sustainability of healthcare supply chain in COVID-19 has been a serious issue in Europe too. There have been procurement challenges and ensuring the availability of vaccines and healthcare facilities has proved difficult at different stages of the pandemic (Alexander Spieske et. al., 2022).

Chowdhury et. al (2021) have published a review of existing literature specifically on the COVID-19 pandemic in supply chain disciplines Their results suggest that research has mainly been on the impact of the COVID-19 and the strategies for resilience and supply chain sustainability in view of pandemic. Based on the analysis of the literature review, these authors conclude that there is a lack of empirical and theory based/supported studies in this area (Chowdhury, et. al., 2021).

In this paper, we have presented modelling based research that directs on how to optimise the healthcare resources availability and improve the efficiency in handling the problems, issues and challenges due to pandemic such as COVID-19.

Literature on healthcare DEA models

The data envelopment analysis (DEA), a linear programming model is used in a number of published papers to assess the relative efficiency of decision-making units (DMUs). Each DMU is a collection of "inputs" and "outputs" (Banker et al., 1984; Charnes et al., 1978).

There are many articles on health care sector, which are widely using DEA technique to calculate and compare performance within and between countries. Many DEA models like CCR, BCC, and Super efficiency are used to calculate the efficiency of the DMUs. Number of applications based on DEA techniques are increasing and the most frequently used tools are in the efficiency evaluation (Zakowska and Godycki-Cwirko, 2020). The efficiency of hospitals in Greece was calculated using DEA considering medical facilities as inputs, and patients treated as output parameters (Kontodimopoulos et al., 2006). Efficiency of public healthcare systems in Europe were calculated using DEA technique by considering "the number of hospital beds, the number of doctors, and public health expenditures as a percentage of GDP," as input parameters and the output parameters were " infant mortality rates, life expectancy at birth, and health adjusted life expectancy." They found some developing and developed countries focused on the efficiency frontier, and that a number of the countries are not efficient (Asandului et al., 2014). The output-based DEA model is used for calculating the research performance at People's Hospital, Peking University. The results were for policy making of medical subjects (Liang et al., 2017). The Input-Oriented DEA model and the Malmquist Index Model is used to assess the efficiency of primary health care institutions in Hunan Province from 2009 to 2017 (Zhong et al., 2020). Then, the influencing factors to efficiency were estimated using Tobit model. The study of change in efficiency and total factor productivity of local public hospitals in Japan for financial year 2006 to 2011 suggested the need for region tailored health care policies (Zhang et al., 2018). Recently, 262 papers of DEA application in health care sectors were analysed to know inputs, outputs, and reforms (Kohl et al., 2019).To determine the efficiency of 36 African countries, health expenditure, number of physicians, nurses, hospital beds per thousand people, and Gini coefficients were considered as input variables. Life expectancy at birth and reciprocal of infant mortality rate as output variables (Top et al 2020),   Efficiency of intensive care units in Iran (Bahrami et al., 2018) and healthcare efficiency assessment in the Slovak Republic (Stefko et al., 2018) also used DEA. Hospital performance and their further improvement (Weng et al., 2009) used extended DEA model. To measure the efficiency and productivity of country-level public hospitals of China (Liang et al., 2017) used the DEA model and the Malmquist Index technique. In the context of COVID-19, the efficiency of Malaysia's health system was assessed for prevention and treatment (Hamzah et al., 2021). Global response to novel 2019 Coronavirus-SARS-COV-2 was evaluated using DEA technique (Adabavazeh et al., 2020). Mariano et al., 2021evaluated performance of Brazilian states using Network DEA technique in the context of COVID-19 pandemic. The efficiency for the selected country is evaluated by using DEA tools and considering confirmed cases, population density, and urbanisation degree as the inputs parameters, recovered, and death as outputs parameters (Su et al., 2021). In a two-step approach, Shirouyehzad et al., 2020 measured the performance seriously affected countries regarding contagion control and medical treatment of COVID-19 is evaluated using DEA. Finally the countries are classified into four groups, and some suggestions and analyses are presented. Study of Xu et al., 2021 integrates DEA with four different machine learning (ML) techniques to assess the efficiency and evaluate the U.S.'s COVID-19 response performance. DEA is applied first to measure the efficiency of fifty U.S. states considering four inputs: public funding, number of health care employees, number of tested, number of hospital beds. Number of recovered as a desirable output and number of confirmed cases are considered as a undesirable output. Classification and Regression Tree, Boosted Tree, Random Forest, and Logistic Regression were applied to predict the response performance based on fifteen environmental factors. Lupu et al (2022) evaluated 31 European countries for the period of Jan 20 to Jan 21 taking 6 parameters.

In this paper, first we have measured the contagion control efficiency of different states of India having population more than ten millions for the first two phases of COVID-19 infection. Medical efficiency was measured for these states for both the phases of infection separately. Input parameters are divided as discretionary and non-discretionary whereas output parameters are classified as desirable and un-desirable outputs. Based on slacks and benchmarking of inefficient states, reconfiguration of supply chains is proposed for better management.

DEA Model Formulation

To achieve the objectives of minimising infections and mortality a two-stage model consisting of Phase-1 and Phase-2 is developed. Discretionary inputs to Phase-1 are vaccination cases, health index and non-discretionary input is population density. Discretionary inputs to Phase-2 are health index, medical personnel, covid hospitals, beds in hospitals for covid patients, and the output from Phase-1 which is infected cases. Desirable output from Phase-2 is recovery cases and undesirable output is death.

For DEA models, it is customary to minimise inputs and maximise outputs (Jahanshahloo G R. et.al. 2005) but in this application, undesirable output 'infected cases' from Phase-1 needs to be decreased and from Phase-2, desirable output 'recovery cases' needs to be increased and undesirable output 'death' needs to be decreased. For this, combined models presented here are most suitable.

Use of non-discretionary inputs and undesirable outputs in efficiency evaluations

The data envelopment analysis (DEA) uses linear programming (LPP) to assess the relative efficiency of decision-making units (DMUs) using a collection of performance parameters. (Charnes et al., 1978, Banker et al., 1984). These parameters are inputs and outputs to DMUs. Various DEA models have been developed to assess the efficiency. Earlier models were developed with constant return to scale (CCR) in 1978 (Charnes et al., 1978) and variable return to scale (BCC) in1984 (Banker et al., 1984). The DEA data domains are as follows:

Suppose n DMUs: $DMU_j, j = 1, …, n$, Let the input and output data for DMU_j be $(x_{1j}, …, x_{mj})$ and $(y_{1j}, …, y_{sj})$, respectively. The input data matrix X and output data matrix Y can be arranged as follows.

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} = (x_j) \qquad\qquad Y = \begin{pmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ y_{s1} & \cdots & x_{sn} \end{pmatrix} = (y_j)$$

The data deals with the pair of positive input and output vectors (x_j, y_j), $j = 1, …, n$ of n DMUs.

To accommodate all discretionary, non-discretionary inputs and desirable, undesirable outputs, Jahanshahloo's model can be modified as follows:

$$min \quad 1 - \left[\frac{1}{m+s}\left(\sum_{i \epsilon I_D} t_i^{-D} + \sum_{r \epsilon O_D} t_r^{+D}\right)\right]$$

Subject to $\sum_{j=1}^{n} \lambda_j x_{ij}^D + t_i^{-D} = x_{io}^D, \quad i \in I_D,$

$$\sum_{j=1}^{n} \lambda_j x_{ij}^{ND} + t_i^{-ND} = x_{io}^{ND}, \quad i \in I_{ND}, \qquad\qquad (1)$$

$$\sum_{j=1}^{n} \lambda_j y_{rj}^D - t_r^{+D} = y_{ro}^D, \quad i \in O_D,$$

$$\sum_{j=1}^{n} \lambda_j y_{rj}^U - t_r^{+U} = y_{ro}^U, \quad i \in O_U,$$

$$\sum_{j=1}^{n} \lambda_j = 1,$$

$$t_i^{-D}, t_i^{-ND}, t_r^{+D}, t_r^{+U} \geq 0, \quad i \in I_D \cup I_{ND}, \ r \in O_D \cup O_U,$$

$$\lambda_j, \geq 0, \quad j = 1, \dots, n,$$

The discretionary variables $x_{io}^D \in I_D$ are under management control which can be decreased, desirable outputs $y_{ro}^D \in O_D$ can be increased. The non-discretionary inputs $x_{io}^{ND} \in I_{ND}$ neither can be changed nor the undesirable outputs $y_{ro}^U \in O_U$ can be increased.

Data requirement, sources, and collection process

Data required for the application of DEA models for this research have been collected from secondary sources. Data sources include the government online data portals, published reports, WHO data portal, and the global data sets published by John Hopkins University. For India, data for 21 states with the population of 10 million and over were collected. As DEA models produce results on relative basis for the states selected it is not desirable to include smaller states. The raw data collected is shown in table-1 for a particular date (25.5.2021).

Next step was to establish what time period should be considered for the analysis? In India, the pandemic had catastrophic impact during the second wave in the first nine months of year 2021 in terms of infections, deaths, shortage of oxygen, and non-availability of medical facilities. With this in view, data were collected for the months of April 2021 to August 2021.

Due to the time gap between the confirmed infection, hospitalisation and possible mortality, it was considered necessary to discuss with medical professionals who were the front runners to deal with the positive cases. Authors interviewed medical personnel including the resident doctor at BIMTECH on this aspect and it came out clearly that this time gap for different stages and the impact of infections would be best reflected by using 10 days moving average for data points for the DEA models developed for this research. For model validation, the same data were collected for one day in May 2020 and June 2020 which were the infection months for the first wave of pandemic in India and the vaccinations were not yet available. Most of the data were collected from the portals set by Indian Government Ministry of Health (mohfw.gov.in) Niti Ayog (niti.gov.in) and WHO online portals.

Attempt was made to collect data for the United Kingdom for the four nations (England, Scotland, Wales and Northern Island) for including the additional four points in the DEA model taking it to 25 states. Unfortunately, the data compatibility became a complicated issue which could not be resolved. There were differences on the data parameters, dates, and time gaps not just between India and the UK but also among the four nations. It was therefore necessary not to include the four nations of the UK in the analysis for this research.

Analysis of Data and Application of Combined DEA Model In this paper, efficiency was measured using the combined model given in eq. (1). In principle, to measure efficiency, less inputs and more outputs are desirable for which complement of some data such as health index and population index were taken and the data were standardized before running for efficiency. Since both discretionary (like medical facilities) and non-discretionary (like population density) inputs, desirable (like recovery) and undesirable (like death) outputs were considered, we required to find the efficiency using Excel solver

using VBA. Contagion control efficiency of states are shown in table 2 whereas medical efficiency are in table 3. Table 4 shows the reference states for example for selected four inefficient states (Jharkhand, Maharashtra, Karnataka and Tamil Nadu). For example, if we consider Jharkhand, an inefficient state, its data has recommended to follow Delhi and Kerala to curb contagion control, whereas Delhi, Gujrat and Uttarakhand for medical efficiency as per the efficiency calculated for 24th May 2021.

Reconfiguration of Supply Chains to improve the efficiency

It can be seen from the efficiency tables 2 and 3 for 21 states, some states such as Delhi, Gujrat, Kerala, and Uttar Pradesh have performed well, and others have failed to do so. This is likely to be due to better resources availability in discretionary inputs.

The states with efficiency less than '1' such as Jharkhand, Maharashtra, Karnataka, Tamilnadu perhaps needed additional resources such as vaccines, oxygen cylinders, medical staff including doctors, and hospital beds. This is only possible by reconfiguring related supply chains to enable the availability of required resources at the right location, in right quantity, at right time for the patients that needed most. Supply chains for this facilitation of moving resources among Indian states are demand driven. States have to generate the orders for allocation/reallocation of resources based on their needs to handle the covid cases efficiently.

The resource needs include the supply from production sites of vaccines, hospitals, doctors and other medical staff base. Required logistics including transport and distribution networks have to be integrated into supply chains. Capacity constraints and government regulations have to be considered. Controls based on government regulations and infrastructure are shown in Table 4.

Conclusions and Recommendations

The main objective of data envelopment analysis developed and applied here is to get the highest values of good outputs, lowest values of bad outputs from both discretionary and non-discretionary inputs. Model in eq. (1) is used to evaluate both contagion control and medical efficiency during non-vaccination period and vaccinated period (two doses). The results suggest that only three states were able to control the contagion in the non-vaccinated period of 2020. This changed to four states in the fully vaccinated period of the year 2021. Four states achieved the maximum medical efficiency '1' in non-vaccinated period which changed to eleven states in fully vaccinated period.

It is proposed that for the states which had lower medical efficiency in vaccinated period due to lack of resources in terms of medical staff, availability of medical equipment, facilities such as availability of beds, should be assisted by the authorities concerned including central and state governments. This could be achieved by reconfiguring the supply chains at short notice creating direct links with relevant suppliers for communication and logistics for transport and distribution (Table 4). Regulations and controls for interstate movement of medical staff and required facilities should be modified or removed, if possible, for natural disasters such as Covid-19 pandemic. The main limitation of this research is the lack of testing of covid required in numbers which could have changed the medical efficiency of states. We were unable to cover the qualitative characteristics for the decisions made due to data constraints.

Further work is needed on two aspects of this research. Firstly, supply chain reconfiguration should be carried out using simulation to run experimental trials for the states which had lower medical efficiency in vaccinated period considered in this study. Additional data will be required on existing transport and distribution network and the demand and supply of tangible resources in the same period. Secondly, the impact of low percentage of testing for the infection would have on the number of infected cases being registered should be analysed

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Table-1 Covid-19 data for 21 states of India with population more than 10 million

State	Cumulative up to (25-05-2021)				Popln/sq mi	Doctors	Number of hospitals	Number of beds	Health Index
	Confirmed Cases	Cured/ Discharged	Death	Double dose					
Andhra Pradesh	1593821	1379837	10222	3800534	788	102924	928	83230	65.31
Assam	375404	318585	2823	1837320	1030	24083	1792	24178	50.02
Bihar	692420	649835	4642	4851326	2863	45795	2403	30857	32.43
Chhattisgarh	953209	879625	12646	1497811	489	10020	396	17430	53.97
Delhi	1418418	1370431	23409	1257459	29298	26685	176	39455	59.68
Gujarat	791657	713065	9621	4655625	799	69746	1408	64862	63.72
Haryana	741785	696059	7607	1694337	1485	14517	2148	36141	54.08
Jammu and Kashmir	272858	223619	3609	998748	253	16491	157	7995	62.92
Jharkhand	331811	309371	4871	1323710	1072	6837	1364	26496	53.67
Karnataka	2450215	1983948	25811	4444503	825	130698	10684	262109	61.77
Kerala	2365787	2098674	7554	2270147	2226	65685	3342	99227	74.65
Madhya Pradesh	767274	706003	7618	5244025	610	40171	971	64939	38.69
Maharashtra	5602019	5182592	89212	6233948	946	188540	3203	231739	64.53
Odisha	703441	601224	2516	2524374	698	24780	2501	25650	36.35
Punjab	543475	475011	13468	1436028	1427	51685	2320	60997	63.41
Rajasthan	920456	812775	7806	4095140	519	46253	5644	93176	43.23

Tamil Nadu	1877211	1554759	20872	3995783	1437	148216	2439	155375	60.5
Telangana	556320	513968	3146	2447882	809	7931	4110	99919	59.42
Uttar Pradesh	1673785	1577720	19362	1073072	2148	84560	17103	281402	29.16
Uttarakhand	315590	260084	5927	762354	488	9348	1289	23843	39.61
West Bengal	1284973	1141871	14517	5303644	2664	75917	2263	113535	59.5

Efficiency scores considering discretionary and non-discretionary inputs, desirable and undesirable outputs (Phase-1)

Table 2: ND-UD. (Contagion contr

Phase 1	2020						
States	07-05-2020	07-06-2020	04-Apr	14-Apr	24-Apr	04-May	15-May
Andhra Pradesh	0.73076	0.73076	1	1	1	0.99849	0.98009
Assam	1	0.5072	1	1	1	1	0.96655
Bihar	1	1	1	1	1	1	1
Chhattisgarh	1	0.93108	0.99642	0.99382	0.99054	0.98518	0.97628
Delhi	1	1	1	1	1	1	1
Gujarat	0.69873	0.69873	1	1	1	1	1
Haryana	0.55205	0.55205	0.99177	0.98927	0.98576	0.97707	0.97021
Jammu and Kashmir	0.68366	0.68366	1	0.99754	1	0.98742	0.97895
Jharkhand	0.97861	1	0.99761	0.99216	0.98591	0.97864	0.97639
Karnataka	0.85998	0.66309	0.99334	0.98899	0.9863	0.98116	0.97616
Kerala	1	1	1	1	1	1	1
Madhya Pradesh	0.41347	0.41347	0.99311	0.98953	0.98367	0.98197	0.98676
Maharashtra	0.71469	0.71469	0.9915	0.98802	0.9844	0.9783	0.9735
Odisha	0.67591	0.39827	1	1	0.99732	0.98436	0.96832
Punjab	0.69281	0.69281	0.98898	0.98551	0.98662	1	0.96134
Rajasthan	0.44654	0.44654	1	1	0.99729	0.98874	0.97857
Tamil Nadu	0.64177	0.64177	0.99042	0.98767	0.98646	0.974	0.96167
Telangana	0.62469	0.62469	0.99588	0.99007	0.98586	0.97663	1
Uttar Pradesh	0.42205	0.37411	0.99746	0.99223	0.98557	0.98736	0.997
Uttarakhand	0.66049	0.41977	1	0.99933	1	0.99926	1
West Bengal	1	0.6319	1	1	1	1	0.97883

Efficiency scores considering discretionary and non-discretionary inputs, desirable and undesirable outputs (Phase-2)

Table 3. ND-UD (Medical efficiency)

Phase 2 States	2020		2021												
	07-05-2020	07-06-2020	04-Apr	14-Apr	24-Apr	04-May	15-May	24-May	04-Jun	14-Jun	25-Jun	05-Jul	15-Jul	26-Jul	05-Aug
Andhra Pradesh	0.73076	0.85213	1	1	1	1	1	1	1	1	1	1	1	1	1
Assam	1	0.90206	1	1	1	1	0.981214	0.97747	0.97655	0.977476	0.97682	0.972122	0.964441	0.9611	0.955122
Bihar	0.61568	0.60181	1	1	1	1	1	1	1	1	1	1	1	1	1
Chhattisgarh	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Delhi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Gujarat	0.72794	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Haryana	0.55205	0.68723	1	1	0.996299	0.991135	1	1	1	0.996753	0.9962	1	1	1	1
Jammu and Kashmir	0.81026	0.7762	1	1	1	1	1	1	1	1	1	1	1	1	1
Jharkhand	0.94018	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Karnataka	0.85998	0.66683	0.994148	0.991166	0.987177	0.981966	0.97779	0.9762	0.973277	0.971877	0.966122	1	0.9609	0.962722	0.960098
Kerala	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Madhya Pradesh	0.41347	0.49139	1	1	1	1	1	1	1	1	1	1	1	1	1

State															
Maharashtra	0.7643	0.96986	0.99371	1	1	1	0.99556	0.98937	0.98192	0.97923	0.97694	0.97625	0.9765	0.97625	0.98288
Odisha	0.67591	1	1	1	1	1	1	1	1	1	1	0.99978	1	1	1
Punjab	0.69281	1	0.98898	1	1	1	0.9613	0.96044	0.95743	0.9756	1	1	0.98803	0.98937	0.99153
Rajasthan	0.47011	0.6406	1	1	1	1	0.99785	1	1	1	1	1	1	1	1
Tamil Nadu	1	1	0.99044	0.99934	0.99282	1	0.96212	0.95983	0.95556	0.95373	1	1	0.92243	0.91871	0.91197
Telangana	0.63541	0.65699	1	1	1	1	1	1	1	1	1	1	1	1	1
Uttar Pradesh	0.40016	0.50613	0.9978	0.9944	0.99248	1	1	1	1	1	1	1	1	1	1
Uttarakhand	1	0.42346	1	1	1	1	1	1	1	1	0.99906	1	1	1	1
West Bengal	0.75107	0.6318	1	1	1	1	1	1	1	1	0.99135	0.99135	0.99135	0.99135	0.99135

Table 4 Reference States for selected Inefficient States

Contagion Control Efficiency														
Phase 1	07-05-2020	07-06-2020	04-04-2021	14-04-2021	24-04-2021	15-05-2021	24-05-2021	04-06-2021	14-06-2021	25-06-2021	05-07-2021	15-07-2021	26-07-2021	05-08-2021
Jharkhand	4,11	11	5,6,20	5,6	5,6,20	5,6,20	5,11	5,11	5,6,11	5,6,11	5,6,11	5,6,11	5,6,11	5,6,11
Maharastra	11	11	5,11	6,11	5,6,11	6,11	5,6,11	5,6,11	1,6,11	5,6,11	6,11	1,6,11	1,5,6,11	1,5,6,11
Punjab	11	11	5,6,11	5,6,11	1,5,6,21	5,6,11	5,6,11	5,6,11	5,6,11	5,6,11	5,6,11	1,5,6	1,5,6	1,5,6
Tamilnadu	11	11	5,6,8,20	5,6,21	2,6,21	5,11	5,11	5,11	5,6	5,11	5,6,11	5,6,11	5,6,11	5,6,11
Medical Efficiency														
Jharkhand	4,11	5,11	5,8,11,16	5,6,8,20	6,11,16	6,11	5,6,20	5,6,11	5,11	1,5,11	-	5,6,11	5,6,11	5,6,11
Maharastra	5,11	5,6,11	5,6,8,11	-	-	1,5,6,11	1,5,6,11	1,6,11	5,6,11	1,5,11	1,6,11	1,5,11	1,6,11	1,6,11
Punjab	11	11	5,6,11	-	-	6,11	5,6,11	5,6,11	5,6,11	-	-	1,6	1,6	-
Tamilnadu	11	11	5,6,8,16	1,6,8,11,14	5,6,11,14,21	5,6,20	5,6,20	5,6	5,11	-	-	5,6,11	5,6,11	5,6,11

Table 4: Dynamic supply chain components and controls for allocation/reallocation of resources

DEA Model Discretionary	Resources needed	Flow of goods from other locations	Controls	DEA Model Outputs

Inputs Phase 1 and 2				
Number of People Vaccinated	Vaccines, medical staff	Demand from State Government	Controlled by the Central Govt. Central Govt.	Number of people Infected
Health Index	As per Niti Ayog Indicators	State Govt		
Medical Personnel	In three domains	Govt. Hospitals and Private Hospitals	State Govt Controls on Govt Hospitals only	Recovery Cases
Covid Hospitals	Doctors, Nurses	State Govt. mostly and few such as AIIMS are with Central Govt.	Mostly State Govt,	Deaths
Covid beds in hospitals	Infrastructure including equipment and facilities	Doctor Assessment	Hospital monitoring	
	L1, L2, and L3			

OPTIMAL COVID-19 VACCINE WAREHOUSE LOCATIONS WITH MULTIPLE FACILITY LOCATION PROBLEMS

Soomin Hong[1], Su-Han Woo[2], Tae-Young Kim[2]

1: Graduate School, Chung-Ang University, Korea, Republic of (South Korea); 2: Department of International Logistics, Chung-Ang University, Korea, Republic

Introduction

Humanitarian logistics operation tends to aim at distributing relief items rapidly and efficiently to affected areas while meeting beneficiaries' demand and requirements (Balcik and Beamons, 2015). In the course of COVID-19 vaccine distribution and delivery, facility location problem arises. It is expected that COVID 19 vaccines are distributed and transported in the emergency facility which is built in the optimum location. Therefore the hypothetical site selection can contribute to the further efficient planning of vaccine distribution and delivery.

Facility location problem is a set of mathematical models to find the optimum logistics location. In humanitarian logistics, it is commonly used to find the optimum location for emergency operation and management as pre-positioning decision process for quick-onset response (Balcik and Beamon, 2008). Finding the optimum place through employing one model connected to cost could be straightforward and rather simple. However it would be comparatively incomplete unless it contains the reference to the characteristics of disaster. It is, therefore, suggested that multiple location problems are employed and their results are compared to find out the most desirable place which is adequate for the purpose.

This study aims at applying different facility location problems to a real data of metropolitan city in Korea to find out optimal sets of locations for humanitarian COVID-19 vaccine warehouses. Considering the vaccine warehouse as a pre-positioning humanitarian facility, this study uses the classical discrete-deterministic facility location problems as a tool for decision making under different constraints. Three different facility location problems with different objectives are applied to the same existing geographical data set.

Furthermore, input parameters are varied considering three conditions: (1) when the facility is not capacitated and capacitated; (2) when the possible establishment of the facility number is varied from only one to many; (3) when the servicing distance is limited.

Literature

P-median location problem is an integer linear programming known to be first introduced by Hakimi (1964) to find the optimum location of the absolute centres in a highway system. This model seeks to find 'the location of the facility where the maximum distance from the facility p is a minimum' by locating the p facilities where the total distance from the p facilities to the demand points are to be minimised. The optimum locations of p facilities are called the 'median'. Church and ReVelle (1976) suggested links between the various facility location models. In the study, the p-median problem and two types of covering problems are presented and their links were identified by giving perspectives of historical development the models by theoretical and computational experience. Kim (2009) suggested a modified p-median location problem model for optimal location selection for 119ERU which enabled meeting all the possible accident point within certain distance and the time limit.

Capacitated p-median location problem (CPMP) seeks to find the optimum facility location where the total weighted distance or cost is minimised when the capacity of each facility is limited while allocating demands to the facility. CPMP adds capacity constraints to the classical p-median problem. In CPMP, the number of p-centres and its capacity are assigned prior. In other words, the optimum location is determined according to the capacity of each facility. Lee and Yang(2009) introduced how spreadsheets can be used to quickly find an answer to the CPMP and explained by conducting computational experiments comparing other methods for the evaluation of calculating time and capability of the model. Ye et al. (2011) proposed 2-stage facility location problem model that gained accurate result to improving the layout of recycling facilities in Taiwan. The study figured models to be integrated to find the maximised number of recycling centres and minimised distance between the recycling centres and their assigned collection depots. The integrated model showed that the method was more efficient than the traditional separate models.

P-centre location problem is a minimax solution to find a set of points of facility that minimises the worst performance of the network system, which mean that it minimises the maximum distance between a demand point when they are only serviced from the closest facility (Çalık et al., 2015). With capacity constraints, it is called Capacitated P-centre Location Problem, or CPCP (Kramer et al, 2018). Kim et al. (2013) formulated a maximum covering problem and a minimax location problem to determine the optimal location for expressway patrol where minimises additional troubles of treatment of car accident being delayed by using a crash-weighted distance parameter.

In humanitarian logistics, population comes to be one of the constraints more frequently than other sectors. Church and ReVelle(1974) proposed Maximal Covering Location Problem for the first time by adapting the concept of set-covering problem but with fixed distance constraint and with the number of p-centres to be designated in advance. According to Church and ReVelle (1974), maximal covering location problem can be defined as "by locate a fixed number of p facilities, the coverage of the population is maximised within the desired distance S." The pre-defined verge of coverage area is called 'coverage radius' (Zarandi et al., 2013). Integrating the concept of maximum travel distance and the coverage, question rose to whether the servicing facility could cover the demand population of the area or not. Church and ReVelle(1976) answered this question with an introduction of a model which could cover as many people as possible within service distance, in the meantime everyone could be assigned to the closest facility. Chanta et al.(2012) proposed an optimization model to select an appropriate site for shelter during the flood disaster, testing the real-world data of Bangkruai, one of the districts in the central part of Thailand. In this study, as a part of humanitarian relief operation, the possible candidates for the shelter areas are selected by solving maximal covering problem and p-median location problem. Guzmán et al.(2016) implicated a fuzzy constraint into a maximal covering location model, which gave a flexibility to the coverage radius.

Maximal covering location problem is a useful way to apply for health and medical sector. For example, Taiwo (2020) presented optimal location for testing facility of COVID-19 in Nigeria, which resulted in covering 82.04% of population to reach at least one of the facilities within at most 10hr of drive. Kassim and Stephan(2017) gave an example of an application of maximum covering location problem for the implication on Community-Based Health Planning and Services facility siting plans and test the model to ensure that they are accessible for the largest number of citizens.

Mathematical Formulation

2.1. Capacitated P-median Location Problem(CPMP) and PMP

Index sets, decision variables, and input parameters of the formulations are as follows based on the previous studies (Hakimi, 1964; Lee et al., 2009; Boonmee et al., 2017; Kramer et al., 2018) :

Index sets
I: set of demand point; $i \in I$
J: set of warehouse location cadidates; $j \in J$

Decision Variables
$X_j = 1$ if a warehouse is located at eligible area J, 0 if not
$Y_{ij} = 1$ if a warehouse j services the demand point i, 0 if not

Input parameters
d_{ij}: the distance between demand point i and cadidate warehouse j
P: the number of vaccine warehouse to be placed
cap_j: the capacity of vaccine doses in warehouse j
w_i: demand(population) at the demand point i

Objective function:

$$Z_{CPMP} = min \sum_i \sum_j w_i d_{ij} Y_{ij} \tag{1}$$

Subjected to:

$$\sum_j X_j = P \tag{2}$$

$$\sum_j Y_{ij} = 1 \qquad \forall\, i \in I \tag{3}$$

$$\sum_i w_i Y_{ij} \leq cap_j X_j \qquad \forall\, j \in J \tag{4}$$

$$X_j,\, Y_{ij} \in \{0,1\} \qquad \forall\, i \in I, j \in J \tag{5}$$

The objective function (1) minimises the total weighted distance while (2) ensures that the facility number is limited and (3) guarantees that one demand point is only serviced by one warehouse. (4) states that the allocation of one warehouse should not exceed its capacity. (5) defines the binary variables.

$$Y_{ij} \leq X_{ij} \qquad \forall\, i \in I, j \in J \tag{6}$$

To formulate uncapacitated p-median problem(PMP), (4) could be substituted with (6).

2.2. Capacitated P-centre Problem(CPCP) and PCP

Decision Variables(addition):
D: the maximum distance between a selected location and a demand point
Objective function:

$$Z_{CPCP} = min\, D \tag{7}$$

Subjected to:

$$\sum_j X_j = P \tag{8}$$

$$\sum_j Y_{ij} = 1 \qquad \forall\, i \in I \tag{9}$$

$$\sum_i w_i Y_{ij} \leq cap_j X_j \qquad \forall\, j \in J \tag{10}$$

$$D \geq \sum_j d_{ij} Y_{ij} \qquad \forall\, i \in I \tag{11}$$

$$X_j,\, Y_{ij} \in \{0,1\} \qquad \forall\, i \in I, j \in J \tag{12}$$

The objective function (7) minimises the maximum distance between a selected location and a demand point while (8) ensures that the facility number is limited and (9) guarantees that one demand point is only serviced by one warehouse. (10) states that the allocation of one warehouse should not exceed its capacity. (11) forces that the maximum distance between facility and demand point should be farther than any other distance between selected points, that is, every demand point is serviced from the nearest facility. (12) defines the binary variables.

$$Y_{ij} \leq X_{ij} \qquad \forall\, i \in I, j \in J \tag{13}$$

To formulate uncapacitated p-centre problem(PCP), (10) could be substituted with (13).

2.3. Capacitated Maximal Covering Location Problem(CMLCP) and MCLP

Decision Variables(addition):
$Z_i = 1$ if demand point i is coverd by a warehouse within the distance limit R, 0 if not.

Input parameters(addition):
R: distance limit whithin which a warehouse can service demand point i

N_i: the set of eligible warehouse site within the distance limit ($N_i = \{j | d_{ij} \leq R\}$)

Objective function:

$$Z_{CMLCP} = max \sum_i w_i Z_i \qquad (14)$$

Subjected to:

$$\sum_{j \in N_i} X_j \geq Z_i \qquad \forall\, i \in I \qquad (15)$$

$$\sum_{j \in N_i} X_j = P \qquad (16)$$

$$\sum_i w_i Y_{ij} \leq cap_j X_j \qquad \forall\, j \in J \qquad (17)$$

$$X_j, Z_i \in \{0,1\} \qquad \forall\, i \in I, j \in J \qquad (18)$$

The objective function (14) maximises the coverage of demand points, while (15) sets a coverage threshold that all demand points are covered if eligible within the desirable distance. (16) is the number of predetermined warehouses. (17) states that the allocation of one warehouse should not exceed its capacity. (18) defines the binary variables.

$$Y_{ij} \leq X_{ij} \qquad \forall\, i \in I, j \in J \qquad (19)$$

To formulate uncapacitated maximal covering location problem, (17) could be substituted with (19).

Case Study

2.4. Data Description

Metropolitan city Incheon is selected to apply the stated mathematical formulations. Incheon is one of the biggest and most populated cities in Korea, and it is located on the west side of Seoul. Incheon has 10 sub-districts (8 'gu's and 2 'gun's) and has about 3 million of population (GIS Incheon, 2021). The location of pre-existing 12 inoculation centres in the metropolitan city are assumed to be potential warehouse location. The metropolitan city currently utilises the public health and sports centres as emergency disaster relief centres. Thus, pre-existing public 4 health and sports centres that are spacious enough to accommodate more than 1,000 people are driven to be the potential location of vaccine warehouse. Total of 16 potential warehouse locations are alphabetised from A to P (see Table 1).

The locations of demand point are assumed to be pre-existing 12 public vaccine inoculation centres and they are numbered from 1 to 12(see Table 2). Euclidean distance is frequently used to simplify the estimation, but in humanitarian logistics perspective, the movement of victim and actual road situation should be reflected except that the main transportation is airborne, so that the real travel distance is often used as input parameter. Distance between potential warehouse location and the demand point is measured by Google Maps® (See Appendix).

Demand of each area is prior group of vaccine recipients, adults 65 years old and older, which is 434,529 vaccine doses in total. Capacity of vaccine warehouse is assumed to be homogenous in each warehouse and is the sum of 5 most populated areas in the city, which is 279,201 doses. Both demand and capacity of vaccine warehouses are driven from the official census result of may in 2021 of Korean Statistical Information Service (KOSIS, 2021) (see Table 2). To set the coverage radius, travel time(distance) threshold is set(Table 3). t=1, t=2, t=3, and t=4 is the first, second, third, and fourth quartile of distance input set.

Table 10 Potential Location of Warehouses

Potential Location of Warehouse	Alphabetised
Seonhak Gymnasium	A

Ongnyeon International Shooting Range	B
Geomdan Welfare Centre	C
Incheon Asiad Main Stadium	D
Samsan World Gymnasium	E
Yeolwoomul Tennis Stadium	F
Songlim Gymnasium	G
Ganghwa Arts Centre	H
Ganghwa Dolmen Gymnasium	I
Gyeyang Gymnasium	J
Haneul Culture Centre	K
Incheon Univ. Jemulpo Campus Arts & Sports Centre	L
Munhak Park Tae-hwan Swimming Pool	M
Gil Hospital	N
Namdong Multipurpose Indoor Gymnasium	O
Ongjin National Sports Centre	P
Total	16

Table 11 Demand point and vaccine dose demand of each area(Source: KOSIS)

Province	Demand point	Demand Doses
Yeonsu-gu	1	41,021
Seo-gu Gumdan	2	17,162
Seo-gu	3	45,141
BuPyeong-gu	4	76,493
Dong-gu	5	14,670
GangHwa-gun	6	23,751
GyeYang-gu	7	40,840
Joong-gu	8	21,735
MiChooHol-gu	9	72,320
Namdong-gu	10	31,407
BukNamdong-gu	11	44,226
OngJin-Gun	12	5,763
Total	12	434,529

Table 12 Time threshold and Coverage Radius

Time Threshold	Coverage Radius R (km)
t=1	9.125
t=2	17.8
t=3	43.5
t=4	96.2

2.5. Computational Result

Input parameter P are varied in CPMP from 12 to 1. When P=12, the authority establishes every vaccine warehouse in the sub-district area. When P=1, the authority establishes only one facility in the city. While P varies, the authority's objective is always to minimise total distance of movement of vaccine transportation(or the cost of transportation). In case of Z-cpmp, it is not eligible to find the optimal subset of location when P=1 because it exceeds the capacity. It is shown that Z-cpmp presents slightly longer distance(or higher transport cost) overall. Each subset of location indicates the optimal location of vaccine warehouses (see Table 4).

Table 13 Result of CPMP

P	Z-cpmp	Distance	Optimal Subset of Location	Z-pmp	Optimal Subset of Location

P	Z-cpmp	Distance	Optimal Subset of Location	Z-pmp	Distance	Optimal Subset of Location
12	0	0	A, C, D, E, G, H, J, K, L, N, O, P		0	A, C, D, E, G, H, J, K, L, N, O, P
11	32274	2.2	A, C, D, E, H, J, K, L, N, O, P		2.2	A, C, D, E, H, J, K, L, N, O, P
10	132776.4	5.4	A, C, D, E, H, J, K, O, P		5.4	A, C, D, E, H, J, K, O, P
9	261491.4	12.9	A, D, E, H, J, K, L, O, P		9.2	C, D, E, H, J, K, L, N, P
8	449355.4	17.5	A, D, E, H, K, L, O, P		13.8	C, D, E, G, H, K, N, P
7	643949.8	21.9	A, D, E, H, K, L, P		21.3	C, G, H, J, K, N, P
6	898085.5	32.6	A, D, E, K, L, P		32	C, E, G, K, N, P
5	1165044	78.7	D, E, K, L, O		45.6	C, E, K, N, P
4	1647561	100.9	D, E, L, O		66.2	E, K, M, P
3	2301987	117.3	D, E, M		97.6	E, N, P
2	3143670	147.1	E, N		147.1	E, N
1		Not Eligible			210.4	N

Note: Z-cpmp: objective function of CPMP: minimised weighted total distance; Z-pmp: objective function of uncapacitated; PMP: minimised total distance

Input parameter P are also varied in CPCP from 12 to 1. When P=12, the authority establishes every vaccine warehouse in the sub-district area. When P=1, the authority establishes only one facility in the city. While P varies the authority's objective is always to minimise the worst performance of vaccine transportation(or the highest cost of transportation). In case of Z-cpcp, it is not eligible to find the optimal subset of location when P=1 because it exceeds the capacity. Z-cpcp and Z-pcp show the same travel distance overall. Each subset of location indicates the optimal location of vaccine warehouses (see Table 5).

Table 14 Result of CPCP

P	Z-cpcp	Distance	Optimal Subset of Location	Z-pcp	Distance	Optimal Subset of Location
12	0	0	A, C, D, E, G, H, J, K, L, N, O, P	0	0	A, C, D, E, G, H, J, K, L, N, O, P
11	2.2	2.2	A, C, D, E, H, J, K, L, M, N, P	2.2	2.2	A, C, D, E, H, J, K, L, M, N, P
10	5.4	5.4	C, D, E, G, H, J, K, N, O, P	5.4	5.4	C, D, E, H, J, K, L, M, O, P
9	9.2	9.2	C, D, E, H, J, K, L, N, P	9.2	9.2	C, D, E, H, J, K, L, M, P
8	13.8	13.8	C, D, H, J, K, L, N, P	13.8	13.8	C, D, E, G, H, K, M, P
7	21.3	21.3	C, E, H, K, L, N, P	21.3	21.3	D, E, G, H, K, N, P
6	32	32	D, E, G, K, N, P	32	32	D, E, K, L, N, P
5	45.6	45.6	C, E, K, N, P	45.6	45.6	D, E, K, N, P
4	66.2	66.2	E, K, N, P	66.2	66.2	E, K, N, P
3	97.6	97.6	E, N, P	97.6	97.6	E, N, P
2	147.1	147.1	E, N	147.1	147.1	E, N
1		Not Eligible		210.4	210.4	N

Note: Z-cpcp: objective function of CPCP: minimised maximum distance between facility and demand point; Z-pcp: objective function of uncapacitated; PCP: minimised maximum distance between facility and demand point

On the other hand, MLCP focuses on the demand coverage, hence the coverage radius, or the possible maximum travel distance, should be designated prior. Thus, the travel threshold was set as stated. The coverage radius being shortened, the more facilities are needed. For example, in case of t=2(*R=17.8*), to achieve full coverage rate of demand, 4 facilities are needed whether the facility has capacity constraints or not. In the cases of both CMCLP and uncapacitated MCLP, the facilities are not needed more than 6 to meet 100% coverage of the demand. In case of Z-cmlcp, it is not eligible to find the optimal subset of location when P=1 because it exceeds the capacity. Each subset of location indicates the optimal location of vaccine warehouses (see Table 6 and Table 7).

Table 15 Result of CMLCP

T-threshold	P	Z-cmlcp	Coverage	Optimal Subset of Location
t=1	1		Not Eligible	
	2	327770	75%	D, F
	3	383280	88%	C, F, J
	4	407031	94%	C, E, I, N
	5	428766	99%	D, H, J, K, N
	6	434529	100%	C, E, I, K, N, P
t=2	1		Not Eligible	
	2	407031	94%	E, J
	3	428766	99%	E, K, L
	4	434529	100%	E, J, K, P
t=3	1		Not Eligible	
	2	428766	99%	J, M
	3	434529	100%	G, H, P
t=4	1		Not Eligible	
	2	434529	100%	I, N

Note: Z-cmlcp: objective function of CMLCP: maximised demand coverage

Table 16 Result of uncapacitated MLCP

T-threshold	P	Z-mlcp	Coverage	Optimal Subset of Location
t=1	1	280137	64%	F
	2	342440	79%	C, N
	3	383280	88%	C, E, N
	4	407031	94%	D, E, I, N
	5	428766	99%	C, E, H, K, N
	6	434529	100%	C, E, H, K, N, P
t=2	1	3823280	88%	F
	2	407031	94%	E, M
	3	428766	99%	C, E, K
	4	434529	100%	E, G, K, P
t=3	1	428766	99%	C
	2	434529	100%	C, P
t=4	1	434529	100%	H

Note: Z-mlcp: objective function of uncapacitated MLCP: maximised demand coverage

Discussion

This paper applied multiple mathematical models to find optimum location for humanitarian vaccine warehouses when the demand points and the inoculation centres are already decided. A model does not fit in all the problems in humanitarian logistics in particular. Humanitarian operation life cycle consists of the four phase: mitigation, preparedness, response, and recovery (Çelik et al. 2012). Different facility location problems can be applied according to its phase and characteristic as shown in Table 8.

Table 17 Disaster type and Disaster Operation

Types of Disaster (Duijzer et al., 2018)		The four phase of Disaster operations life cycle (Kumar & Havey, 2013)			
	example	1. mitigation	2. preparedness	3. response	4. recovery
Childhood vaccination	Polio	CPCP	-	-	-
Expected outbreak	Seasonal influenza	MCLP	CMCLP	CPMP	CPCP

| Sudden outbreak | COVID-19 | - | - | CPMP | CMLCP/ CPCP |
| Intentional bioterror attacks | Anthrax | - | - | PMP | PCP |

Childhood vaccination, such as polio, is in the mitigation phase because it is infantile disease and almost eradicated except few countries. CPCP can be applied to build vaccination centres in the disease outbreak area. Expected outbreak, such as seasonal influenza, is an epidemic that comes around regularly but the type is changing so that each phase is relevant and should be sequentially managed. In the mitigation and preparedness phase, MCLP and CMCLP are adequate to build infrastructure and pre-positioning resources. In the response phase, when the epidemic comes to outbreak regionally, CPMP is applicable for the construction of relief centres to prevent further spread. In the recovery phase, it is apt to use CPCP.

Sudden outbreak, such as COVID-19, is a pandemic in which situation the disease spread rapidly and hazardous enough to threaten society and economy while causing a lot of human casualties. In this case, it is not possible to mitigate or prepare, but the responsiveness and recovery operation management is significant. In the response phase, CPMP should be applied, because it seeks to find the location where total travel distance is minimised; considering the trade-off between efficiency and equity, it is more important to locate a facility where citizens would draw nearer. In the recovery phase, as the pandemic remains prominent factor while the society gets to recover, the wider coverage of patients and equity become more important so that CMLCP and CPCP are pertinent choice. COVID-19 vaccine warehouse location is in the recovery phase, therefore the CMLCP and CPCP could be appropriate choice.

International bioterror attacks, such as Anthrax, is a disastrous event that is not able to mitigate or prepare, while causing a lot of sudden and desperate human casualties. In this case, uncapacitated PMP is apt to find the emergency facility to provide a lot of citizens with service. After the emergency response phase passes, uncapacitated PCP can be applied.

Conclusion

This study applies different facility location problems to a real data of metropolitan city in Korea to find out optimal sets of locations for humanitarian COVID-19 vaccine warehouses. Several sets of locations were given as optimum answers. The result demonstrates different sets of locations when the input parameters vary. It is shown that comparing the total distance of each case, MCLP-1 provided the most adequate result for the optimum warehouse location.

Through the optimum sets of the location, the practitioners may use as reference for planning the COVID-19 vaccine warehouse by comparing the sets of result, considering the equity and efficiency issue in humanitarian facility location. While the parameters and input data set could be differentiated the geographical data remains one of the most relevant factors in the emergency relief operation. Therefore, the presented set of problems and its result are applicable to not only finding COVID-19 vaccine warehouse locations but also locating various emergency relief facility and stakeholders such as Infectious Disease Specialist EMS Teams, Community Treatment Centres where accommodates patients with weaker symptoms and low risk factors, temporary testing centres for infectious disease special management areas, etc. It is also possible to apply this methodology to broader way to find hypothetical spot for optimum location of warehouses, shelters, and temporary accommodation places in the time of pandemic and other disasters.

Future research is needed to find the optimum sets of location under uncertain factors. In this study, the candidate locations for the facility were assumed to be the same location of the pre-existing inoculation centres, while in the real life, it is not probable that the warehouse would locate adjacent to the demand point. Furthermore, the actual construction planning, costs or the budget of the district were not opened to public hence were not considered as constraints. Therefore, it would be more practical to select potential

location among the available construction sites, assuring the establishment budget in the authority's planning and the connectivity between the stakeholders to give valuable insight for the practitioners.

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Appendix

Appendix A Distance set between potential warehouse and each demand point

	Demand Point										
Potential Warehouse Location	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
	0	34.6	16	11	9.4	55.8	17.6	30.6	8.9	3.2	4.4
	7.7	28.9	16.1	16.4	7.8	50.6	19	23.4	6.4	8.7	10
	34.6	0	7.5	17.8	15.3	26.8	15	26.9	17.8	21.3	24.5
	16	7.5	0	10.3	10.6	38.7	9.2	22.2	12.9	14.1	19.7
	11	17.8	10.3	0	55.4	10.7	4.6	37.1	18.4	8.8	10.7
	6.6	15.9	10.2	8.6	5.1	47.3	13.2	31	5.4	5.1	8.4
	9.4	15.3	10.6	55.4	0	43.5	14.3	27	2.2	8.3	11.5
	55.8	26.8	38.7	10.7	43.5	0	42.1	49	47.6	51.1	54
	52.9	30.2	35.6	48.5	41.4	2.4	42.7	50.3	45.8	49.4	55.1
	17.6	15	9.2	4.6	14.3	42.1	0	34.6	14.3	11.4	13.5
	30.6	26.9	22.2	37.1	27	49	34.6	0	27.6	31.4	32.2
	8.9	17.8	12.9	18.4	2.2	47.6	14.3	27.6	0	7.5	9.5
	2.5	23.3	16.1	11.6	8.9	52	18.7	28.4	7.3	3.2	4
	3.2	21.3	14.1	8.8	8.3	51.1	11.4	31.4	7.5	0	3.8
	4.4	24.5	19.7	10.7	11.5	54	13.5	32.2	9.5	3.8	0
	49.8	76	69.7	55.4	56.6	96.2	58.5	66.9	55.4	49.5	45.5