ICLT 2023

THE 13TH INTERNATIONAL CONFERENCE ON LOGISTICS & TRANSPORT 2023

CIRCULAR SUPPLY CHAIN FOR RESILLIENCE

THAMMASAT BUSINESS SCHOOL

GRADUATE SCHOOL

HANKEN SCHOOL OF ECONOMICS

SCEM

CENTER OF EXCELLENCE IN CONNECTIVITY

Proceeding of International Conference on Logistics and Transport 2023
[FULL PAPER]

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INTRODUCTION

International Conference on Logistics and Transport This is the 13th international conference organized by the Centre for Logistics Research at Thammasat Business School, Thammasat University, the Graduate School of Chiang Mai University and the Supply Chain and Engineering Management Research Unit of Chiang Mai University. This is a major event for researchers in transport, logistics, supply chain and value chain management, especially in the Asia Pacific region.

This year's event in Krabi (Thailand), is a continuation of past successful conferences held in 2009 in Chiang Mai (Thailand), 2010 in Queenstown (New Zealand), 2011 in Malé (Maldives), 2012 in Chiang Mai (Thailand), 2013 in Kyoto (Japan), 2014 in Kuala Lumpur (Malaysia), 2015 in Lyon (France), 2016 in Singapore, 2017 in Bangkok (Thailand), 2018 in Okinawa (Japan), 2019 in Hanoi (Vietnam), 2022 in Krabi (Thailand). This year's event will be held in Helsinki, Finland, during September 27th to 29th, 2023, hosted by Hanken School of Economics.

The theme for this year's event is "Circular Supply Chain for Resilience". With the current movement towards an eco-friendly future, the role of repurposing what is once viewed as "waste" are recycled back in the manufacturing operation. Along with the adaption of data analytics in supply chain, physical internet, blockchain in supply chain, digital supply chain, computer applications in supply chain and disruptive technologies, resilience in circular supply chain have received a considerable attention in the current domain of supply chain management.

Under the theme of "Circular Supply Chain for Resilience", the following topics were welcomed at the conference:

- Procurement & Supply Management
- Planning & Forecasting
- Relationship & Collaboration
- Production Planning & Operations
- Inventory Fulfilment
- International Logistics
- Humanitarian Logistics
- Maritime Logistics
- Logistics Services Providers
- Logistics Development Policies
- Supply Chain Design/Configuration
- Supply Chain Risk Management
- Sustainable Supply Chain
- Production & Inventory
- Supply Chain Performance
- Global Supply Chain
- Multimodal Transport
- Freight Logistics
- E-Logistics
- Logistics Facilitation

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WELCOME ADDRESS FROM THE CONFERENCE CHAIRS

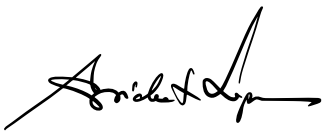
On behalf of the organizing committee, we would like to welcome all participants to the 13th International Conference on Logistics and Transport (ICLT2023). It has been more than a decade since the first conference was hosted in Chiang Mai (Thailand). This ICLT conference is expected to continue on an annual basis in order to facilitate the sharing of ideas, research findings, and teaching directions related to logistics and supply chain from an academic perspective. The theme for this year's event is "Circular Supply Chain for Resilience". This highlights the role of resilience in the ever-evolving supply chain practices and its endless economic possibilities in the current digitalization era.

"Circular Supply Chain for Resilience" is an important concept. It can be used as a guiding principle to help improve firms' resources, capabilities, and operational efficiencies through sustainability across the entire supply chain continuum. The challenge to harmonize these subtle changes between supply chain members remains a critical issue. Our carefully curated program features a range of sessions, including keynote presentations, panel discussions, workshops, and paper presentations, all designed to provide valuable insights and foster intellectual growth.

We would like to sincerely thank all presenters, reviewers, our scientific committees, and keynote speakers for their appreciated contribution. We cannot forget the important contribution of our sponsors, SeaOil (Public) Co. Ltd, Wice Logistics (Public) Co. Ltd., and Prima Marine (Public) Co. Ltd who have supported us through the years. We would also like to acknowledge the hard work and commitment of our organizing committee and volunteers who have put in countless hours to ensure that everything runs smoothly during this conference. Their efforts have been instrumental in bringing us all together today. We also apologize in advance if there are any difficulties you may encounter while participating in the conference.

Last but not the least, we would like to thank the HUMLOG Institute at the Hanken School of Economics for being our host this year. Would could not have run a successful conference without their support. We would like to particularly acknowledge the role of Professor David Grant and Gabriel Kieto Mahaniah in making our event successful.

Finally, we hope that you will enjoy this conference and we hope that the deliberations will be fruitful and successful.



Ruth Banomyong
ICLT General Chair

Apichat Sopadang
ICLT General Chair

WELCOME ADDRESS FROM THE LOCAL CHAIRS

As hosts of the local chair committee, we would like to welcome all participants to the 13th International Conference on Logistics and Transport (ICLT2023) at Hanken School of Economics in Helsinki. It is our privilege to extend a warm and heartfelt welcome to all of you. We are pleased to welcome those of you that have been with us for some time, as well as those of you who are new to our group.

Today marks the 13th annual conference and we are very proud to host this memorable conference here in Finland with all of you. Your strong support and active participation have made the ICLT2023 an excellent event. We have many papers and people registered. The quality of the papers is top class, and the spectrum of topics is very current and broad.

This conference is not only a gathering of brilliant minds and experts from various fields but also an opportunity to showcase the rich cultural heritage and hospitality of our region. Our city, and indeed Finland, is not only known for its scenic beauty and historical landmarks but also for its vibrant academic and research community. We are proud to be a part of this global conversation and to contribute to the intellectual growth that conferences like this foster.

We would like to express our gratitude to all those working generously helping behind the scenes, including local organizations and enterprises, to make ICLT2023 a success. Furthermore, we would like to express our thanks to all presenters, reviewers, and keynote speakers for their contribution.

We trust your conference participation experience will not encounter any difficulties, however, please reach out to anyone with the ICLT badge for assistance if something is amiss. Finally, we hope that you enjoy this conference and sincerely hope that all deliberations and conversations will be fruitful and successful.

Dr Anna Aminoff and Professor David B. Grant

ICLT Local Chairs, Hanken School of Economics

CONTENT

A COMPREHENSIVE FRAMEWORK AND GUIDELINES FOR SUSTAINABLE CITY DEVELOPMENT IN CHIANG MAI, THAILAND

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Abstract
Purpose: The purpose of this work is to provide practical guidelines for policymakers, urban planners, and stakeholders in Chiang Mai and to ensure that the city grows in a manner that preserves its environmental integrity, enhances the well-being of its residents, and fosters economic prosperity. **Design/Methodology/Approach:** The research adopts a comprehensive approach to studying sustainable city development in Chiang Mai. It utilizes a combination of qualitative and quantitative methods, including data analysis. These methods enable a holistic understanding of the current state of the city and its sustainability challenges. **Findings:** The framework for the development of the city of Chiang Mai was proposed. Future urban Chiang Mai development should focus mainly on increased utilization of renewable energy in relation to total energy consumption, improving air quality, improving waste management, and implementing sustainable transport options. **Research Limitations:** Certain limitations were encountered, such as time constraints and data availability. These limitations may have influenced the scope and depth of the study. **Practical Implications:** The guidelines derived from the study will serve as a practical tool for policymakers, urban planners, and stakeholders in Chiang Mai, enabling them to make informed decisions and take effective actions to promote sustainable city development. **Value:** This research presenting a comprehensive framework for evaluating cities using indicators. The framework developed in this study can be adapted and applied not only to Chiang Mai but also to other cities globally.

Keywords: Sustainable cities and communities; Urban development plan; City indicator; Clean energy

Introduction

The Sustainable Development Goals (SDGs) are a set of global objectives adopted by the United Nations in 2015 to address the most pressing economic, social, and environmental challenges facing the world (Pradhan et al., 2023; Breuer et al., 2023). As cities around the world grapple with the challenges of rapid urbanization, sustainable urban development emerges as a critical concept for promoting long-term environmental, social, and economic well-being (Asadzadeh et al., 2022; Yang and Qian, 2022). Chiang Mai, a bustling city in Thailand, has embarked on a transformative journey towards sustainability (Pongruengkiat et al., 2022).

The research conducted in Chiang Mai, which focuses on promoting sustainable development through indicators and guidelines, aligns with the SDGs (Blasi et al., 2022; Sucupira Furtado et al., 2023). The SDGs provide a comprehensive framework for sustainable development, encompassing goals such as affordable and clean energy (SDG 7), sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), and climate action (SDG 13), among others (Grossi and Trunova, 2021; Greenland et al., 2023). By addressing sustainability challenges in areas such as air pollution, water quality, energy consumption, transportation, and waste management, the research in Chiang Mai contributes to multiple SDGs. For example, efforts to increase the utilization of renewable energy and improve air quality contribute to SDG 7 and SDG 13, respectively. Enhancing waste management practices aligns with SDG 12, while

implementing sustainable transportation options supports SDG 11(Obaideen et al., 2022; Saiu et al., 2022; Hussain et al., 2023).

In previous research (Pongruengkiat et al., 2023a; 2023b), we delve into the state of sustainable urban development in Chiang Mai, employing a comprehensive multi-dimensional framework that examines various indicators, shown in Figure 1. The analysis reveals that Chiang Mai has made commendable progress in certain areas. However, pressing challenges in transportation, waste management, air pollution, and energy consumption demand urgent attention. The research underscores the significance of sustainable urban development and offers valuable insights for policymakers, urban planners, and stakeholders seeking to shape a sustainable future for the city.

The previous research work also introduces a comprehensive framework for evaluating cities through expert-selected indicators, which can be adapted and applied to other urban centers worldwide. In evaluating Chiang Mai, a set of 35 indicators was used whose 28 indicators surpassed the assessment criteria. The overall score of 2.69 out of 3 indicates commendable progress towards sustainable development. However, certain indicators fell short, emphasizing the ongoing need for concerted efforts to achieve sustainability goals.

The purpose of this work is to offer practical guidelines for policymakers, urban planners, and stakeholders in Chiang Mai, aiming to ensure that the city's growth aligns with the preservation of its environmental integrity, the enhancement of residents' well-being, and the promotion of economic prosperity. Based on the research findings, a comprehensive framework for the development of Chiang Mai has been proposed. The future urban development of Chiang Mai should primarily prioritize increasing the utilization of renewable energy in relation to total energy consumption, improving air quality, enhancing waste management practices, and implementing sustainable transportation options. By focusing on these key areas, Chiang Mai can make significant strides towards becoming a sustainable and livable city, setting an example for other urban centers to follow.

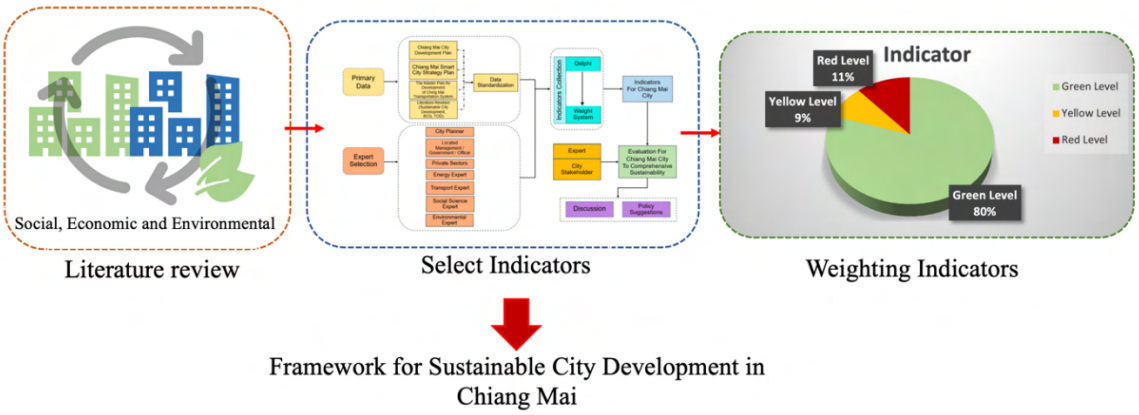

Figure 1: Research framework

Materials and Methods

Based on our prior research, a sustainability guideline for Chiang Mai has been established, incorporating concise indicators (Pongruengkiat et al., 2022; 2023a; 2023b). Consequently, this study aims to propose a development guideline for Chiang Mai. The indicators presented in this research comprise a selection of indicators previously categorized as yellow and red. Yellow-rated indicators encompass water quality, population density, and number of crimes, while red-rated indicators include the proportion of renewable energy usage to total energy, air quality, waste management, and transportation type. The scores of indicators are displayed in Figure 2. The yellow and red graded indicators identified in the research play a crucial role in guiding efforts towards achieving sustainable development in Chiang Mai. These

indicators highlight areas that require further attention and improvement to elevate their performance to the green level. By focusing on addressing the challenges represented by the yellow and red graded indicators, Chiang Mai can work towards finding sustainable solutions to enhance its overall sustainability. For example, for indicators such as water quality, population density, and number of crimes falling within the yellow level, specific measures can be implemented to improve their performance. This may involve implementing stricter regulations to minimize pollution, implementing urban planning strategies to manage population density effectively, and enhancing law enforcement and community engagement to reduce crime rates. Similarly, for indicators in the red level, such as proportion of using renewable energy to total energy, air quality, waste management, and type of transport, concerted efforts are needed to address the significant areas of concern. This may include implementing policies and incentives to promote the use of renewable energy sources, adopting stricter emission standards to improve air quality, enhancing waste management infrastructure and practices, and investing in sustainable and efficient public transportation systems.

By actively addressing these yellow and red graded indicators and finding sustainable solutions, Chiang Mai can strive towards achieving the green level across all indicators for sustainable development. This holistic approach will contribute to creating a more resilient, livable, and environmentally friendly city for its residents while also serving as a model for other cities seeking sustainable development.

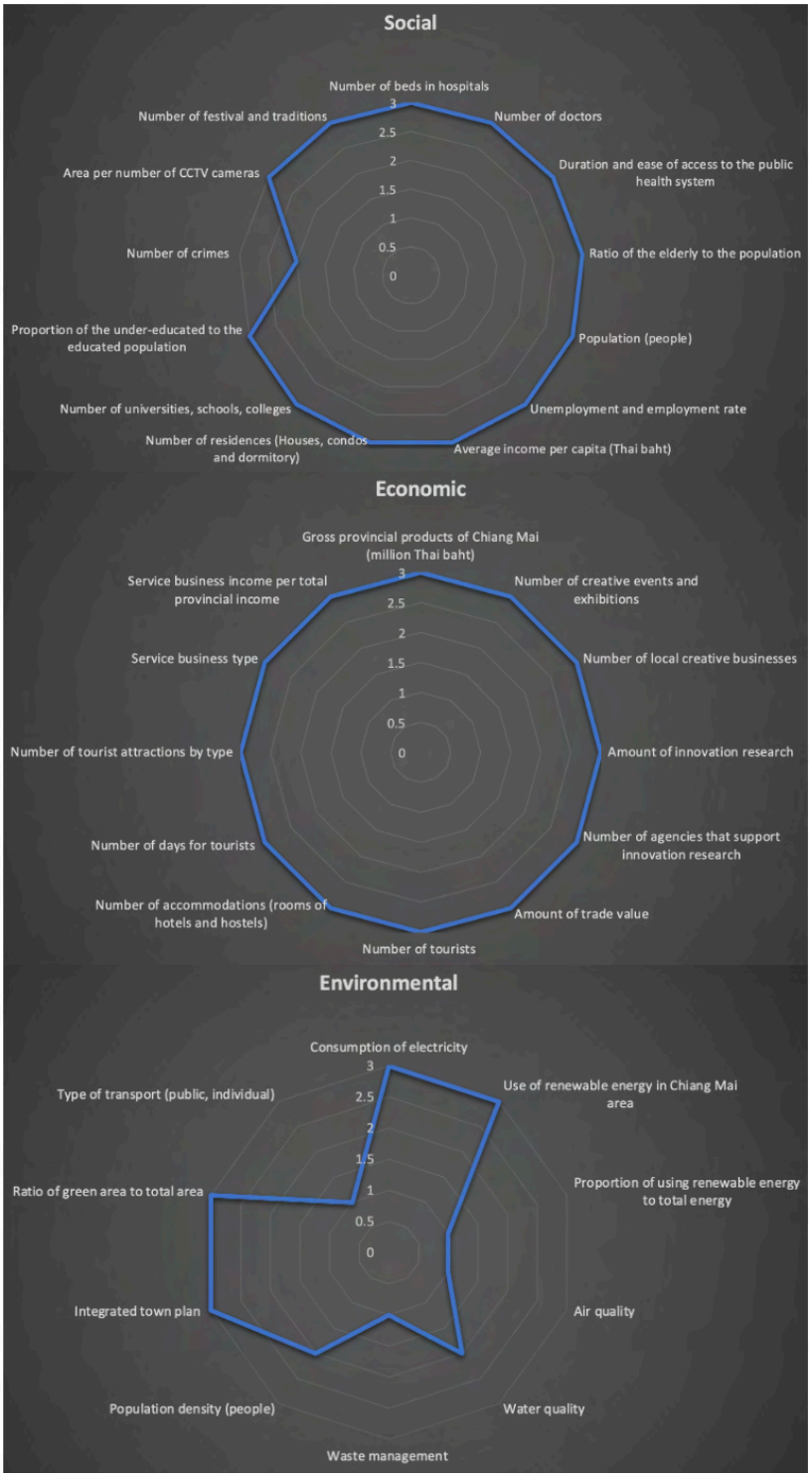

Figure 2: Scores of indicators separated by Social, Economic and Environmental groups

Results and Discussion

Based on the study of various aspects of Chiang Mai and the indicators that have not met the evaluation criteria, several methods and guidelines can be proposed to improve these indicators and promote sustainable development in the city.

Water quality

Improving water quality in Chiang Mai is a critical step towards achieving sustainable development and ensuring the well-being of its residents. To address this challenge, a multi-faceted approach is needed. First and foremost, comprehensive wastewater treatment measures should be implemented, requiring industries to treat their wastewater before it enters water bodies. Furthermore, promoting sustainable agricultural practices that minimize chemical runoff and encourage responsible irrigation techniques can help safeguard water quality. Regular monitoring of water sources is essential to identify contamination sources promptly and take corrective actions. Engaging and educating local communities about the importance of clean water and involving them in monitoring initiatives can foster a sense of ownership and responsibility. Upgrading water treatment facilities and protecting water catchment areas, such as forests and wetlands, are vital steps in ensuring clean and safe water for the population. Lastly, collaborative governance and regulation, involving government agencies, water management authorities, and environmental organizations, can support the development and enforcement of effective policies and practices. By implementing these measures, Chiang Mai can effectively tackle its water quality issues, paving the way for a sustainable future for the city and its residents.

Population density

To address Chiang Mai's population density challenges, the following strategies can be implemented: prioritizing compact and mixed-use development through smart growth principles, investing in efficient public transportation systems, developing satellite towns and decentralized employment centers, promoting affordable housing and mixed-income neighborhoods, and fostering citizen participation and engagement. These measures aim to distribute the population more evenly, reduce congestion, improve land use efficiency, and enhance the overall livability and sustainability of the city. By implementing these strategies, Chiang Mai can effectively manage its population density and create a more balanced and inclusive urban environment.

Number of crimes

To address the issue of high crime rates in Chiang Mai, several strategies can be implemented. First and foremost, enhancing law enforcement efforts and increasing police presence in high-crime areas can help deter criminal activities and improve public safety. Additionally, investing in community policing initiatives and fostering strong relationships between law enforcement agencies and local communities can promote trust, cooperation, and timely reporting of crimes. Implementing targeted crime prevention programs, such as neighborhood watch programs and youth engagement initiatives, can also play a significant role in reducing criminal activities. Furthermore, improving street lighting and implementing effective urban design strategies, such as creating well-lit public spaces and improving the overall physical environment, can help enhance surveillance and discourage criminal behavior. Finally, providing support and resources for rehabilitation and reintegration programs for offenders can contribute to reducing recidivism and promoting long-term community safety. By implementing these comprehensive approaches, Chiang Mai can effectively address the challenges associated with the number of crimes and create a safer and more secure city for its residents and visitors.

Proportion of renewable energy usage to total energy

To address the challenge of increasing the proportion of renewable energy usage to total energy in Chiang Mai, several measures can be implemented. Firstly, it is crucial to establish supportive policies and regulations that incentivize the adoption and integration of renewable energy sources. This can include feed-in tariffs, tax incentives, and subsidies for renewable energy projects. Encouraging investment in renewable energy infrastructure, such as solar and wind farms, can also help boost the overall capacity of renewable energy generation in the city. Additionally, promoting energy efficiency measures and raising awareness about the benefits of renewable energy among the public can encourage individuals and businesses to transition to clean energy sources. Collaborating with local and international partners to access expertise, technology, and funding for renewable energy projects can also accelerate progress in this area. Furthermore, conducting research and development activities to explore innovative solutions, such as energy storage technologies, can enhance the reliability and stability of renewable energy systems. By implementing these strategies, Chiang Mai can significantly increase the proportion of renewable energy usage and reduce its dependence on fossil fuels, leading to a more sustainable and environmentally friendly energy future.

Air quality

To tackle the issue of air quality in Chiang Mai, comprehensive measures need to be taken. Firstly, reducing sources of air pollution is crucial. This can be achieved through stricter regulations on industrial emissions, enforcing vehicle emission standards, and promoting cleaner transportation options such as electric vehicles or improved public transportation. Additionally, addressing the problem of open burning, particularly during the agricultural season, is essential. Implementing effective policies and awareness campaigns to discourage this practice and provide alternative solutions can significantly improve air quality. Furthermore, promoting green spaces and urban forestry can help mitigate air pollution by absorbing pollutants and improving air circulation. Enhancing monitoring systems and establishing early warning systems can provide real-time data on air quality, allowing for prompt actions and public awareness. Lastly, public engagement and education initiatives are vital to raise awareness about the importance of clean air and encourage individuals to adopt sustainable practices. By implementing these measures, Chiang Mai can effectively address air quality issues and create a healthier living environment for its residents.

Waste management

To address Chiang Mai's waste management problem, a multi-faceted approach is necessary. Firstly, promoting waste reduction and recycling initiatives can significantly reduce the amount of waste generated. This can be achieved through public awareness campaigns, educational programs, and incentivizing recycling and composting practices. Implementing a comprehensive waste segregation system is crucial, ensuring that different types of waste are properly sorted and disposed of. Developing efficient waste collection and transportation systems, including regular pickups and designated collection points, can help prevent waste accumulation and illegal dumping. Investing in modern waste treatment facilities, such as waste-to-energy plants or anaerobic digestion facilities, can provide sustainable solutions for managing the remaining waste. Collaboration with local communities, businesses, and organizations is vital to create a sense of responsibility and ownership in waste management efforts. Finally, implementing stricter regulations and enforcement measures, along with penalties for improper waste disposal, can help ensure compliance and accountability. By adopting these measures, Chiang Mai can work towards a more sustainable and efficient waste management system, minimizing environmental impacts and promoting a cleaner city.

Transportation type

To address Chiang Mai's transportation challenges, a comprehensive strategy focused on sustainable and efficient modes of transportation is crucial. Firstly, promoting the use of public transportation, such as buses and trains, can help reduce the reliance on private vehicles and alleviate traffic congestion. Enhancing the public transportation infrastructure by expanding routes, increasing frequency, and improving accessibility can make it a more attractive option for residents and visitors. Encouraging active modes of transportation, such as walking and cycling, through the development of pedestrian-friendly infrastructure and dedicated cycling lanes can promote a healthier and greener city. Implementing intelligent transportation systems and technologies, such as traffic management systems and real-time information services, can improve traffic flow and optimize transportation routes. Furthermore, incentivizing the adoption of electric and hybrid vehicles through subsidies, tax incentives, and the development of charging infrastructure can contribute to reducing air pollution and carbon emissions. Collaborating with stakeholders, including transportation providers, urban planners, and the community, is essential to ensure the effective implementation of these measures. By prioritizing sustainable transportation options and reducing reliance on private vehicles, Chiang Mai can create a more efficient, environmentally friendly, and people-centric transportation system.

Towards sustainability

This research study focuses on promoting sustainable development in Chiang Mai, Thailand, while aligning with the goals of the SDGs (Biermann et al., 2017). By evaluating various aspects of the city, including water quality, population density, number of crimes, proportion of renewable energy usage to total energy, air quality, waste management, and transportation, practical guidelines and solutions are proposed to address these challenges.

To enhance water quality, the study emphasizes the importance of implementing robust water treatment systems, promoting responsible agricultural practices to reduce pollution, and raising awareness about water conservation among residents and businesses. In addressing population density concerns, the research highlights the need for strategic urban planning, including the development of satellite towns, affordable housing projects, and efficient land use practices. Additionally, investment in infrastructure and amenities, such as schools, healthcare facilities, and recreational spaces, is essential to support the growing population.

To tackle the issue of high crime rates, the study recommends strengthening law enforcement measures, enhancing community policing initiatives, and fostering social programs that address the root causes of crime, such as poverty, unemployment, and inequality. In terms of renewable energy, the research emphasizes the need for promoting clean energy sources, including solar and wind power, through incentives, regulations, and partnerships with energy providers. Increasing the proportion of renewable energy usage to total energy can significantly reduce carbon emissions and contribute to mitigating climate change. Addressing air quality concerns involves adopting stricter emissions standards, promoting green technologies, and encouraging the use of electric and hybrid vehicles. Additionally, the research emphasizes the importance of tree planting and green spaces to improve air quality and enhance urban resilience.

Regarding waste management, the study proposes a comprehensive waste management strategy that includes waste reduction, recycling, and the implementation of efficient waste disposal systems. Public education campaigns, community involvement, and collaborations with waste management companies are essential to achieve sustainable waste management practices. Lastly, in addressing transportation challenges, the research suggests promoting sustainable modes of transportation, such as public transit, walking, and cycling. This involves expanding public transportation networks, developing pedestrian-friendly

infrastructure, and incentivizing the use of electric and hybrid vehicles. Additionally, implementing intelligent transportation systems can optimize traffic flow and reduce congestion.

By implementing the recommendations provided in this research, Chiang Mai can progress towards achieving the SDGs, particularly Goal 6 (Clean Water and Sanitation), Goal 7 (Affordable and Clean Energy), Goal 11 (Sustainable Cities and Communities), Goal 12 (Responsible Consumption and Production), Goal 13 (Climate Action), and Goal 16 (Peace, Justice, and Strong Institutions) (Subramaniam et al., 2023). The findings of this study can guide policymakers, urban planners, and stakeholders in their efforts to ensure a sustainable and prosperous future for Chiang Mai, while contributing to the global agenda of sustainable development.

Framework for Chiang Mai sustainable city

For the city to achieve sustainability, it requires three essential elements: livability, viability, and fairness. These elements stem from the development of environmental, social, and economic indicators, totaling 7, which Chiang Mai must improve upon. Figure 3 illustrates these indicators. The challenges faced by Chiang Mai are denoted by red and yellow circles and encompass waste management and water management, both crucial for a healthy environment. Additionally, addressing crime indicators contributes to the betterment of society and the economy. While implementing air policy and renewable energy measures may involve expenses, they lead to cleaner air. Furthermore, the transport indicator significantly impacts various aspects like affordable reduce private vehicle, public and green area, reduced congestion, and supports tourism. Population density indicators also influence congestion and land use. By improving clean air, reducing congestion, and efficient land use, the city can enhance its environment, society, and economy, ultimately driving Chiang Mai towards sustainability. The interplay between transport and population density indicators becomes evident as they impact various dimensions. This relationship needs to be cultivated initially. Simultaneously, the aforementioned indicators necessitate concurrent management.

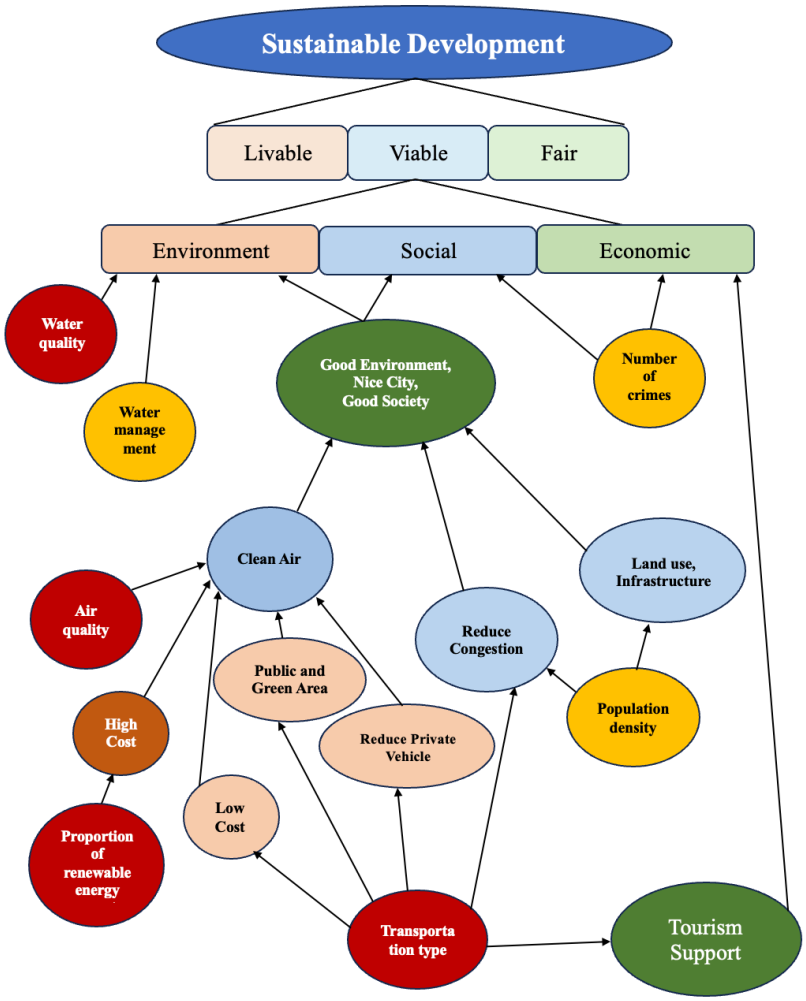

Figure 3: Framework for Chiang Mai sustainable city

Conclusions

This research study provides a comprehensive approach to promoting sustainable development in Chiang Mai, Thailand, aligned with the SDGs. By addressing key indicators such as water quality, population density, crime rates, renewable energy usage, air quality, waste management, and transportation, the study offers practical solutions and guidelines to overcome these challenges. By adopting the recommendations of this research, Chiang Mai can make significant progress towards achieving the SDGs, particularly in the areas of clean water and sanitation, affordable and clean energy, sustainable cities and communities, responsible consumption and production, climate action, and peace, justice, and strong institutions. The findings of this study provide valuable guidance to policymakers, urban planners, and stakeholders in their efforts to ensure a sustainable and prosperous future for Chiang Mai, while contributing to the global agenda of sustainable development.

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References

Asadzadeh, A., Kotter, T., Fekete, A., Moghadas, M., Alizadeh, M., Zebardast, E., Weiss, D., Basirat, M., and Hutter, G. (2022), "Urbanization, migration, and the challenges of resilience thinking in urban planning: Insights from two contrasting planning systems in Germany and Iran", *Cities*, vol. 125, article no. 103642.

Biermann, F., Kanie, N., and Kim, R. E. (2017), "Global governance by goal-setting: the novel approach of the UN Sustainable Development Goals", *Curr Opin Environ Sustain*, vol. 26–27, pp. 26–31.

Blasi, S., Ganzaroli, A., and De Noni, I. (2022), "Smartening sustainable development in cities: Strengthening the theoretical linkage between smart cities and SDGs", *Sustain Cities Soc*, vol. 80, article no. 103793.

Breuer, A., Leininger, J., Malerba, D., and Tosun, J. (2023), "Integrated policymaking: Institutional designs for implementing the sustainable development goals (SDGs)", *World Dev*, vol. 170, article no. 106317.

Greenland, S. J., Saleem, M., Misra, R., Nguyen, N., and Mason, J. (2023), "Reducing SDG complexity and informing environmental management education via an empirical six-dimensional model of sustainable development", *J Environ Manage*, vol. 344, article no. 118328.

Grossi, G., and Trunova, O. (2021), "Are UN SDGs useful for capturing multiple values of smart city?", *Cities*, vol. 114, article no. 103193.

Hussain, S., Ahonen, V., Karasu, T., and Leviäkangas, P. (2023), "Sustainability of smart rural mobility and tourism: A key performance indicators-based approach", *Technol Soc*, vol. 74, article no. 102287.

Obaideen, K., Shehata, N., Sayed, E. T. Abdelkareem, M. A., Mahmoud, M. S., and Olabi, A. G., (2022), "The role of wastewater treatment in achieving sustainable development goals (SDGs) and sustainability guideline", *Energy Nexus*, vol. 7, article no. 100112.

Pongruengkiat, W., Pichayapan, P., Tippayawong, K. Y., and Tippayawong, N., (2022), "Applying sustainable city assessment framework for Chiang Mai's future urban development", *AIP Conference Proceedings*, vol. 2681, no. 1, article no. 020015.

Pongruengkiat, W., Tippayawong, K. Y., Aggarangsi, P., Pichayapan, P., Katongtung, T., and Tippayawong, N. (2023a). "Applying Delphi method to develop sustainable city indicators. A case study of Chiang Mai, Thailand", *TEMA J Land Use, Mobility Environ*, vol. 16, no. 1, pp. 165-182.

Pongruengkiat, W., Tippayawong, K. Y., Aggarangsi, P., Pichayapan, P., Katongtung, T., and Tippayawong, N. (2023b). "Assessing sustainability of Chiang Mai urban development", *Discover Sustainability*, accepted for publication.

Pradhan, B. K., Yadav, S., Ghosh, J. and Prashad, A. (2023), "Achieving the sustainable development goals (SDGs) in the Indian State of Odisha: challenges and opportunities", *World Dev*, vol. 3, article no. 100078.

Saiu, V., Blečić, I., and Meloni, I. (2022), "Making sustainability development goals (SDGs) operational at suburban level: Potentials and limitations of neighbourhood sustainability assessment tools", *Environ Impact Assess Rev*, vol. 96, article no. 106845.

Subramaniam, N., Akbar, S., Situ, H., Ji, S., and Parikh, N. (2023), "Sustainable development goal reporting: Contrasting effects of institutional and organisational factors", *J Clean Prod*, vol. 411, article no. 137339.

Sucupira Furtado, L., da Silva, T. L. C., Ferreira, M. G. F., de Macedo, J. A. F., and de Melo Lima Cavalcanti Moreira, J. K. (2023), "A framework for digital transformation towards smart governance: using big data tools to target SDGs in Ceará, Brazil", *J Urban Manag*, vol. 12, pp. 74-87.

Yang, C. and Qian, Z. (2022), "Urbanization through resettlement and the production of space in Hangzhou's concentrated resettlement communities", *Cities*, vol. 129, article no. 103846.

ACCOUNTING TRANSFORMATION IN SUPPLY CHAIN: INSIGHTS ON SHARED SERVICES CENTER

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ABSTRACT

Purpose: This research examines how the Siam Cement Public Company Limited (SCG) Corporate Accounting Office transformed its cost center to shared service center. Specifically, the article objectives are to investigate design, implementation, and transformation processes by SCG corporate accounting office.
Design/methodology/approach: The research method used in this study was a deep single-case study. The unit analysis is the Corporate Accounting Department, the Siam Cement Public Company Limited. The research method was designed according to the guidelines of Eisenhardt (1991) and Yin (2009).
Findings: The findings indicate that the organizational structure with a management team form of governance is influenced by original SCG culture. In this case, leadership is necessary contributed to effectiveness of design, implementation, and transformation processes. Mechanism also requires planning, people, and processes, with technology as the accelerator.
Practical implications: The implemetation involves strengthening the accounting department. Provide commercial information of the same standard across all business units of affiliates. Delivering services to these business units. It's not just about publishing accurate financial reports and tax information. It also values the visualization of strategic management as well as a comment on the trends and forecasts of companies for clients. There are big data as data mining, which is useful for analyzing data at both business unit levels and big picture data for the Siam Cement Group.
Originality: The research shows that SCG Corporate Accounting Office plays important role in creating value at the 1) individual level, 2) organizational level, and 3) profession level.

Keywords: Accounting Transformation, Shared Service Center

Introduction

The organizational structure of a for-profit organization was originally intended to divide the line to delegate authority and responsibility to executives and employees at various levels. These may be referred to as departments, divisions, entities, or business units. The design of divisions within such an organisation can be divided into groups called responsibility centres can be divided into 4 types: 1) revenue center, 2) cost center, 3) profit center, and 4) investment center.

From the above organizational structure, we can see that the accounting service is a cost center whose main activities consist of serving other parts of the organization that is not profitable. It is a business unit that only generates costs and expenditures, which makes the accountant's role in this type of organization less important and the added value to the organization is limited.Thus, the idea of converting cost centers like the accounting department into an organization shared service center began in the early 1990s (Cacciaguidi-Fahy, Currie & Fahy, 2002). It is a form in which an organization operates by merging common business functions with previously separate divisions with independent operations in a subsidiary or subsidiary. Be a centralized unit to deliver services to all affiliates by calling this shared service centre (Ulrich, 1995).

For example, there is an accounting service that is responsible for accounting and preparing financial statements. Specifically in a company for operations in the form of a joint service center for supporting work, shared accounting services center has a major management concept that is a form of pooling accounting personnel from all affiliates together. Provides accounting services in a variety of dimensions for all national and international affiliates, divided into: 1) recording accounts, 2) reporting & analysis, 3) accounting system & process development / it support, and 4) accounting professional standards & taxation.

The Shared Services Centre is a business tool to improve organizational effectiveness. More precisely, the objectives of the Shared Services Centre are to:

1. reduce redundant work, make work efficiency, better services, increase customer satisfaction,
2. focus on improving the quality of service,
3. reduce costs,
4. elevate the woring standards and use modern technology to assist workforces.
5. be able to move resources to carry out other tasks that constitute the core work.
6. provide flexibility in the event that new services or jobs are added.

To support change and stable business development, the Siam Cement Public Company Limited has set up a central accounting service center as a shared services center. It provides accounting support functions to Siam Cement's business units. Ideally, the Siam Cement had adapted and modified the accounting business model by assigning a new role as a business partner. That is the Corporate Accounting Department, the Siam Cement Public Company Limited. It is notable for being Thailand's first accounting share service center and serves as a model for other large firms to utilize as a reference point for establishing a joint service center with similar characteristics. Of the importance of the shared services center as mentioned above, researchers are interested in studying the design process of the SCG accounting shared services center, its application, and the transition from a cost center to a value creation center.

Research methodology

The research method used in this study was a deep single-case study. The unit analysis is the Corporate Accounting Department, the Siam Cement Public Company Limited. The research method was designed according to the guidelines of Eisenhardt (1991) and Yin (2009) as follows:

Research in the form of a case study is an empirical research method when it involves the study of specific problems or phenomena in the unit requiring in-depth analysis. In the context of real-life work (real-life context), in addition, the area that needs to be studied must be able to provide important knowledge that has not been studied before. The identification of a case study or unit of analysis is the first step in a case study-based research design. A case-study methodology utilized in this research is in accordance with the advice of Eisenhardt (1991) and Yin (2009).

In this step, analytical approaches were applied to the data analysis method suggested by Miles and Huberman (1994) as the main method to analyze, summarize, evaluate, and respond to research questions using all the interview data, field notes, and observations. First, organizational approaches for matching patterns of similar and contradictory data are used. To demonstrate the validity of the analytical findings by comparing the results to the theoretical triangulation, which serves as a guideline for data analysis. The two researchers will examine the data independently. Next, the results of the analysis will be compared and reviewed with the theory and interview data. Finally, all researchers reviewed the findings and delivered conclusions.

Research results

1. The beginning of the transition from being a cost center to a shared service center of the Corporate Accounting Department.

In 2000, the idea of creating an accounting department as a shared services center first emerged. How to make the accounting department valuable and profitable was the main concern at SCG Group.

Thus, the organization started to spread this idea. To reconstruct the accounting support agency in its original form as a service center for accounting work was something top management talked about at a meeting of its executives. However, at this early point, no formal policy had been announced. Management recognized the importance of this issue. They were concerned that it will have an impact on numerous accounting department staff. Therefore, there needs to be a strategy for a smooth transition within the organization. Importantly, they did not lead to opposition within the organization or against this policy. It is, therefore, shrouded in secrecy, just a top executive-only working group. The accounting department's initial focus was on the key objectives of this transition, which include welfare, wages, and labor laws.

Establishing the Corporate Accounting Department as a shared services center has the principal aim in the initial phase, which is to reduce operational costs, improve execution quality management and improvement of work processes to be able to compete with competitors. At the management meeting, they talked about transforming the support units into units that elevate the level and increase the capacity of the accounting department. First, SCG wanted businesses to focus on their core business and minimize the burden of caring for support agencies. Second, to ensure effective control systems, the Corporate Accounting Department was the primary function responsible for providing information to senior management for administrative control, such as warehouse control, cash flow control, and performance control. In addition, it was intended to provide significant information in the decision-making at the business group level of all affiliates of the Siam Cement Public Company Limited. Third, to reduce the cost of doing business and jointly create benefits for the business units that were customers of the Corporate Accounting Department. The goal is to reduce costs after using the services of the the Corporate Accounting Department, or to be able to keep costs under control.

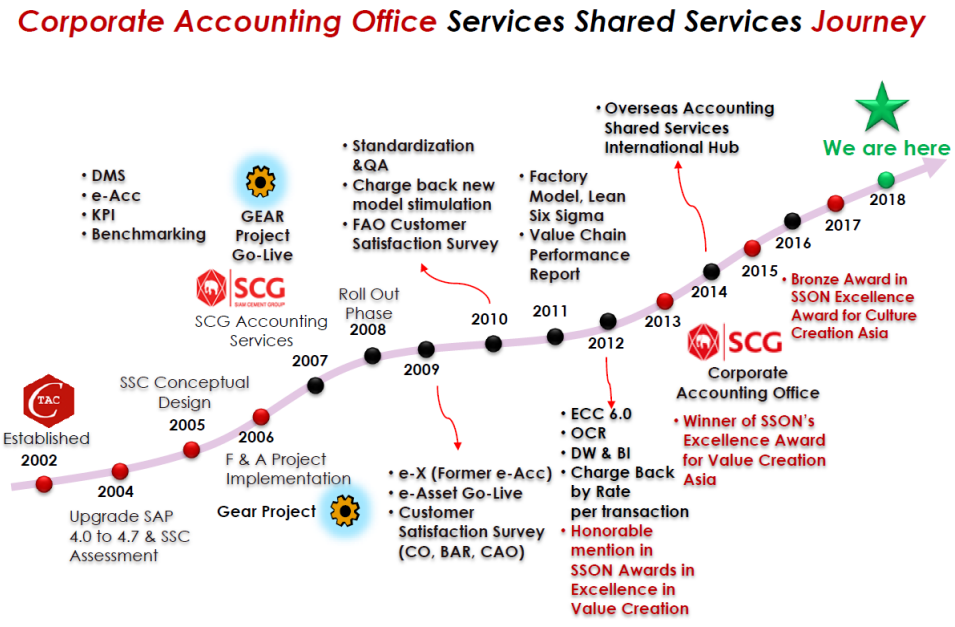


Exhibit 1: The SCG Accounting Shared Service Journey

2. Design process, Implimentation and Transition

The process of transforming the organization from the traditional operating model to the establishment of a joint service center has 4 important processes, which are:

1) Organization design

The structure of the accounting firm has continually evolved and changed since the establishment of the organization in 2002. Currently, the organizational structure is organized according to

an organization's vision, which provides services to reach the leading accountancy work in the region and create value for the Siam Cement Group.

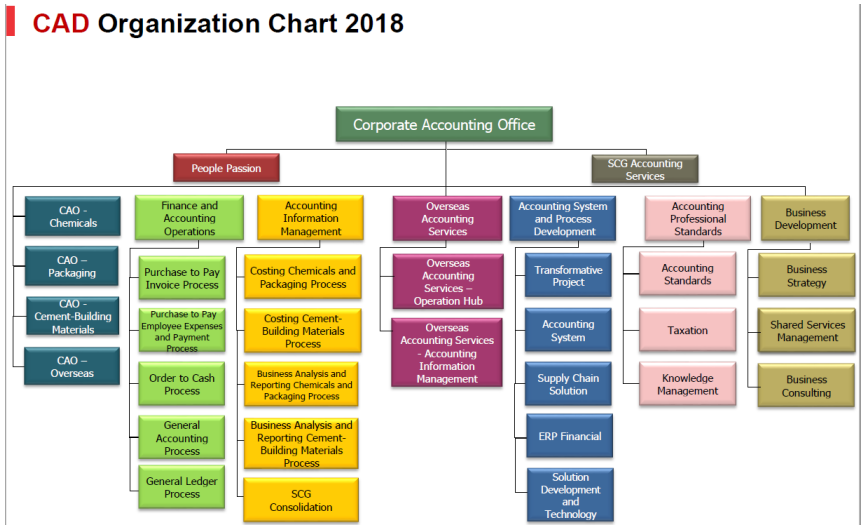
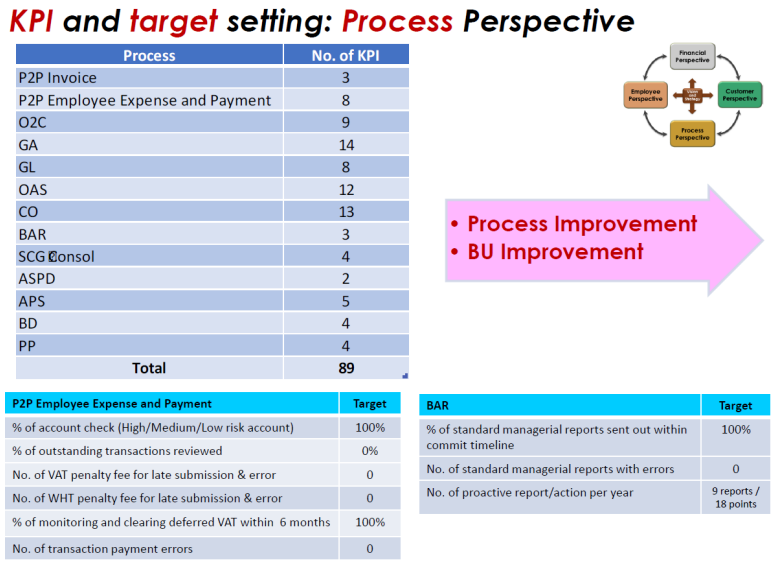


Exhibit 2: The SCG Shared Accounting Services Center Organization Chart in 2018

2) Work process design

The design of the first stage of work began by replicating best practices within the organization. Survey the work of accountants from all affiliates to see where they have the best processes and use them as a model. In addition, lessons learned from other organizations' best practices enable separate studies for each accounting function, such as accounts receivable, accounts payable, capital asset management, etc. In this phase, emphasis is placed on adjusting how quickly work is done. Obtaining the best work process at that time, it was announced as a work manual for each function. Additionally, it is the work design that responds to the differences between each business unit that is a client. Each group of accountants continued to manage its respective business unit, dealing primarily with one client.

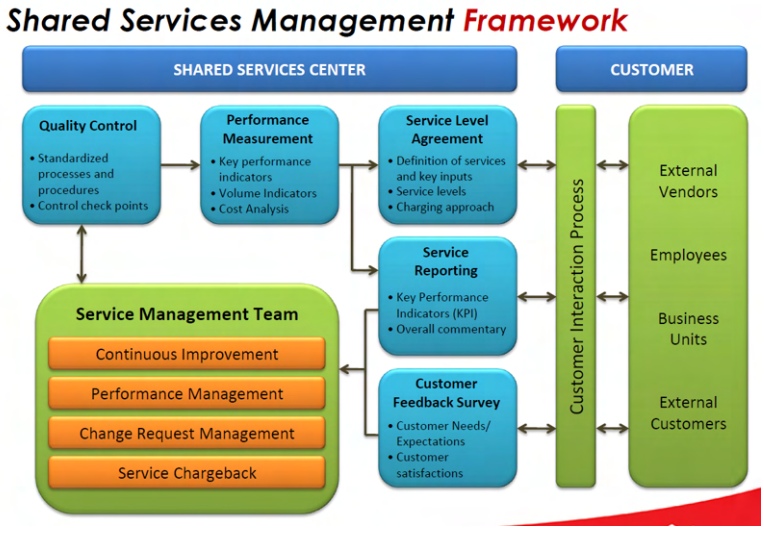


The second phase of the design is a process-based functional design. By emphasizing this process, the accountant's job is no longer related to looking after a single client. Rather, accountants will be able to work on a process for several business units. An important aspect of the process redesign at this point is the presence of a dedicated HR function within the organization. Reskill is the creation of new skills required to perform tasks according to the redesigned workflow. In addition, upskill is the development of upgrading existing skills to support the upgrade of services to business units according to the new plan. This phase of work will conform to the system (workflow), including the standards of storage of accounting documents. This represents the beginning of the use of a management framework that facilitates access to an internationally standardized shared service centre.

Functional Design Phase 3 is a functional design that emphasizes development and value creation for clients or business units that deliver services (business development and value creation). The workloads and manpower of accountants as well as the process have suitable jobs. What process is not in place? and which process is overworked for surplus jobs. A business unit support had been established to provide consulting services in various areas for business units of the Siam Cement Group, including SAP implementation, accounting system implementation and accounting services, etc.

3) Change management design

Starting in 2005, consideration was given to hiring a consultant to launch the project in 2006, given the desire to design a successful organization. The standard which is essential to the Shared Services Centre is process design and change management design. The outcome of hiring a consultant, Ascenture Consultancy Services (ACS), leads to a self-evaluation. (Self-Assessment) What is this process? What services do you provide? How is the pattern? Identification of best practices within the working group. Started to do Gear Project by Ascenture in 2006. Collecting information on organizations in various aspects, which aims at designing work that is intended to be an organization in the form of a world-class shared services center. It is interesting to note that the transformation process within the organization is dynamic on an ongoing basis and that changes in many processes always come with barriers. It is one of the benefits of hiring a consultant to contribute to the transformation of the organization. An external consultant discussed and directed change on a number of issues. Facilitate the transition rather than being manually led by people in the organization. The corporate image had been changed to SCG Accounting Services Company Limited to support a new business model. This new brand created awareness and trust among clients early on because the SCG brand was initially believed by public. It created pride for the employees of the organization that they were part of SCG. They were proud to be part of SCG and when they communicated with clients, it builded trust in business negotiations.



4) Designing application processes for success

Enterprise Resource Planning (ERP) technology was used, the SAP system, prior to the 1997 economic crisis and underwent major modernisation in 2004. However, the technical department of technology remains a central unit of the head office of Siam Cement. Not yet under the supervision of the Corporate Accounting Department. Following the improvement of the work process, the result was that the work process was more efficient. From the beginning, the work plan focused on cost savings and the delivery of quality services that were not less than the original when an accounting firm was created. He moved into the era of focus on creating value for business units (value creation), giving importance to being a business partner with business units. While this was a work process that emphasizes creating value for business units. But it could also reduce costs in the work process and increase the efficiency of the work simultaneously. Key drivers that improved the successful application process were a skilled workforce and supportive technology that contributes to service value creation.

The fact-finding process is a common process among members of the organization. Not all projects or plans implemented will achieve the intended results for each project. But learning from mistakes is a process of insertion which occurs periodically due to the vision of the organization to become a leader in the accounting profession. As a result, it always leads to pilot investments before other organizations. Of course, there are risks associated with this. However, this is a risk that can be assessed at that time.

Conclusion

This research aims to study the design process of the SCG accounting shared services center, its application, and the transition from a cost center to a shared services center. The results showed that there are two major factors in moving from a normal business model to shared services center: economic factors and strategic incentives. This conforms to the findings of Janssen and Joha (2006), Goh et al. (2007), and Paagman et al. (2015). While the transformation process into a shared service center consists of 1) corporate design, consistent with the research results of Ratz et al. (1991), and Wang and Wang (2007). 2) Workflow design, which is consistent with the findings of McCracken and Mclvor (2012) Mclvor et al. (2011). 3) Change management design, this is in line with the findings of Su et al. (2009). Finally, 4) designing an application process for success, this aligns with the conclusions of Knol et al. (2013), Lacity and Fox (2008).

The important management strategies are: 1) a good governance structure that is linked to the duties and responsibilities in the decision-making process of the organization and internal communication Interaction between the service provider and the client. This is consistent with the findings of Janssen and Joha (2006). 2) Management and strategy, this is a process whereby the Common Service Centre must work with other organizations that end up using the service as a value in terms of increasing competitiveness. This is in keeping with findings from Janssen and Joha (2006). 3) cooperation mechanism. This is an issue with service centers receiving services for the purpose of adding value together. The way the joint service center works with the agencies that come and use the service smoothly. This is consistent with conclusions from Minnaar and Vosselman (2013) and Maatman et al. (2010).

References

Cacciaguidi-Fahy, S., Currie, J., & Fahy, M. (2002). *Financial Shared Services Centres: Opportunities and Challenges for the Accounting Profession*. London: The Association of Chartered Certified Accountants.

Eisenhardt, K. M. (1991). Better stories and better constructs: The case for rigor and comparative logic. Academy of Management Review, 16, 620-627.

Goh, M., Prakash, S., & Yeo, R. (2007). Resource-based approach to IT shared services in a manufacturing firm. *Industrial Management & Data Systems,* 107(2), 251-270.

Janssen, M., & Joha, A. (2006). Motives for establishing shared service centers in public administrations. *International Journal of Information Management,* 26(2), 102-115.

Knol, A., Janssen, M., & Sol, H. (2014). A taxonomy of management challenges for developing shared services arrangements. European Management Journal, 32(1), 91-103.

Lacity, M. C., & Fox, J. (2008). Creating global shared Services: Lessons from Reuters. MIS Quarterly Executive, 7(1), 17-32.

Maatman, M., Bondarouk, T., & Looise, J. K. (2010). Conceptualising the capabilities and value creation of HRM shared service models. Human Resource Management Review, 20(4), 327-339.
McCracken M, McIvor R (2012) Transforming the HR function through outsourced shared services: insights from the public sector. *The International Journal of Human Resource Management 24*(8): 1685–1707.
McIvor, R., McCracken, M., & McHugh, M. (2011). Creating outsourced shared services arrangements: Lessons from the public sector. *European Management Journal*, *29*(6), 448-461.
Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis : an expanded sourcebook*. Thousand Oaks: Sage Publications.
Minnaar, R., & Vosselman, E. G. J. (2013). Shared service centres and management control structure change: Exploring the scope and limitations of a transaction cost economics approach. Journal of Accounting & Organizational Change, 9(1), 74-98.
Paagman, A., Tate, M., Furtmueller, E., & de Bloom, J. (2015). An integrative literature review and empirical validation of motives for introducing shared services in government organizations. *International Journal of Information Management,* 35(1), 110-123.
Su, N., Akkiraju, R., Nayak, N., & Goodwin, R. (2009). Shared services Transformation: Conceptualization and valuation from the perspective of real options. Decision Sciences, 40(3), 381-402.
Ulrich, D. (1995). Shared Services: From Vogue to Value. *Human Resource Planning,* 18(3), 12-23.
Wang, S., & Wang, H. (2007). Shared services beyond sourcing the back offices: Organizational design. Human Systems Management, 26(4), 281-290.
Yin, R. K. (2009). Case study Research: Design and Methods: Design and methods. SAGE Publications.

ACTIVITY-BASED COSTING FOR INTRA-HOSPITAL TRANSFER

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Abstract

Purpose: This research aims to examine the activity-based cost and evaluate the feasibility of outsourcing the intra-hospital transfer system at Nakornping Hospital, Chiang Mai.

Design/methodology/approach: The research commenced by studying and collecting data on the existing procedures. Idef0 was used to present a series of functions related to intra-hospital transfer activities together with data and objects that interrelate those functions. This involved observing the activities of the intra-hospital transfer staff from start to finish, accurately timing each activity. Additionally, wages of the intra-hospital transfer staff were obtained to facilitate calculations based on the principles of activity-based costing analysis.

Findings: The study showed that activities of intra-hospital transfer system can be grouped into three phases: pre-transfer, during-transfer, and post-transfer activities. The results revealed that the activity-based costing of intra-hospital transfer is higher than the budget allocated.

Originality/value: Currently, Nakornping Hospital lacks cost information related to the intra-hospital transfer system services, and there has been no analysis conducted on the cost-effectiveness of outsourcing this transport systems. Hospital administrators of the inpatient ward can use the results of this study as a guideline for planning appropriate intra-hospital transfer service activities.

Keywords: Activity-Based Costing, Intra-Hospital Transfer, Idef0, Outsourcing

Introduction

The Intra-hospital transfer department is responsible for the care and assistance of patients within the hospital. This includes using wheelchairs or specialized transfer equipment to help patients enter and exit vehicles, as well as facilitating patient movement between different departments. Additionally, they are tasked with maintaining and ensuring the availability of necessary devices, tools, and equipment for their work. Intra-hospital transfer workers rely on their expertise, skills, and knowledge to ensure accurate, swift, and safe patient transfers. Teamwork and a well-maintained inventory of transportation equipment are essential components of their operations.

Nakornping Hospital has undergone a transformation, evolving from a general hospital into a comprehensive medical center that supports patient referrals from Chiang Mai, Lamphun, and Mae Hong Son. The hospital has also developed into a specialized trauma center, equipped to deliver emergency care services. It boasts expertise in brain surgery and cardiovascular care, with capabilities in surgical procedures and cardiac catheterization. The hospital's neonatal care unit is a hub for critical care for newborns, and it excels as a center for cancer treatment. These service centers are primarily centered

around the surgical department or operating room. Given its critical nature, the operating department requires meticulous attention to safety and precision to ensure that patients recover quickly and without complications.

Recognizing the pivotal role played by the surgery department in patient outcomes, Nakornping Hospital has opted to engage an outsourced Intra-hospital transfer team, specifically dedicated to the surgery department. This strategic move is aimed at reducing the time and distance involved in patient transfers. While other hospital departments utilize the hospital's own Intra-hospital transfer staff, the surgery department necessitates a specialized team. The outsourcing of the Intra-hospital transfer system requires two teams: Intime (Monday to Friday) with 12 personnel, and Out time (Saturday to Sunday) with 6 personnel. This results in an annual total cost of 1,915,000 baht.

However, Nakornping Hospital has never previously considered the activity-based cost of the Intra-hospital transfer workers within the surgery department, nor has it conducted an analysis on the cost-effectiveness of outsourcing the Intra-hospital transfer system. Consequently, a service cost analysis of the surgery department's Intra-hospital transfer employees is imperative. This research utilizes Activity-Based Costing to scrutinize the feasibility of outsourcing the Intra-hospital transfer work system, ultimately determining whether Nakornping Hospital should continue to do so.

Research Concept

This research employs the activity-based costing concept, which represents a contemporary approach to cost management. Its primary objective is to steer executives towards concentrating on activities and their associated costs. Consequently, it entails categorizing costs into various activities, with each activity being regarded as the root cause of a specific cost related to a product. Activities are actions that transform an entity's resources into products. Therefore, in activity-based cost accounting, the emphasis is not only on identifying these activities but also on determining their respective costs. This information serves as a basis for calculating product costs and provides a framework for enhancing operational efficiency.

After the observation, it became evident that the cost structure of the Intra-hospital transfer system can be segmented into labor and material costs. Furthermore, the key activities were categorized into three distinct phases: pre-transfer, during-transfer, and post-transfer. The driving factors for costs were found to be material consumption and the time allocated to each employee's activities. This segmentation allows for the calculation of labor and consumables costs. For further details, please refer to Figure 1.

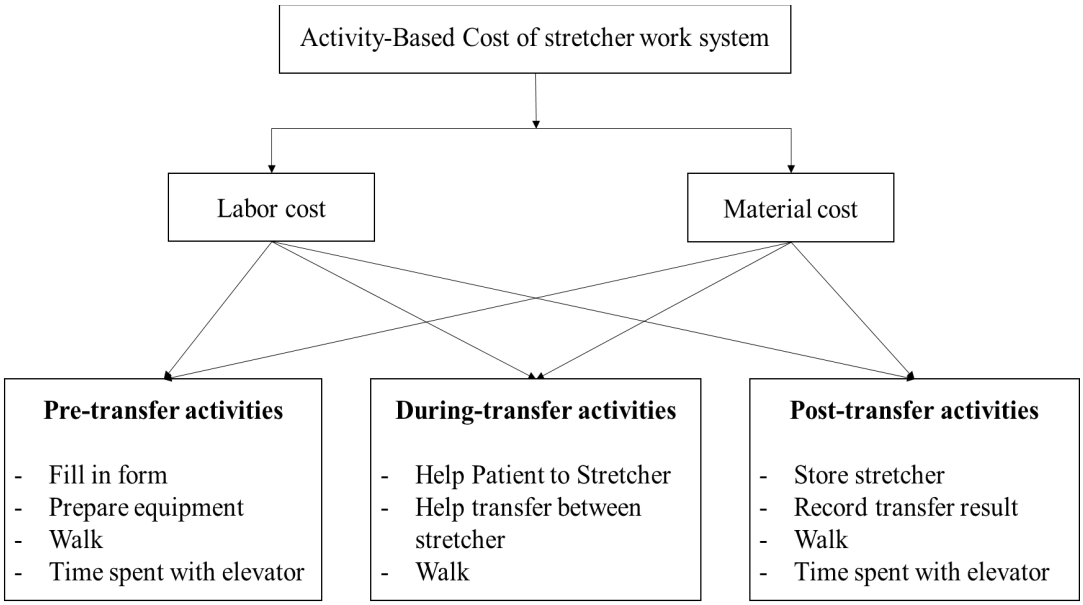

Figure 1 Conceptual of activity costs for intra-hospital transfer system.

Idef0 for Intra-Hospital Transfer

This study uses a descriptive approach to examine the cost activities associated with both the primary Intra-hospital transfer work system and the outsourced Intra-hospital transfer work system within the operating department. It employs the conceptual framework of activity-based cost accounting. The monitoring process involves observing Intra-hospital transfer workers in both departments from initiation to completion, disaggregating activities into subtasks. Subsequently, time data is collected through precise timekeeping, commencing at the start and concluding at the end of each task. This temporal data can be further classified into three phases: pre-transfer, during-transfer, and post-transfer. Post-monitoring, activities observed in the Intra-hospital transfer worker are segregated and input into a tool known as Integration Definition Function Modeling (IDEF0). This step aims to elucidate the interrelationships between the various activities. Figure 2 displays the pre-transfer activities carried out by the outsourced Intra-hospital transfer workers in the operating department while figure 3 illustrates the pre-transfer activities of the internal Intra-hospital transfer work system. The operational timing of Intra-hospital transfer staff then is executed from initiation to completion using a cumulative timing method. This entails the continuous recording of time, which starts with the first sub-activity and continues uninterrupted until the entire activity is concluded. At the conclusion of each sub-activity, the time is recorded. The duration of each sub-activity is determined by calculating the time difference after the timer has concluded. Therefore, the activity costs of intra-hospital transfer can be estimated shown in the following section.

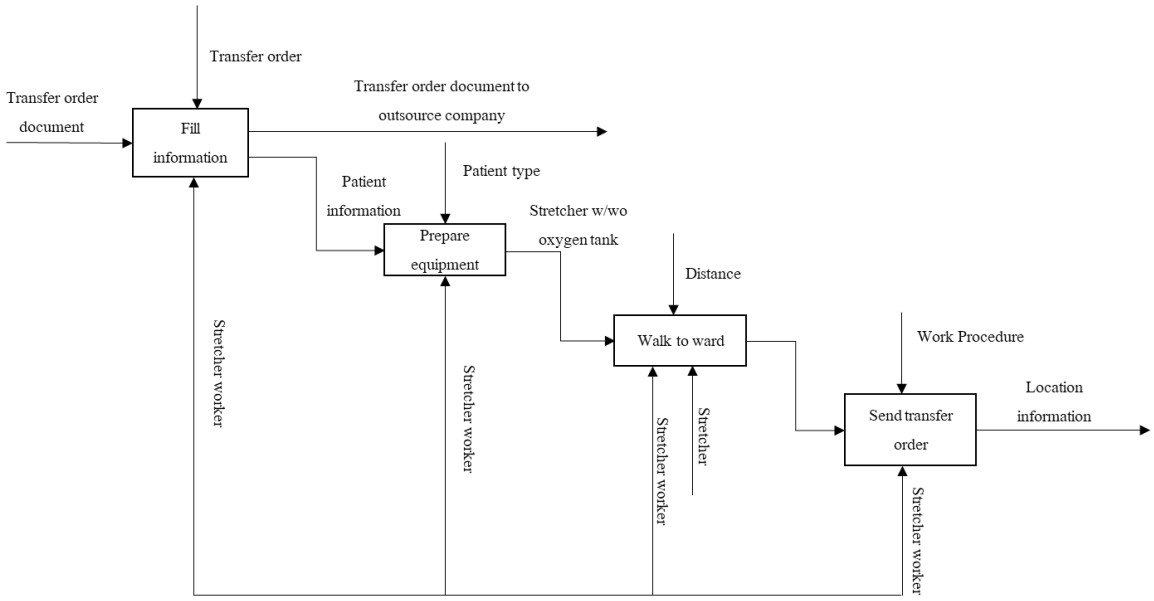

Figure 2 The pre-transferred of the outsource Intra-hospital transfer system.

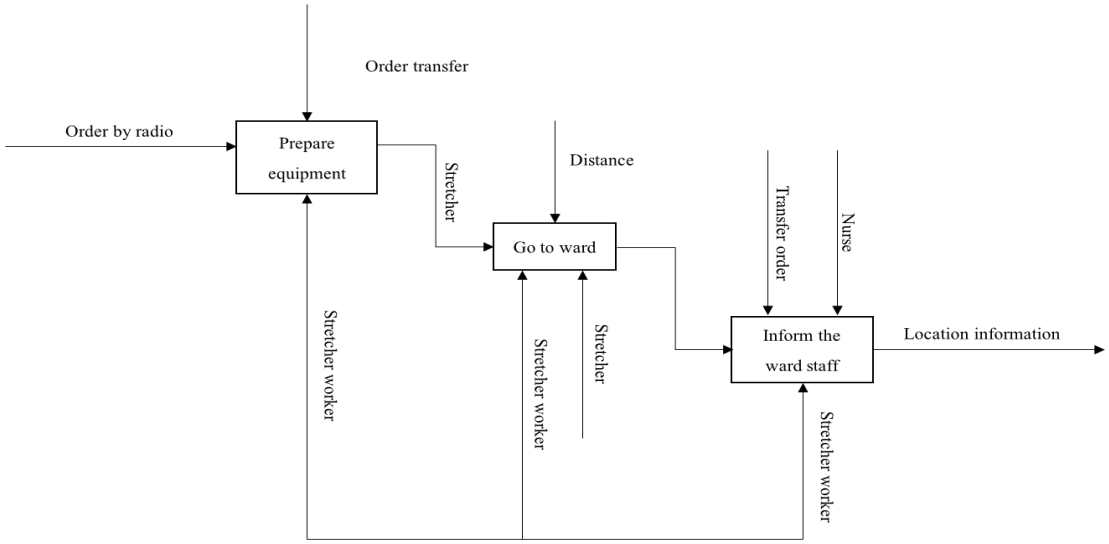

Figure 3 The pre-transferred of the inner Intra-hospital transfer system.

Activity-Based Costing

1. Labor cost

1.1 The cost of activities related to Intra-hospital transfer personnel is derived from the total labor expenses, encompassing pre-tax wages. This allows us to compute the average cost per person per minute. The data collected over a span of two months is presented in equation 1.

$$average\ wages\ of\ person\ per\ minute = \frac{wages\ of\ each\ employee}{minute\ of\ work} \quad (1)$$

1.2 Multiplying the average cost per person per minute by the duration of each activity yields the corresponding wages for each activity, as demonstrated in equation 2.

$$wages\ in\ each\ activity = average\ wages\ per\ minute \times time\ spent\ in\ each\ activity \quad (2)$$

1.3 Determining the average wages for each activity involves dividing the total wages for a specific activity by the number of work instances, as outlined in equation 3.

$$average\ wages\ in\ each\ activity = \frac{wages\ in\ each\ activity}{number\ of\ times\ of\ work} \quad (3)$$

2. Material Cost

Material costs are evaluated by utilizing the expenses associated with supplies and equipment to ascertain the average depreciation for each Intra-hospital transfer activity. The straight-line depreciation method, illustrated in equation 4, is employed for this computation.

$$depreciation = \frac{cost\ of\ supplies\ and\ equipment}{lifetime\ used} \quad (4)$$

Results and Discussions

The cost study of two Intra-hospital transfer systems, namely the outsourced Intra-hospital transfer system and the in-house Intra-hospital transfer system, revealed a total cost differential of 288.72 baht. The inner Intra-hospital transfer system incurred a total cost of 28,029.57 baht with a cost per activity of 11.69 baht, while the outsourced system had a total cost of 27,740.85 baht and a cost per activity of 13.90 baht. Further details are outlined in Table 1.

However, it was determined that opting for the outsourced Intra-hospital transfer system may not be cost-effective. In the event of a 20% increase in activities within the operating department, the total cost would equal that of the inner Intra-hospital transfer system. Nevertheless, the disparity in the number of activities would be a substantial 401-fold.

Alternatively, if the hospital were to reassign the inner Intra-hospital transfer staff to the operating department while maintaining their current salary rates, a reduction in total costs by 9.45% would be achieved. This adjustment would also lead to a decreased cost per activity, down to 12.58 baht, as demonstrated in Table 2.

Table 1 the study result of the activity cost for the intra-hospital transfer system

Department	Total cost (Baht)	Cost per activity (Baht)	Number of activities (Times)
Outsource	27,740.85	13.90	1,996
In-house	28,029.57	11.69	2,397

Table 2 The calculation of cost of outsource Intra-hospital transfer by using the salary rate of inner Intra-hospital transfer staff.

Activities	Time per activity (Minuite)	Total Time (minuite)	Labor cost (baht)	Equipment cost (baht)	Total cost (baht)	Fequency of Activities (times)	Cost per Activity (baht per activity)
Fill in form	2.61	5,212.86	3,529.54	-	3,529.54	1,996	1.77
Prepare Equipment	0.63	1,266.97	857.85	129.32	987.17	1,996	0.49
Help patient to stretcher	2.02	4,034.23	2,731.51	411.79	3,143.29	1,996	1.57
Hand in the orderd sheet	0.14	283.52	191.97	-	191.97	1,996	0.10
Help transfer	0.85	1,687.17	1,142.36	172.22	1,314.57	1,996	0.66
Store the stretcher	0.56	1,114.28	754.46	113.74	868.20	1,996	0.43
Record the result	0.22	437.99	296.56	-	296.56	1,996	0.15
Walk	5.02	10,029.23	6,790.63	989.83	7,780.45	1,996	3.90
Time spent with elevator	4.25	8,483.00	5,743.70	1,263.29	7,006.99	1,996	3.51
Total	16.31	32,549.26	22,038.56	3,080.18	25,118.75		12.58

In the study, it was observed that the outsourced Intra-hospital transfer work system comprises three distinct service phases. Notably, the Pre-transfer phase incurred the highest cost, totaling 5,522.59 baht. Within this phase, labor costs, case taking, and form filing accounted for most expenses, summing up to 4,442.78 baht. In contrast, the post-transfer phase exhibited the lowest cost, amounting to 1,322.95 baht. Here, the primary cost-driving activity was the storage of Intra-hospital transfers, costing 949.67 baht. Furthermore, activities unrelated to the core functions, with walking being the costliest at 8,547.64 baht. The study also examined the In-house Intra-hospital transfer team's service activities, which were divided into three phases. The During-transfer phase emerged as the most expensive, totaling 9,862.61 baht. Within this phase, assisting patients with Intra-hospital transfers incurred the highest cost, amounting to 5,460.91 baht. Conversely, the Post-transfer phase exhibited the lowest cost at 471.61 baht, which included labor costs of 434.96 baht and equipment expenses of 36.66 baht for its sole sub-activity.

References

[1] Karakate Keereruk, Phechnoy Singchungchai and Narumon Pathumarak *Nursing Activity Costing Analysis of Cesarean Section Management in a Private Hospital*, Nursing Journal volume 47 No.2 April-June 2020.
[2] Wilai Channaem *Activity-Based Costing Analysis for Patients at the Eye Clinic of Outpatient Department, Hatyai Hospital,Songkhla Province.*
[3] Nettaya Wirotwanit, Renukar Thongkhamrod and Poonsuk Hingkanont *Cost Analysis of Nursing Service Activities in Emergency Department Naresuan University Hospital*, Journal of Nursing and Health Sciences Vol.8 No.3 (Supplement) September-December 2014.
[4] Vilawan Tipmongkol and Nongyao Puriwattanakul *Cost Analysis of Nursing Service Activities and Time Service for ALC Reconstruction Patients in the Male Orthopedic Surgical Ward of Songklanagarind Hospital*, Journal of Health and Health Management Vol.2 No.2 May-August 2015.
[5] Sirorat Phuetsaka *Cost Analysis of Distribution System for consideration of Outsource Service*, Chulalongkorn University 2007.
[6] Boonruen Chaichana *Cost Analysis of Nursing Service Activity Based on Activity-Based Costing system: In Patient Units.*

AI IMPLEMENTATION IN INNOVATION PROCESSES: AN UNCERTAINTY PERSPECTIVE

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ABSTRACT

Purpose: AI applications are increasing in accuracy and effectiveness, and simultaneously gaining more popularity internationally. While consumers online have historically been the main target market for businesses, AI may have several uses, including decreasing company risks, streamlining HR tasks, and anticipating cash flow and other functions in supply chains. The potential advantages of AI have been recognized and used, particularly in larger companies with plenty of resources. Its application to supply chains, however, is still in its early stages.
Design/methodology/approach: Drawing upon existing literature, this research presents a comprehensive framework that empowers supply chains to seamlessly integrate AI at various levels of the product innovation process, enabling them to stay competitive and overcome uncertainties associated with introducing innovative products.
Findings: The proposed framework provides valuable guidance for organizations in supply chains, fostering efficient and effective utilization of AI in their quest for introducing cutting-edge products. Managers need to develop an understanding of utilizing different AI functions effectively for innovative products, reducing uncertainty during this process and gaining competitive advantage at the same time.
Originality/value: For supply chains the use of AI can bring considerable opportunities as the technological and green transfer challenge them decision loaded with complexity and uncertainty in supply chains. The paper aims to integrate different functions of artificial intelligence, information acquisition, divergent data processing, and usage of neural networks, at the different levels of innovation process stages to reduce uncertainty and to facilitate networked designing of innovative products meeting the modern-day business environment requirements.

Keywords: AI Integration, Innovation process, Conceptual framework, Uncertainty, Supply Chain

Introduction

Innovation processes are seen as one of the main sources of competitiveness for many organizations. While the processes have the possibility to offer great opportunities of value for the organizations, those can be costly and time-consuming effort with high uncertainty involved. Many different models for managing innovation processes have been proposed in the previous literature, however only a few of those focus on the uncertainty in the process and how it could be managed. Indeed, managing uncertainty can be crucial point for companies in order to ensure successful results from the different stages of the innovation process.

Artificial intelligence (AI) model like ChatGPT, that relies on deep learning techniques to make use of the enormous amount of data for producing text responses, has triggered a debate regarding its effective utilization for different domains of businesses (Wenzlaff and Spaeth, 2022) and particularly innovation management (Bahoo et al., 2023; Bouschery et al., 2023). In this regard, researchers have argued that artificial intelligence can rationalize arbitrary and chaotic innovation processes by reducing confusion and

random behavior in decision-making (Pietronudo et al., 2022) to generate novel ideas for exploration (Haefner et al., 2021). Most of the existing literature on artificial intelligence and innovation is restricted to analyzing artificial intelligence influence on innovation process or different types of innovation, however, the

question remains how AI could influence innovation management processes along dealing with different types of uncertainty.

Uncertainty in the innovation processes is caused by a number of things and the sources typically are numerous challenging the decision-makers abilities to make the best choices (Vilko et al., 2014). While the product cycles in the marketplace are getting shorter and products and services increasingly complex, the solutions related have become more complex to manage and inherently more uncertain with their outcomes (Dost et al., 2016). This can be especially challenging for small and medium sized enterprises with limited resources and capabilities. Simultaneously, the new technological innovations such as AI have been seen as an answer as an efficient way to help in managing the innovation processes by offering access and ability to structure vast information and even providing solution options to some complex problems (Haefner et al., 2021). Indeed, as a new relatively new service the AI has gained much popularity especially with the newly invented language-model based solutions like Chat-GPT, which has enabled the accessibility and easiness- of-use of the software. Furthermore, researchers have reported that adoption of AI technology can improve corporate business model innovation, product innovation, process innovation, social innovation, and other innovation outcomes(Bahoo et al., 2023; Mariani and Nambisan, 2021).

Clearly, AI can provide benefits for the innovation process, however as a new phenomenon the full potential of it, is still somewhat unclear. In order to shed some light to this issue we put forward a conceptual model of how a language-based AI model could be applied in the innovation process to manage uncertainty. In doing this, the paper synthesizes innovation process management and uncertainty theories with AI literature. As a result, aim of the paper is to provide understanding how AI can assist innovation process dealing with different levels of uncertainty and different amounts of information. More precisely, our contribution is in putting forward a conceptual framework and furthermore to instigate scientific discussion about the role of AI in the innovation process from the perspective of two essential elements, namely the amount of data available and the level of uncertainty related.

Theoretical foundation

The theoretical foundation of the paper is based on three different scientific literatures. Firstly, the innovation literature, where we are focusing on the process of innovation management. Secondly, AI literature where we focus on its implementation in innovations and finally to the supply chain uncertainty literature where we focus on the different natures of uncertainty and decision-making.

Innovation process

Understanding of the innovative process has been changing through the years with the development of new technologies (Žižlavský, 2013). Scholars divide this process into a minimum of three stages. For example, some scholars have included 1) searching, 2) selecting, 3) implementing and 4) learning (Tidd and Bessant, 2020) while other scholars have identified five stages: 1) idea generation and mobilization, 2) advocacy and screening, 3) experimentation, 4) commercialization, and 5) diffusion and implementation (Mariello, 2007). In frames of this study the next stages of the innovation process will be considered: 1) new idea generation and discovery, 2) idea screening, 3) concept experimentation, and 4) idea development and monetization (Truong and Papagiannidis, 2022). The innovation process model is not linear and is presented in the Figure 1 below.

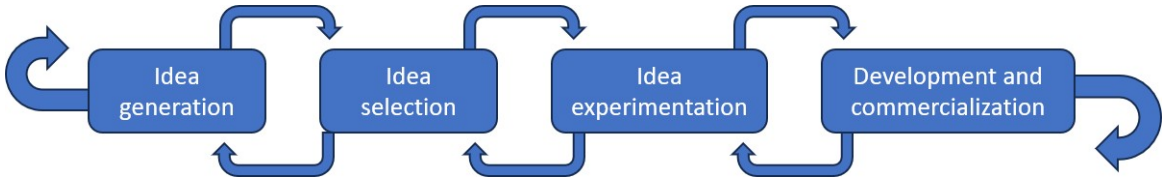

Figure 1: A four-step innovation process

1) New idea generation and discovery is the start of the innovation process for development of new products, services, and business models. This stage includes identification of existing unsolved

problems demanding novel solutions and application of various techniques (e.g., brainstorming, creative and or design thinking, complex opportunity recognition) (Truong and Papagiannidis, 2022).

2) Idea selection stage focuses on screening of ideas, identification of the most innovative ones for further development (Truong and Papagiannidis, 2022). It involves evaluation of ideas, identification and measuring benefits and threats. At this stage it is essential to develop a strategy and criteria for transparent evaluation of ideas (Truong and Papagiannidis, 2022).
3) Idea experimentation is a core phase of innovation process (Thomke, 2001). This involves testing ideas in the exact setting and time, and in many cases involving customers on this stage is essential (Mariello, 2007; Truong and Papagiannidis, 2022). Systematic experiments assist in refinement of ideas and creation of new products or solutions. Accepted by target groups, innovations are taken to the next stage. In addition, the application of certain technologies leads to more efficient experiments or even to the discovery of new possibilities and new products and solutions (Thomke, 2001).
4) Development and commercialization embrace further development of a validated idea into the product or service and bringing it to the market (Truong and Papagiannidis, 2022). The inherent part of this stage is marketing activities and preparing customers for the launch of innovative products or services (Eveleens, 2010). Some scholars follow approaches considering post-launch stages focused on support of innovation, re-innovation and scaling.

AI implementation in innovation

Artificial intelligence (AI) can be defined as the system's capacity for data interpretation and makes use of computers and other devices to improve personal capacity for decision-making, problem-solving, and innovation (Bahoo et al., 2023). Due to AI's capacity to foster creativity, existing literature has just lately begun to focus on understanding how AI may enhance innovation management procedures (Bahoo et al., 2023; Haefner et al., 2021; Truong and Papagiannidis, 2022). By encouraging creative and unconventional thinking, AI can be said to play a substantial part in the invention process (Martin and Wilson, 2016). AI has a substantial impact on the innovation process, because of corporate digital transformation, automated services, e-commerce, and technology adoption (Bahoo et al., 2023; Haefner et al., 2021).

Additionally, the stage of business innovation known as idea generation benefits greatly from information processing and the use of data sources (Nelson, 1985). Without technology, managers might have trouble collecting and analyzing the data they need to find new opportunities or resolve issues for their businesses (Bahoo et al., 2023; Williams and Mitchell, 2004). Thus, the organization has adopted and implemented general-purpose AI-based technologies because humans are unable to process enormous amounts of data. Therefore, idea creation strategies and research methodologies for organizations in supply chains are transformed by AI technology (David, 1990).

Moreover, due to human limitations, managers' knowledge built on their learning is constrained; consequently, the prospects and answers they discover resulted in incremental innovation (Bahoo et al., 2023; Gavetti and Levinthal, 2000). Managers use advanced AI-based technologies like machine learning, which broaden their current knowledge domain to form a new field, to develop competence in radical innovation (Bahoo et al., 2023; Posen et al., 2018). The managers must also assess and put into action the best opportunity or problem-solving strategy. A business normally cannot generate a valuable incrementally creative offering or alternative without implementing AI-based technologies. Adopting AI-based technology will thereby increase the success of the evaluation and implementation (Bahoo et al., 2023; Bresnahan and Trajtenberg, 1995).

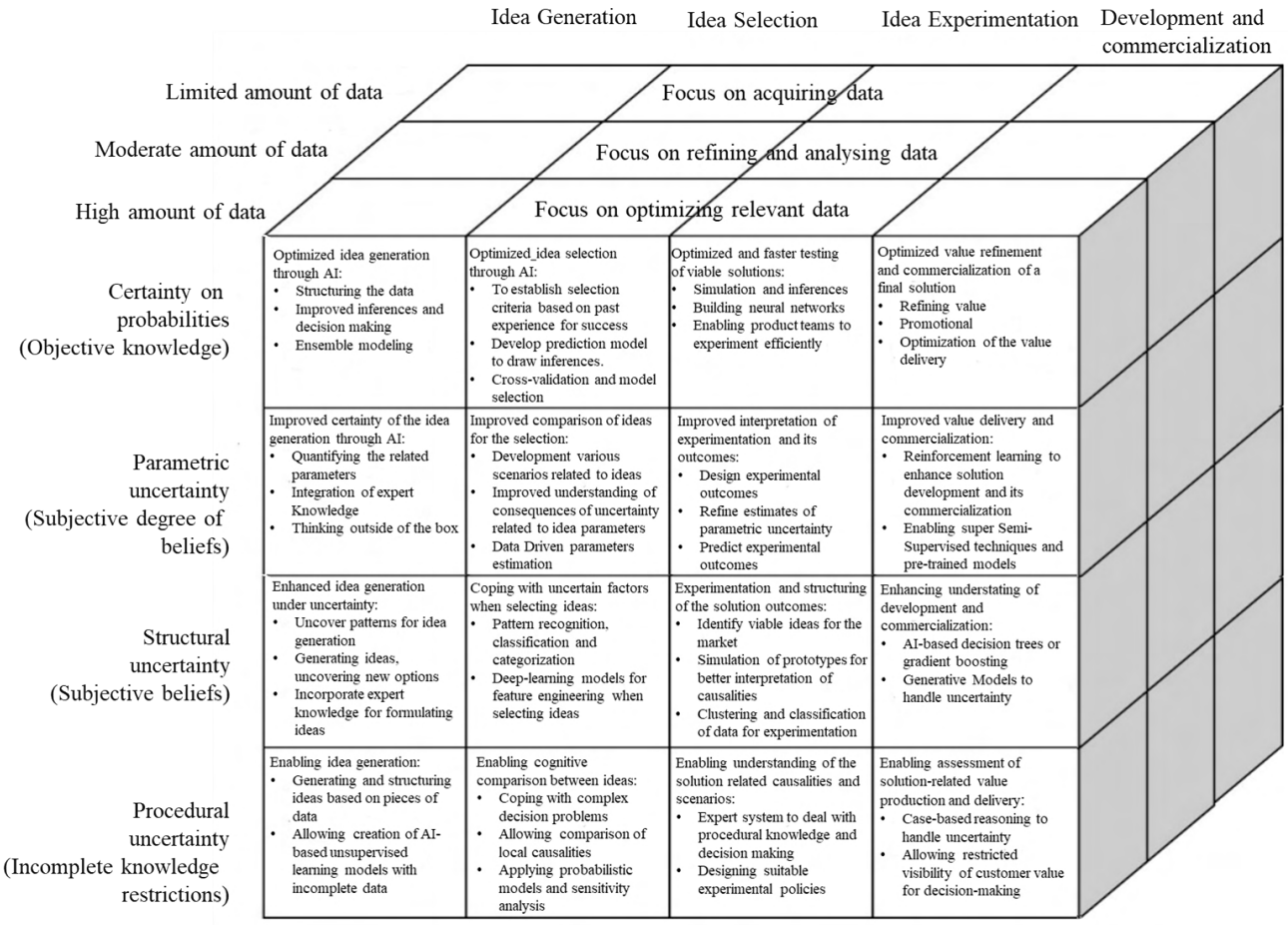

Figure 2: Proposed conceptual framework integrating AI for managing uncertainty in innovation process

Uncertainty in innovation

The uncertainty theory is based mostly on Knight's (1921) theories of certainty, risk and uncertainty, where the main distinctive feature of uncertainty is described to be unmeasurable concept (Knight, 1921) meaning that it can't be calculated. The uncertainty related to the innovation process can be considered to derive from within the innovation system or outside of the system (Bergek et al., 2010). One of the ways to classify uncertainty is by distinguishing it to three different types, namely parametric, structural and procedural depending on the level of information is available from the environment and on the decision-makers cognitive decision-making abilities (Dosi and Egidi, 1991; Langlois, 1983; Vilko et al., 2014).
The uncertainty related to innovations has been discussed in innovation literature by several authors (Freel, 2005; Jalonen, 2012). Overall, eight different types of uncertainty can be distinguished in the literature (Jalonen, 2012): 1) technological uncertainty, 2) market uncertainty, 3) regulatory/institutional uncertainty, 4) social/political uncertainty, 5) acceptance/legitimacy uncertainty, 6) managerial uncertainty, 7) timing uncertainty, and 8) consequence uncertainty

While the types are essential in determining the source of uncertainty, the level and how uncertainty could be managed in different levels is typically neglected. Therefore, the aim in this paper is in the management of different levels of uncertainty in the innovation process.

Conceptualizing AI-integrated uncertainty management in innovation processes

Innovation management by nature is proactive by nature and always includes 'unknown' uncertainties in it. However, in many ways it is necessary to manage the different uncertainties related to the innovation process for the decision-maker to handle. By introducing AI into the process, some of the limitations of the decision maker can be overcome which can give improve the success rates of the process. in Figure 2 we illustrate a proposed conceptual model of an AI-integrated innovation process uncertainty management cube. The process is divided into a four-step innovation process as can be noticed from above the cube. The upper left side of the cube determines the amount of data available for the process and the focus in management in different levels. Thereafter the left side of the cube illustrates the different levels of uncertainty ranging from certainty on probabilities (where there is certainty about the probability and impact of different events in the innovation process) which can be calculated and optimized using AI. The second level refers to parametric uncertainty, where the decision maker has only degree of subjective beliefs about the probability of the events (structure of future is known, parameters are uncertain), where AI can improve the process and related certainties of the parameters. Third level indicates structural uncertainty, where the structure of the future is not clear and the decision maker struggles in forming a clear picture of all the up-coming events, their causalities and impacts. In here, the role of AI is in building the bigger picture and helping in forming understanding about the causalities. Finally, the procedural level refers to the situation where only bits and pieces of the future are known, and the cognitive abilities of the decision maker do not allow proper decisions to be formed. In here, the role of AI is to help to form partial cause-and-effect relations and to help decision-makers to structure the relations between data bits to enable at least partial understanding of the innovation process.

Discussion and implications

The use of AI has become a increasingly popular both in scientific and managerial literature. While the utilization and different applications of the large-scale language-based models is becoming more common in different solutions, the scientific literature about the integration of AI to the organizational innovation processes is still in its infancy. This paper proposes a three-dimensional theoretical framework to conceptualize the use of AI in managing the uncertainty related to the different stages of innovation process. The framework enhances the understanding of the integration possibilities and the role of AI in different situations, namely with different levels of uncertainty and different amounts of data available. While synthesizing different theories we provide a detailed categorization and suggestions how to apply AI in the different situations which enables more effective.

Scientific implications

This research responds to recent calls for more research on the application of artificial intelligence (AI) to innovation contexts (e.g., Cockburn et al., 2019) and dealing with uncertainty at the same time during these stages. Responding to this, we have developed a practical framework that is useful for scholars in innovation research given the rapid development of digital technologies (AI in particular) and related innovation management practice and have contributed to ongoing debate on AI utilization for innovation management (Bahoo et al., 2023; Haefner et al., 2021).

Practical implications

The framework offers fresh perspectives and may help managers deal with the uncertainty that arises during the various stages of innovation processes and may obstruct the successful launch of innovative products. In particular, managers' thorough understanding of AI's implications for innovation processes and various levels of uncertainty that exist during these stages could lead to effective utilization of resources (financial and intellectual) for innovation. Furthermore, utilizing the AI Innovation-uncertainty framework introduced in this research, managers and decision makers can further assess the best alternatives to launch incremental and radical products based on customer requirements and avoid unwanted results.

Future research directions

We recommend future scholars to test proposed AI innovation-uncertainty framework in the real-world innovation processes context to produce replicable findings. Additionally, scholars can test the proposed framework for developing various types of innovations across different organizational settings. Scholars can also develop different types of scales for proposed models to test it quantitatively and can also rely on qualitative research design to contribute to this debate on AI-utilization in innovation context.

References

Bahoo S, Cucculelli M and Qamar D (2023) Artificial intelligence and corporate innovation: A review and research agenda. Technological Forecasting and Social Change 188. Elsevier: 122264.

Bergek A, Jacobsson S, Hekkert M, et al. (2010) Functionality of innovation systems as a rationale for and guide to innovation policy. In: The Theory and Practice of Innovation Policy. Edward Elgar Publishing.

Bouschery SG, Blazevic V and Piller FT (2023) Augmenting Human Innovation Teams with Artificial Intelligence: Exploring Transformer-Based Language Models. Journal of Product Innovation Management. Wiley Online Library. Epub ahead of print 2023.

Bresnahan TF and Trajtenberg M (1995) General purpose technologies 'Engines of growth'? Journal of econometrics 65(1). Elsevier: 83–108.

David PA (1990) The dynamo and the computer: an historical perspective on the modern productivity paradox. The American Economic Review 80(2). JSTOR: 355–361.

Dosi G and Egidi M (1991) Substantive and procedural uncertainty: an exploration of economic behaviours in changing environments. Journal of evolutionary economics 1. Springer: 145–168.

Dost M, Badir YF, Ali Z, et al. (2016) The impact of intellectual capital on innovation generation and adoption. Journal of Intellectual Capital. Emerald Group Publishing Limited. Epub ahead of print 2016.

Eveleens C (2010) Innovation management; a literature review of innovation process models and their implications. Science 800(2010): 900.

Freel MS (2005) Perceived environmental uncertainty and innovation in small firms. Small business economics 25. Springer: 49–64.

Gavetti G and Levinthal D (2000) Looking forward and looking backward: Cognitive and experiential search. Administrative science quarterly 45(1). SAGE Publications Sage CA: Los Angeles, CA: 113–137.

Haefner N, Wincent J, Parida V, et al. (2021) Artificial intelligence and innovation management: A review, framework, and research agenda☆. Technological Forecasting and Social Change 162. Elsevier: 120392.

Jalonen H (2012) The uncertainty of innovation: a systematic review of the literature. Journal of management research 4(1): 1–47.

Knight FH (1921) Risk, Uncertainty and Profit. Houghton Mifflin.

Langlois RN (1983) Internal Organization in a Dynamic Context: Some Theoretical Considerations. CV Starr Center for Applied Economics, New York University, Faculty of Arts ….

Mariani MM and Nambisan S (2021) Innovation analytics and digital innovation experimentation: the rise of research-driven online review platforms. Technological Forecasting and Social Change 172. Elsevier: 121009.

Mariello A (2007) The five stages of successful innovation. MIT Sloan management review 48(3). Massachusetts Institute of Technology, Cambridge, MA: 8.

Martin L and Wilson N (2016) Opportunity, discovery and creativity: A critical realist perspective. International Small Business Journal 34(3). Sage Publications Sage UK: London, England: 261–275.

Nelson RR (1985) An Evolutionary Theory of Economic Change. harvard university press.

Pietronudo MC, Croidieu G and Schiavone F (2022) A solution looking for problems? A systematic literature review of the rationalizing influence of artificial intelligence on decision-making in innovation management. Technological Forecasting and Social Change 182. Elsevier: 121828.

Posen HE, Keil T, Kim S, et al. (2018) Renewing research on problemistic search—A review and research agenda. Academy of Management Annals 12(1). Briarcliff Manor, NY: 208–251.

Thomke S (2001) Enlightened experimentation. The new imperative for innovation. Harvard business review 79(2): 66–75.
Tidd J and Bessant JR (2020) Managing Innovation: Integrating Technological, Market and Organizational Change. John Wiley & Sons.
Truong Y and Papagiannidis S (2022) Artificial intelligence as an enabler for innovation: A review and future research agenda. Technological Forecasting and Social Change 183. Elsevier: 121852.
Vilko J, Ritala P and Edelmann J (2014) On uncertainty in supply chain risk management. The International Journal of Logistics Management. Emerald Group Publishing Limited. Epub ahead of print 2014.
Wenzlaff K and Spaeth S (2022) Smarter than Humans? Validating how OpenAI's ChatGPT model explains Crowdfunding, Alternative Finance and Community Finance. Validating how OpenAI's ChatGPT model explains Crowdfunding, Alternative Finance and Community Finance.(December 22, 2022). Epub ahead of print 2022.
Williams C and Mitchell W (2004) Focusing firm evolution: The impact of information infrastructure on market entry by US telecommunications companies, 1984–1998. Management Science 50(11). INFORMS: 1561–1575.
Žižlavský O (2013) Past, present and future of the innovation process. International Journal of Engineering Business Management 5. SAGE Publications Sage UK: London, England: 47.

ALGORITHM FOR OPTIMIZING TRUCK UTILIZATION USING RESIDUAL CAPACITIES

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ABSTRACT

Purpose: Average truck utilization is only 50-55 percent based on distance travelled. Furthermore, 25 percent of current truck trips are empty runs. These facts lead to increased emissions, more traffic and a waste of time and financial resources. The aim of this paper is to develop an algorithm for logistics service providers to optimize truck capacity utilization and to increase supply chain resilience by identifying, visualizing, and optimizing routes with available residual capacity.
Design/methodology/approach: The development is focused on a logic able to identify tours from a transport network, in which open transport orders can be integrated optimally. Available residual capacities in trucks are calculated based on master data, initial loaded and already delivered orders. Additionally, the distances between the stations of the initial tours and the pick-up/delivery point of the open transport order are calculated and integrated optimally into the existing tours to minimize the total distances travelled and maximize the truck utilization.
Findings: The developed optimization algorithm creates transparency and resilience in supply chain networks by merging customer and freight forwarding data in real time. This results in an integrated route optimization that allocates residual capacities of currently executed truck transports with suitable open transport orders to avoid empty runs and increase truck utilization.
Research limitations/implications (if applicable): Future research includes integrating real-time data sources into the algorithm to make prescriptive decisions. In addition, a suitable decision support system for truck dispatching is to be developed.
Practical implications (if applicable): The algorithm is evaluated by applying it to the transport network of a freight forwarder. It is shown that a significant contribution to the optimization of truck utilization can be made.
Originality/value: The novelty of this contribution is that the developed algorithm combines already running and distributed trucks and their real-time utilization with open transport orders, thereby making optimal use of residual capacities of the already running trucks.

Keywords: residual capacities, truck utilization, optimization algorithm, forwarder

Introduction

In recent years, companies in various industries have tried to cut costs by steadily reducing their storage capacity and relying on short-term deliveries. Therefore, the risk of supply chain ruptures increased. To counteract this, transport logistics and the associated planning of logistical distribution systems have moved into the centre of attention in supply chain planning again (Meier and Portmann, 2016; ten Hompel et al., 2020). With the increasing digitalization of modern logistics chains, the planning systems used to operational planning and scheduling are becoming more information-intensive and technology dependent. Depending on the scenario, companies need high transparency of deliveries for making decisions on short-term to increase the quality of their service level and reduce overall process costs. For this purpose, they are introducing supply chain event management (SCEM) systems (Heinbach et al., 2020; Feng et al., 2017). For these systems to work, the exchange of information between forwarders and shippers is a crucial factor. The current problem is that there are no harmonised interfaces and communication standards that shippers can use to transmit transport orders to their forwarder's dispatching system at short notice. As a result, the potential of data-driven value creation along the supply chain is not used comprehensively and forwarders have to use different systems, interfaces, and databases. In addition to the lack of linkage between existing

systems, the lack of process documentation and the insufficient transparency of the transport chain pose further problems. This is intensified by the fact that participating transport companies often do not want to make confidential and internal company data available. As a result, there is no or only weakly developed cooperation between forwarders and shippers, which is necessary for optimal utilization of transport capacities (Heinbach et al., 2020; Gansterer et al., 2020).

The resulting consequences are an average utilization of loaded trucks of only about 50 to 55 percent. Furthermore, 25 percent of the distance driven is made as empty runs. (Daudi and Thoben, 2020) This increases truck emissions, wasting time and financial resources (Schlott, 2017). Efficiently utilizing transportation assets while ensuring supply chain resilience is further complicated by the following issues (Allaoui et al., 2019; He et al., 2019):

- The number of short-term delivery orders for general cargo is rising continuously. The capacity utilization of the means of transport used for these orders is lower than for long-term delivery orders (Grazia Speranza, 2018).
- Means of transport are limited in terms of maximum transport volume and maximum transport weight. Heavy transport goods often do not use the available space, and large-volume transport goods do not use the available maximum weight (Rizet et al., 2012).
- The ability of combining transports is often not given due to time discrepancies between the receipt of goods and the dispatch of goods, which leads to empty runs. Sustainable and efficient return transports are rare in current transport networks. (Schulte et al., 2017).

This paper aims to develop a concept for logistics service providers to optimize truck capacity utilization and increase supply chain resilience by identifying, visualizing, and optimizing routes with available residual capacity of already dispatched trucks. This concept is to contribute to increase the use of residual truck capacities and to optimize the dispatching process of forwarders regarding time resources. Furthermore, emissions are to be reduced by reducing empty runs. A visualization of the results in a dashboard will be developed to serve dispatchers as a qualitative decision-support tool.

The following structure is chosen in this paper. The following chapter provides an overview of intelligent transport windows and their contribution to improving cooperation in transport networks. Based on this, the development of the concept is done in the steps of data preparation, matching algorithm, tour optimization, and visualization. The validation of the results is carried out in a case study with an Austrian freight forwarder. Finally, the results are concluded, and an outlook for future research is given.

Collaboration through Smart Transport Windows

Due to the increasing pressure to act economically and ecologically, the need for efficient use of available transport capacities is steadily growing. This challenge is to be achieved through improved cooperation and the sharing of resources. An example of this kind of collaboration in logistics is a group of freight forwarders who exchange transport requests (Gansterer et al., 2020; Daudi and Thoben, 2020).

By collaborating and sharing resources, the goal is to reduce truck idle time, logistics costs, and harmful greenhouse gas emissions. In addition, the utilization of all logistics assets is to be improved. Freight forwarding cooperations are usually realized via online portals and auction-based bilateral exchange systems. Matching cargo information with truck information is the key to establishing logistics information-sharing platforms (Feng and Cheng, 2021; Gansterer et al., 2020; Daudi and Thoben, 2020). Smart transport windows represent one possibility for implementing this approach. With them internal and external data of the carriers are to be combined uniformly using a central cloud platform with a collaborative, data-driven transport management model (Heinbach et al., 2020).

In current smart transport windows, weaknesses like incomprehensive tour optimization appear. In most cases, there is no possibility to optimally integrate and visualize the loading and unloading locations of the cargo into existing transport tours (Wang et al., 2021). Selecting the best-fitting transport with the corresponding remaining capacities within a transport network to increase truck utilization is necessary (Park et al., 2021; Aloui et al., 2021).

Developed Concept

In order to close the research gap regarding the automatic dispatching of short-term transport orders in the current state of the art, this chapter describes a developed concept that optimally integrates short-term transport orders into already dispatched truck tours by using their residual capacities. To this end, the requirements for a successful tour allocation and optimization are first defined:

- **Dispatching data:** The dispatching data must include the date and the pick-up and delivery addresses of the current tour as well as the available loading space capacities in terms of area (m^2), volume (m^3) and weight (kg) at each station of the tour.
- **Cargo data:** New transport orders must contain information about the dimensions of the cargo in terms of length (m), width (m) and height (m) as well as the weight (kg). In addition, the exact addresses of the loading and unloading points and information on the desired pick-up and delivery date of the cargo are required.
- **Order confirmation:** As soon as a shipper feeds the data of new loads into the software, its contact details are to be displayed in the dashboard, including telephone number and e-mail address. The forwarder can thus contact the shipper and let him know whether he accepts the order.
- **Tour optimization:** For tour optimization, a developed algorithm must select the optimal route based on the truck and cargo data. Both the required loading space capacities and the distance to the location of the cargo are to be taken into account. Together with the loading and unloading points of the cargo of the new transport order, the tour is then to be optimized so that all stations are approached in the optimal order and the total distance is minimised.
- **Visualization:** The final visualization of the results must be structured in such a way that important information is immediately recognisable. The routes of the respective truck tours and the individual stations must be clearly recognisable on the map. Furthermore, the loading and unloading points of the new transport order must be clearly distinguished from other stations so that any arising detours are clearly visible.

Based on these requirements, the procedure of the concept is shown in Figure 1. First, the relevant data of the forwarder is prepared so that it can be passed to a matching algorithm without further processing. Then, the optimal tour for picking up additional loads is determined and passed on to the tour optimization process. For these steps, Alteryx Designer [1] is used. Finally, the visualization of results is done with Tableau Desktop [2] to support the decision-making of dispatchers. These steps are explained in the following subchapters.

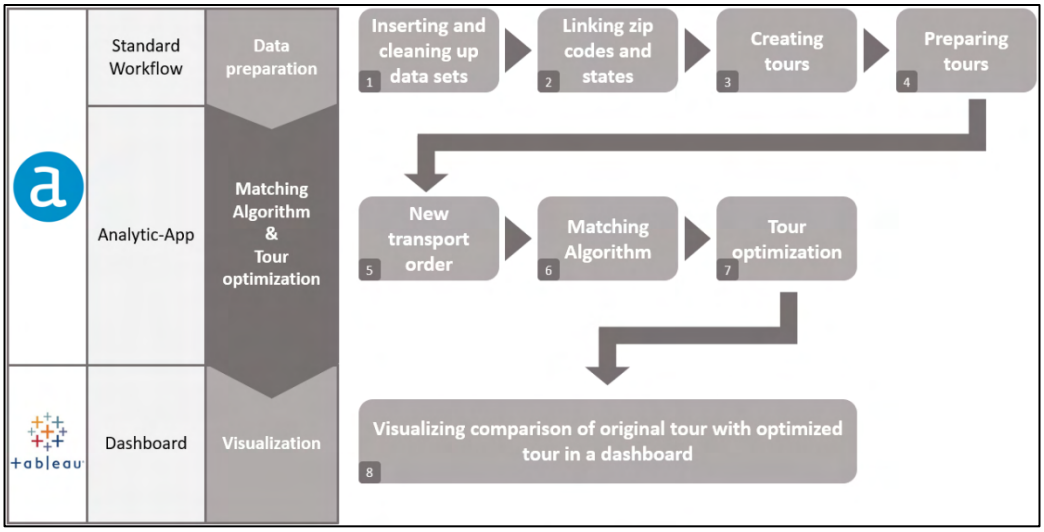

Figure 1: Procedure of the developed concept

Data Preparation

The task of data preparation is to integrate the raw data of the forwarder into the algorithm. Furthermore, this data has to be prepared to provide the matching algorithm and tour optimization with all the information needed about the currently dispatched tours. To fulfil these tasks, data preparation consists of four steps according to Figure 1:

- Inserting and cleaning up data sets
- Linking zip codes and states
- Creating tours
- Preparing tours

First, all open and already scheduled transport orders are read in from the forwarder's master data. These data are provided with unique postal codes, city, and state designations. This step is necessary for the subsequent geocoding. Incomplete data records are cleaned up. The remaining data records are grouped according to their delivery relations and day. Afterwards, the transport orders are assigned to occurring tours. In addition, the individual stations of the respective tours are determined, and their recipient addresses are geocoded. Subsequently, the prepared data records are passed to a batch macro to solve the traveling salesman problem. The casaGeoTSP-Tool [3] is used to determine an optimal tour sequence according to the minimum distance travelled for the entire tour. Furthermore, the deliveries are grouped according to the addresses, and the loads of the respective stations are added. Thus, the available free space, volume, and weight capacity are calculated for each station, considering the tour sequence. Based on these steps discussed, all necessary information for the matching algorithm and the tour optimization could be inserted and prepared.

Matching Algorithm and Tour Optimization

The matching algorithm and tour optimization consist of three steps as shown in Figure 1:

- New transport order
- Matching algorithm
- Tour optimization

A graphical user interface has been created for dispatching new transport orders. This interface is used for entering transport logistic key data by the shipper. Specifically, general contact details, the pickup and delivery address, and freight metrics such as weight, dimension, and load carrier are submitted through this interface.

Subsequently, this new input data is integrated into a matching algorithm. First, the pickup and delivery addresses are geocoded to capture the latitude and longitude coordinates. The freight parameters desired pickup and delivery date, required weight, volume, and space requirements are linked to these coordinates. The actual and already prepared tours of the forwarder are then transferred from the data preparation. This tour data is then compared with the new transport order to evaluate the optimal route for this transport order. This matching procedure is based on the following restrictions to identify the optimal tour, which have to be fulfilled by at least one station i for pick up and at least one station j for delivery of a truck tour j of the forwarders transport network:

(1) $DIS_{\overline{PUi}} \leq FWD \quad \wedge \quad DIS_{\overline{Dj}} \leq FWD$
(2) $TO_{DD} \geq TO_{PUD} = TD_k$
(3) $TO_V \leq AV_i \quad \wedge \quad TO_F \leq AF_i \quad \wedge \quad TO_w \leq AW_i$
(4) $S_j > S_i$

$DIS_{\overline{PUi}}$ Driving Distance between pick up point of transport order and station i of tour k in km
$DIS_{\overline{Dj}}$ Driving Distance between delivery point of transport order and station j of tour k in km
FWD Forwarder's threshold of maximal permitted driving distance from Pick up point to i or delivery point to j of tour k in km
TO_{PUD} Pick up date and time of transport order
TO_{DD} Delivery date and time of transport order
TD_k Execution date and time of tour k
TO_V Volume of transport order in m³
TO_F Floor area of transport order m²
TO_W Weight of transport order kg
AV_i Available volume at station i of tour k in m³
AF_i Available floor area at station i of tour k in m²
AW_i Available weight at station i of tour k in kg
S_i Sequence number of station i of tour k
S_j Sequence number of station j of tour k

Based on these constraints the optimal tour for the new transport order is selected. In case of more than one possible tour, the tour with the lowest Distances to pick up and delivery points is chosen. The next step is to optimally integrate the loading and unloading points into the existing tour to minimize the transport distance on the entire tour. This is done with the casaGeoTSP-Tool [3] considering additionally the restrictions defined above. The results of this tour optimization are passed on to the subsequent visualization of the results. The entire implementation of the described algorithm is done via an Analytic App in Alteryx Designer [1].

Visualization

Finally, the visualization of the tours is provided to the forwarder in a Tableau [3] dashboard. Its structure is shown in Figure 2. The original tour selected by the matching algorithm to include additional loads is plotted left. The optimized tour with integrated new loading and unloading locations is visualized in the right plot. In addition, the locations to be approached are shown in coloured legends. In the upper bar, the contact details of the shipper are displayed. This information supports the dispatcher to accept or reject the order and to contact the shipper.

Case Study

The developed algorithm was applied in a nationally operating, medium-sized, Austrian freight forwarding company. The company's core business is less than truckload and full truckload transports. Due to the challenging competitive situation and the increasing pressure to achieve sustainability goals, the company is increasingly facing challenges in truck distribution:

(1) **Lack of transparency** - The dispatching software does not automatically display free capacities and the routes and tour sequence of the tours already dispatched.
(2) **Lack of data interface** - Dispatchers take pick-up orders by phone and must manually transfer the information into the dispatching software.
(3) **Incorrect and time-consuming creation of tours** - Short-term orders are processed manually, which leads to errors in scheduling. Often the optimal tour is not selected from the transport network, and the new stations are not optimally inserted into the existing tour sequence.

To eliminate these challenges, the developed concept and the associated dashboard will be evaluated as a decision-support tool in the company. To this end, limitations of the scope of the case study should be noted. The scope of the evaluation was limited to one depot of the forwarding company. The Austrian regions Vienna, Lower Austria, and northern Burgenland are supplied from this depot. The validation is based on anonymized customer data in which a shipper requests the transport of goods.

Application of the Concept

During data preparation, the transport orders for the current and the next two days are inserted into the system. After data cleaning, the needed zip codes and states are added to the data sets. The data preparation is completed by creating and preparing the current transport routes. Then, the creation of new transport orders is carried out. The validation is based on three new transport orders. These are summarized in Table 1. The data of each order consists of a loading and an unloading location, the weight of the freight, the needed space, and volume. Based on this information, the matching algorithm selects the optimal tour of the forwarder's transport network.

Transport order	Loading location	Unloading location	Weight [kg]	Floor area [m²]	Volume [m³]
1	A	B	6,000	10	10
2	C	D	5,000	8	10
3	C	E	2,000	2.5	2.5

Table 1: Transport orders of the case study

Then, the loading and unloading locations of the transport order must be integrated into the existing tour. This procedure includes meeting the previously defined boundary conditions. Therefore, this paper will focus on transport order 2 from Table 1. For this order, a delivery route in the form of a ring structure has been selected as the optimal transport route by the matching algorithm based on formula 1. The details of this route in terms of the order of the delivery stations, the available weight, the floor area, the volume, the distance to the next station and the utilization rate for each station are shown in Table 2.

Station	Free weight [kg]	Free floor area [m²]	Free volume [m³]	Distance to next station [km]	Utilization rate in regard to the free floor area [%]
0	4,313	7.42	32.62	40.5	66.3
1	4,621	9.18	33.03	2.9	58.3
2	4,701	10.89	35.57	12.7	50.5

3	4,861	12.33	36.63	10.6	44
4	5,011	13.29	37.40	11	39.5
5	5,361	13.78	38.20	12.8	37.4
6	7,376	19.60	42.44	7.1	10.9
7	7,946	21.04	43.20	18	4.4
8	8,000	22.00	45.00	57	0

Table 2: Information about the original transport tour

Subsequently, the free capacities are analysed regarding the available weight, space, and volume requirements. In this specific case, the route optimization shows that sufficient free capacities are available from station 4 and that the loading point of the transport order can be approached. In the second step, the loading and unloading locations are optimally integrated into the existing route regarding distances covered. In the concrete use case of transport order 2, the pick-up station is approached after station 5. The delivery station of transport order 2 is situated as the last station to guarantee minimum distances. Figure 2 shows the visualization of the results of this use case using the developed dashboard. The left plot shows the original tour. The right plot shows the optimized tour with the loading point (green ring) and unloading point (red ring).

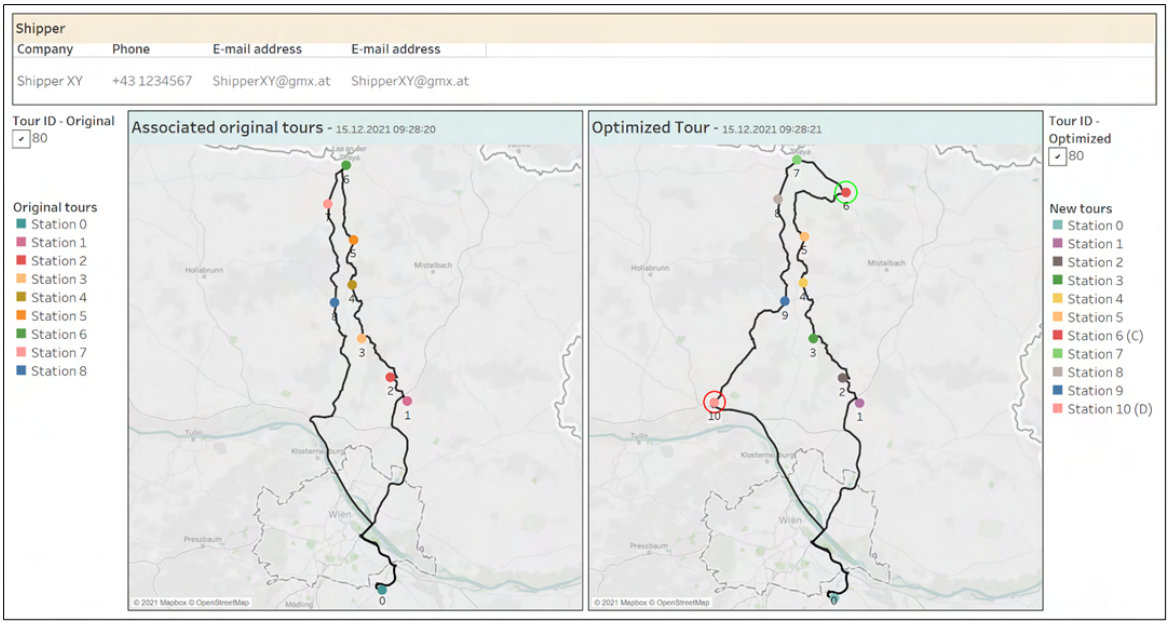

Figure 2: Comparison of the optimized tour (right) with the original tour (left)

The details of the optimized route in terms of the order of the delivery stations, the available weight, the floor area, the volume, the distance to the next station and the utilization rate for each station are shown in Table 3.

Station	**Free weight [kg]**	**Free floor area [m²]**	**Free volume [m³]**	**Distance to next station [km]**	**Utilisation rate in regard to the free floor area [%]**
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3	4,861	12.33	36.63	10.6	44
4	5,011	13.29	37.40	11	39.5
5	5,361	13.78	38.20	14.4	37.4
6	361	5.78	28.2	10	73.7
7	2,376	11.60	32.44	7.1	47.3
8	2,946	13.04	33.20	18	40.7
9	3,000	14.00	35.00	22.3	36.4
10	8,000	22.00	45.00	41	0

Table 3: Information about the optimized transport tour

According to table 2 and 3 for this specific tour, the application of the developed concept increased the weighted utilization rate according to formula 1 of the truck by 21,2% (6,2 pp.) compared to the original tour.

$$\boldsymbol{Weighted\ utilization\ rate}\ [\%] = \frac{\sum_{i=0}^{n} \boldsymbol{U_i} * \boldsymbol{D_i}}{\sum_{i=0}^{n} \boldsymbol{D_i}}$$

$\boldsymbol{U_i}$ Utilization rate for each station [%]
$\boldsymbol{D_i}$ Distance to the next station for each station [km]

Formula 1: Weighted utilization rate

Results and Discussion

The results of the application of the developed concept and the visualization of its results in a dashboard are positive for the user. The automatic creation and correct mapping of the tours increased the transparency of the transport network. Furthermore, the determination of the optimal route sequence was automated, and the time required for this was reduced by 15% in average compared to manual execution. Furthermore, the data acquisition could be simplified. After inputting the data into the user interface and starting the Analytic App, additional orders could be imported within just 5 seconds and suitable original tours could be selected and visualized. The dispatchers only have to contact the client as a final task.

The automatic integration of the loading and unloading points into the already existing tours after an order has been imported via the Analytic App was noted as a particularly positive impact. This means that the dispatchers no longer have to manually search for suitable tours that have enough free loading space capacity. Furthermore, the error rate when assigning orders to tours is reduced by 10%. Tours that were ideal for pick-up transport of a certain load, for example, were automatically displayed in the dashboard. The loads are thus no longer assigned to an additional or incorrect tour. In summary, the use of the dashboard provided a qualitative decision support tool that contributed to a significant increase in the utilization rate of the trucks by 13.4% (4.8pp) in average.

Furthermore, the automated allocation and optimization of existing truck tours avoided bottlenecks and increased the resilience of the transport network. Stacking capabilities and information on dangerous goods are not yet taken into account in this concept. Furthermore, it is assumed that shippers provide correct information on cargo data. Incorrect information or indiscreet cargo cubage leads to errors in the calculation of the matching algorithm and are considered as further limitations.

Conclusions

For the optimal use of residual capacities, the matching of loads and free residual capacities by itself is not sufficient. Challenges such as the lack of transparency in the transport network, the poor integration of data, and the inefficient cooperation of the shipping industry require a more comprehensive solution.
The main contribution of this paper is a comprehensive concept for the optimised use of residual capacities by supporting dispatchers in the allocation of transport orders. In the course of this, an optimization algorithm was developed. This algorithm consists of four steps. The data preparation integrates the current tour data of the forwarder. After the shipper enters a new transport order, the matching algorithm analyses the tour data to identify the optimal tour for the new order. During tour optimisation, the order is integrated into the selected existing tour while minimising the total distance. Finally, the results are prepared graphically for the dispatcher.

The concept creates transparency and resilience in supply chain networks by merging customer and freight forwarding data. The novelty of this contribution is that the developed algorithm combines already dispatched trucks and their current utilization with open transport orders, thereby making optimal use of the residual capacities of trucks. This could also be confirmed in a case study with an Austrian forwarder.

Since qualitatively deficient or missing data often appear, the next step is to develop a sensor system for trucks to close these data gaps. In the future, the algorithm presented will access these real-time data to perform the calculation logic and route optimization discussed. In addition, the collection and integration of weather, traffic, and transport order data in real time will be integrated to increase the dynamics of the tour optimization. Text mining, web scraping, and social media analysis should be used for automatically extracting the relevant content of websites and social networks. Finally, this extended algorithm should be integrated into a suitable decision support system for truck dispatching.

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References

Allaoui, H., Guo, Y. and Sarkis, J. (2019), “Decision support for collaboration planning in sustainable supply chains”, Journal of Cleaner Production, pp. 761–774.
Aloui, A., Hamani, N., Derrouiche, R. and Delahoche, L. (2021), “Systematic literature review on collaborative sustainable transportation: overview, analysis and perspectives”, Transportation Research Interdisciplinary Perspectives, pp. 100291.
Daudi, M. and Thoben, K.-D. (2020), “Self-organizing Logistics Networks for Less-Than-Truckload”, Procedia Manufacturing, pp. 101–106.
Feng, M. and Cheng, Y. (2021), “Solving truck-cargo matching for drop-and-pull transport with genetic algorithm based on demand-capacity fitness”, Alexandria Engineering Journal, pp. 61–72.
Feng, F., Pang, Y., Lodewijks, G. and Li, W. (2017), “Collaborative framework of an intelligent agent system for efficient logistics transport planning”, Computers & Industrial Engineering, pp. 551–567.
Gansterer, M., Hartl, R. F. and Savelsbergh, M. (2020), “The value of information in auction-based carrier collaborations”, International Journal of Production Economics, p. 107485.
Grazia Speranza, M. (2018), “Trends in transportation and logistics”, European Journal of Operational Research, pp. 830–836.
He, P., Zhang, S. and He, C. (2019), “Impacts of logistics resource sharing on B2C E-commerce companies and customers”, Electronic Commerce Research and Applications, p. 100820.
Heinbach, C., Kammler, F. and Thomas, O. (2020), „Smart Forwarding – Datengetriebene Wertschöpfung in der Logistikkette“, Wirtschaftsinformatik & Management, pp. 458–471.

Meier, A. and Portmann, E. (2016), „Smart City“, Wiesbaden.
Park, H., Son, D., Koo, B. and Jeong, B. (2021), “Waiting strategy for the vehicle routing problem with simultaneous pickup and delivery using genetic algorithm”, Expert Systems with Applications, pp. 113959.
Rizet, C., Cruz, C. and Mbacké, M. (2012), “Reducing Freight Transport CO2 Emissions by Increasing the Load Factor”, Procedia - Social and Behavioral Sciences, pp. 184–195.
Schlott, S. (2017), „Fahrzeugtechnik für Logistik 4.0“, ATZ Automobiltechnische Zeitschrift.
Schulte, F., Lalla-Ruiz, E., González-Ramírez, R. G. and Voß, S. (2017), “Reducing port-related empty truck emissions: A mathematical approach for truck appointments with collaboration”, Transportation Research Part E: Logistics and Transportation Review, pp. 195–212.
ten Hompel, M., Bauernhansl, T. and Vogel-Heuser, B. (2020), Handbuch Industrie 4.0, Berlin, Heidelberg.
Wang, Y., Li, Q., Guan, X., Fan, J., Xu, M. and Wang, H. (2021), “Collaborative multi-depot pickup and delivery vehicle routing problem with split loads and time windows”, Knowledge-Based Systems, p. 107412.
[1] https://www.alteryx.com/de/products/alteryx-designer
[2] https://www.tableau.com/de-de
[3] https://www.casageo.de/de/tourenplanung-mit-alteryx.html

BLOCKCHAIN TECHNOLOGY EMPOWERING DIGITAL PRODUCT PASSPORTS FOR SUSTAINABLE SUPPLY CHAIN MANAGEMENT: A CONCEPTUAL FRAMEWORK

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Abstract

Purpose

To address the challenges of efficient and sustainable supply chain management, the EU has introduced the concept of "Digital Product Passports" (DPP) as a potential tool for promoting traceability, transparency, and sustainability throughout supply chains, while enhancing waste management (WM) processes. Therefore, the DPP is a novel project for the EU, engaging both academics and practitioners. The successful implementation of DPP relies on the integration of new information technologies, such as Blockchain Technology (BT). Previous research has shown that this technology has the potential to revolutionize supply chain management, primarily due to its ability to enable transparency, traceability, and accountability, which are essential resources for supporting the DPP and effectively managing product waste. Furthermore, the transparency and visibility provided by BT could enhance the legitimacy of DPPs. This transparency can be further enhanced using global, mutually acceptable, standards that allow the unambiguous identification of the different stakeholders and traceable units of interest. The purpose of this study is to discuss and assess the use of BT in conjunction with global standards to achieve an interoperable, immutable DPP implementation in the EU.

Design/methodology/approach

The authors have conducted an extensive literature review to develop a conceptual framework, which shows how BT empowers the DPP, leading to improved sustainable performance, better waste management, and the creation of social value within supply chains. By drawing upon the Legitimacy and Stakeholders' Theories, the proposed framework emphasizes the significance of transparency and traceability, which ultimately contribute to the creation of social value. It provides a foundational starting point, both to academics and practitioners, for future research and real-world applications, promoting the adoption of sustainable and transparent practices.

Findings

This study contributes to the literature review by offering insights into the integration of BT, appropriate standards and DPP within supply chains, addressing the pressing need for sustainability and efficient waste management. It shows that BT's capabilities enable the DPP to provide verifiable information on product origin, lifecycle, and environmental impact, empowering companies to take informed decisions and consumers to make sustainable choices. The study's findings and proposed framework can form a base for future research on the analysis of the above technologies and on their application to real use case scenarios.

Originality/value

The use of global standards in conjunction with BT, to achieve an interoperable, immutable DPP implementation in the EU, which can serve as an adoption model for other supply chains globally.

Keywords: Blockchain Technology, Digital Product Passport, Supply Chain & Waste Management, Sustainability, Standards

Introduction

In today's globalized and interconnected world, the need for efficient management of supply chains and the adoption of sustainable policies and practices are necessary. To address these challenges, the European Union (EU) has introduced the concept of "Digital Product Passports" (DPP). These types of passports serve as a powerful tool for facilitating traceability and transparency, throughout the supply chain, as well as for improving sustainability and waste management (WM) processes. DPP is a relatively new concept

and project for the European Union, allowing academics and researchers to propose solutions related to its implementation and contribution to companies and society.

This paper suggests that BT can provide a possible solution for the implementation of DPP. During the last decade companies and academics are becoming more interested in this new technology. BT was primarily used in the financial industry and specifically in the cryptocurrency of Bitcoin, but subsequent research (Stroumpoulis and Kopanaki, 2022) and business applications have shown that it could also transform and improve logistics and supply chain management. Due to its structure, it can lead to transparency and traceability and play an important role in supporting the DPP and controlling the waste and loss of products. The paper also suggests that the exchange of information between different companies in a supply chain requires the use of appropriate standards to ensure common understanding of data, such as those contained in the digital product passport.

The authors develop a conceptual framework to explore how BT and appropriate global data standards can empower the implementation of DPP. They show that this combination can lead to transparency, traceability, social value, sustainable performance, and better WM. A literature review analysis (Jia *et al.*, 2020) and conceptual framework, based on the Legitimacy and Stakeholders' Theories are also included. Specific technological solutions are considered and their combination for the implementation of DPP is examined. A theoretical framework is then developed which examines the effects of specific technologies on sustainable supply chain management.

Sustainability and new technologies in Supply Chain Management

Sustainable development was first defined in 1987, as "the ability to make development sustainable, to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (Bruntland, 1987 p.16). Many years later, at the World Summit on Sustainable Development, the three pillars of sustainable development (social, environmental, and economic) were introduced (Roberts and Dowling, 2002).

The supply chain involves various organizations, human activities, information, data, and resources for the delivery of goods or services (Bhuniya *et al.*, 2021). It aims to integrate an organization's social, environmental, and economic goals for long-term economic performance (Carter and Roger, 2008) can lead to a sustainable supply chain. So, Sustainable Supply Chain Management (SSCM) is an extension of the traditional supply chain management, which combines environmental and social issues (Stroumpoulis *et al.*, 2021). Information systems (IS) play a significant role in the management of supply chains. Information technology (IT) is the foundation of supply chains (de Camargo Fiorini and Jabbour, 2017), enabling and supporting the development of an effective and efficient supply chain. Similarly, IS are one of the most important factors in achieving sustainability (Wang *et al.* 2015).

Waste management and circular economy

The Circular Economy is an imperative trend of the time. As the human population grows, so does waste and resource consumption. The Circular Economy is open to various interpretations. It is described based on the philosophy of material cycles, such as processes of recycling, reconstruction, renovation, reuse, and restoration. It involves management practices, such as the reverse supply chain. Basically, it is a business and social philosophy of keeping as much materials as possible (thus constantly feeding back the material in various forms through recycling policies) in the supply chain (Papadakis, 2020).

"Waste management is the set of activities that enable the systematic organization of waste collection and treatment in the so-called reverse chain" (Liu *et al.* 2020). As a result, any information from the forward chain, which includes the stages of product production and consumption, should be usable by the WM system (Liu *et al.*, 2020). WM systems vary based on waste type, disposal strategy, country, and regulations. The Circular Economy model aims to reduce waste by reprocessing products and materials at

the end of their life cycles. Full traceability and new manufacturing processes are essential for a successful CE (Shojaei *et al.*, 2021).

Information tracking in the WM process is difficult due to various partners and lack of technology, resulting in manual data collection and digital storage (Baralla *et al.*, 2023). BT could address the aforementioned issues through its decentralized system and smart contracts.

Blockchain technology and sustainable supply chain management

The visibility of demand, orders, and supply is currently a problem for the majority of organizations (Banerjee, 2018). They are often unable to see the entire picture of their supply chain due to lack of information regarding the location of their products, outside of the network of their company (Banerjee, 2018). According to Nayak and Dhaigude (2019), this problem is related to the fact that supply chains rely heavily on systems like Enterprise Resource Planning Systems (ERP), which store all information in one central location/server. These centralized systems seem insufficient because their primary goal is to enhance internal organizational operations, with a secondary goal of establishing connections with other stakeholders (Banerjee, 2018). Moreover, their design makes it simple to attack, corrupt, and hack (Dong *et al.*, 2017). The lack of trust between partners is a further issue (Nayak and Dhaigude, 2019).

The demand for better information sharing in supply chains has increased due to significant issues in data exchange, security, robustness, and process integrity. Transparency is becoming a more pressing need, and BT (Saberi *et al.*, 2019), a distributed database of records, can provide a solution to these issues (Crosby *et al.*, 2016). BT's design incorporates non-localization, non-centralization (decentralization), security, auditability, and smart execution, making it different than other technologies. It can support any processes and the management of goods inside the supply chain, connecting physical products with their virtual identity inside the blockchain (Abeyratne and Monfared, 2016). Blockchain can assist supply chains in identifying dishonest vendors and fake goods (Saberi *et al.*, 2019).

In conclusion, BT is a ground-breaking decentralized system. However, for the time being, its energy-intensive nature and the requirement for widespread use by many users keep it in the realm of debate and assessment in terms of application. It has the advantage of ensuring the integrity of exchanged data and emanating credibility as users of the technology network have complete transparency and decide on the transactions that take place (Papadakis, 2020). DPP tracks products from start to finish, preventing waste and fraud, making supply chains more transparent and providing accurate information for sustainable choices. It serves its purpose immutably (Papadakis, 2020).

Global data standards as a common language for sustainable supply chains

In a digitalized supply chain landscape, with various stakeholders and IT systems involved for operations management, a need for using a “common digital language” for unambiguous exchange of information is of high importance. This is vastly needed for the “Twin Transition”, where sustainable practices co-exist with digital technologies, accelerating any sustainable transition (Muench *et al.*, 2022). Standards are agreements for products and services that govern processes or improve behaviours used by organizations to demonstrate consistency with business practice. "Standards" and "standardization", which are frequently used interchangeably, are two complementary concepts. (Papadakis and Kopanaki, 2022). Standardization is the process of creating standards, while standards are the results of this process. The use of Standards in Business Operations offers several advantages and measurable benefits for companies that implement them (Papadakis, 2020). Using standards in operations leads to higher customer trust, adherence to laws, lower costs, less waste, greater efficiency, and access to new technology (European Committee for Standardization, 2013).

Presently, companies are using various sustainability standards to guide their practices and demonstrate their commitment to environmental and social responsibility. One widely used standard is the Sustainable Development Goals (SDGs), which build on the “Millennium Development Goals” and aim to end poverty,

fight inequality, and address climate change by 2030 (Kamalam, 2017). The SDGs encompass economic, social, and environmental pillars, emphasizing the interconnectedness of these elements for sustainable development. “BCorp certification”, another known standard, is awarded to profit-oriented businesses that meet rigorous standards in environmental and social performance, accountability, and transparency (Stubbs, 2019). The Global Reporting Initiative (GRI) is also widely accepted as a standard for sustainability reporting (Agrawal *et al.*, 2023). It recommends that companies proactively consider sustainability in their decision-making and provide a framework for reporting on sustainability practices (Agrawal *et al.*, 2023). ISO 14001 is an international standard for environmental management systems that helps organizations manage environmental risks and commit to quality improvement (Sidjabat and Febrian, 2020). The above standards provide companies with guidelines and frameworks to integrate sustainability into their operations, decision-making processes, and reporting practices.

DPP as a tool for circular economies

A DPP is a digital collection of product-related data that combines different data sets about a product from every stage of its lifecycle (Kopelaar *et al.*, 2023). It is a key tool to create product transparency (Walden *et al.*, 2022) and accelerate the transition to a circular economy (Maayke *et al.*, 2022). There are two types of DPPs: static and dynamic. Static passports can only be read by actors who are involved in the life cycle of the product, whereas dynamic passports allow stakeholders from the entire life cycle to read and write the contents (Plociennik *et al.*, 2022). Technically, both online and offline methods of accessing the information in DPPs, (e.g., data carriers on physical product labels), are available (Gligoric *et al.*, 2019) which allows, if needed, to track a product's lifecycle history and trace it at any given time in the broader supply chain (Papadakis, 2015).

The EU has introduced policies to establish sustainable products, reduce waste, and apply circular economy policies globally. These policies include voluntary tools such as the “European Ecolabel” and the “Green Public Procurement Criteria” (European Commission (EC), 2020 and EC, 2022). Given the wide scope of regulation and the size of the EU market, DPP has significant potential to increase the circularity of products and materials (Kopelaar *et al.*, 2023). However, in most cases, the technology required for a circular economy is expensive, and the lack of financial resources hinders the successful implementation of a circular economy. The stakes of the circular economy are many (Kouhizadeh *et al.*, 2019). The subscription model in the “Circular Economy Action Plan” described as "Take - Make - Use - Dispose" (EC, 2019) is a linear consumption and production model that discourages manufacturers from creating more sustainable products. The DPP is one of the most important components for the establishment of a Circular Economy, the foundation of the EU's "Green Deal" and the "Twin Transition” (Berg *et al.*, 2021). The DPP has significant potential to increase the circularity of products and materials, but the technology required is expensive and the lack of financial resources hinders successful implementation.

Sustainable supply chains of various products and the DPP

DPP initiatives are mostly in Central and Northern Europe, with private and public sector efforts. Some Nordic countries also engage in DPP, but it is not seen as an important growth factor for Circular Economy (Jenssen *et al.*, 2022). Nevertheless, the complexity and necessity of the product supply chains where DPP will be implemented (electronic products, batteries and vehicles, plastic packaging, textiles, construction materials, food waste, water, and nutrients) has already initiated several piloting implementations across the EU. The "Keep Project" and "R Cycle Initiative" are two projects that aim to provide traceability solutions for electrical and electronic products to keep them in a circular system. The “Keep Project” tracks materials and components and it is funded by Sweden's Innovation Agency, while the “R-Cycle Initiative” supports the DPP idea and develops a cradle-to-cradle recycling system. Both projects provide trustworthy information about recycled plastic used in packaging (Patorska *et al.*, 2022).

Proposing global data standards for successful DPP BT implementation

Global standards are a key enabler, and this is outlined in the DPP initiative which recognizes as expected outcome the need of standards to ensure interoperability, security, and acceptance by all the stakeholders

and as such be implemented in other value chains (EC, 2019). One of the key benefits of using global data standards in the EU DPP initiative is the improved consistency, dependability, and transparency of data flows throughout the supply chain network (Çetin *et al.*, 2021). Global data standards enable consistent and standardized data exchange, ensuring that the information recorded in the passport is accurate, reliable, and easily understandable by all stakeholders involved (Lövdahl, 2023). This transparency and reliability of data flows enable effective collaboration and decision-making across the value chain, leading to more sustainable and informed choices (Lövdahl, 2023). The EU's DPP initiative uses global data standards to ensure non-European market participants can access the EU market and promote sustainable practices (Bendiek and Römer, 2019). Lastly, standards facilitate interoperability and compatibility between different systems and platforms (Papadakis, 2020). By adopting standardized data formats and structures, the EU DPP can seamlessly integrate with existing digital technologies and platforms, such as building information modeling (BIM) and material databanks (Çetin *et al.*, 2021). This interoperability ensures that the passport can effectively communicate and exchange data with other systems, enabling a holistic and comprehensive view of a product's lifecycle (Adisorn *et al.*, 2021). Global Standards like ISO/IEC 15459-6 (Global Trade Item Number) for products, ISO/IEC 6523 (Global Location Number) for physical/digital locations, ISO/IEC 15459-1 (Serial Shipping Container Code) for shipments, ISO/IEC 15459-4 & 5 for assets (individual/returnable), ISO/IEC 15418 (Global Document Type Identifier) for operational documents, ISO/IEC 16022 and ISO/IEC 18004 (for 2D data carriers placed on products and encoding the data of interest), ISO/IEC 19987 (EPC Information Services (EPCIS)) together with ISO/IEC 19988 (GS1 Core Business Vocabulary (CBV)) and GS1 Digital Link standard together with 2D Data Carriers can be exploited for a data quality based DPP supply chain when deployed via a BT ledger.

Impact of DPP on SSCM

For a long time, businesses believed that social and environmental issues were not as significant as financial ones because they were difficult to quantify. Additionally, they thought that corporate social responsibility was primarily linked to financial success. However, this viewpoint has gradually changed as businesses and shareholders have realized how crucial and relevant the aforementioned issues are to sustainability-related issues (Al Amosh and Mansor, 2018). So, nowadays, stakeholders expect companies to be more sensitive to both social and environmental issues (Duker and Olugunna, 2014). In order to better understand the contribution of the implementation of DPP, based on BT and Global standards, specific theories, such as the legitimacy and stakeholders' theories, can be considered and used.

Legitimacy Theory

Based on this theory, companies and organizations should realize that they are part of a broader ecosystem and that they are not the only ones having the right to use the resources (Deegan, 2019). To get the recognition of legitimate, organizations must prove to the society that they are capable to use these resources in a legitimate way (Mathews, 1997). Therefore, managers should ensure that their organization is functional in a way that there is alignment with the different social groups and the society in general. Sustainability policies led to the development of DPP, supported by BT and appropriate standards. Product traceability improves waste management, legitimacy, business performance, information visibility, and reduces fraud, leading to increased social value (Deegan, 2019). To sum up, legitimacy has a significant contribution in the way that companies handle their operations.

Stakeholders' Theory

According to this theory, the company's and all other stakeholders should benefit from the existence of the company. According to Freeman and Reed (1983), stakeholders are social groups that without their support, an organization or company would cease to exist. Based on this theory, the different groups of stakeholders have the right to be informed about the environmental and social issues (Ali and Rizwan, 2013), associated with the operation of a company. Nevertheless, as stated in the literature, there are not many companies or organizations, that clearly examine their social and environmental impact in a holistic way (Duker and Olugunna, 2014).

Conceptual Framework

The conceptual framework for blockchain-based DPP revolves around the integration of Legitimacy Theory, and Stakeholder's Theory. BT serves as a strategic resource that enhances data security, privacy, traceability, and transparency (Saberi *et al.*, 2019). Through its decentralized and immutable nature, BT reduces the reliance on centralized authorities, allowing for trustless verification of digital passport data (Niranjanamurthy *et al.*, 2019). This, in turn, enables the reduction of resource consumption and waste by streamlining processes, improving supply chain traceability, and supporting sustainable sourcing and production practices (Kshetri, 2017). Furthermore, the transparency and visibility provided by BT could enhance the legitimacy of DPPs. When stakeholders can trust the information contained within digital passports, it increases social performance by facilitating informed decision-making, reducing inefficiencies, and promoting responsible practices (King *et al.*, 2023). By actively engaging stakeholders, BT-based DPPs create a collaborative environment where collective efforts contribute to the circular economy and sustainable supply chain management.

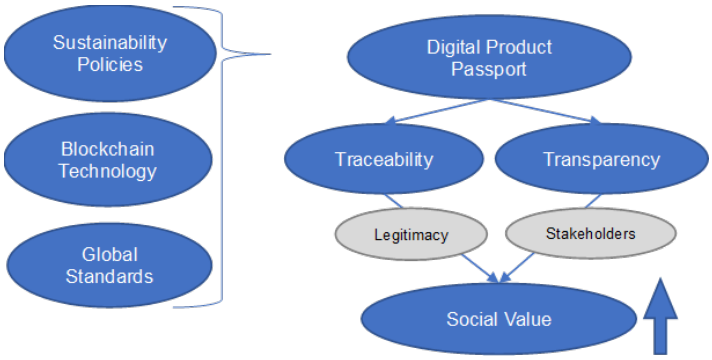

Figure 1, Impact of DPP on SSCM

As shown in the framework (Figure 1), Sustainability policies led to the development of DPP, supported by BT and appropriate standards. Product traceability improves waste management, legitimacy, business performance, information visibility, and reduces fraud, leading to increased social value.

Discussion and conclusions

The EU DPP initiative aims to enhance sustainability and circularity by providing comprehensive product information throughout the lifecycle of a product. To ensure the effectiveness and interoperability of this initiative, the use of global data standards is highly recommended. Utilizing various policies and incentive tools, such as public and private financing mechanisms, regulatory controls, and institutions to reduce initial economic compliance barriers and increase the benefits of certification for producers and value chain actors may be necessary to achieve such targeting (Smith *et al.*, 2018). The EU, as the largest consumer market globally, has the ambition to set global standards and regulations (Bendiek and Römer, 2019). In conclusion, the use of global data standards is highly recommended in the EU DPP Passport initiative. These standards enhance transparency, reliability, interoperability, and compatibility, ensuring effective collaboration and decision-making across the value chain. Furthermore, global data standards facilitate global trade and market access, promoting the adoption of sustainable practices worldwide. By adopting global data standards, the EU can establish a robust and effective DPP system that contributes to the circular economy and sustainability goals in the built environment. Further benefits can be achieved by the adoption of BT. However, BT has certain drawbacks related to complexity, network size, transaction costs, network speed, and political implementation concerns (Papadakis, 2020) that need to be addressed. Furthermore, it should be taken into consideration that most businesses or business collaborations, even if they do act in favor of circularity and subsequently sustainability, do so primarily out of self-interest and profit-orientation or with an eye toward potential regulations (Jenssen *et al.*, 2022). Therefore, business

models must be tested not only from a technological, but also from a business point of view, so that a successful application of DPP is achieved (Mullhall *et al.*, 2019).

The study evaluated technologies for DPP implementation and proposed a framework for assessing their social impact. To achieve wider adoption, more pilots, governance, auditing protocols, and a framework should be established for interoperable and sustainable supply chains.

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References

Abeyratne, S.A. and Monfared, R.P. (2016), "Blockchain ready manufacturing supply chain using distributed ledger", *International journal of research in engineering and technology*, 5(9), pp.1-10.

Adisorn, T., Tholen, L., Götz, T. (2021), *"Towards a Digital Product Passport Fit For Contributing To A Circular Economy"*, Energies, 8(14), pp. 2289.

Agrawal, R., Arora, S., Arora, G. (2023), *"Global Reporting Initiatives and Firm Performance: A Stakeholder's Perspective In Indian Companies".*

Aivaliotis, P., Anagiannis, I., Nikolakis, N., Alexopoulos, K. and Makris, S. (2021), *"Intelligent waste management system for metalwork-copper industry"*, Procedia CIRP, 104, pp.1571-1576.

Al Amosh, H.A.M. and Mansor, N. (2018), *"Sustainability and corporate reporting: A review on environmental and social accounting disclosure"*, International Journal of Accounting, Finance and Business, 3(8), pp.78-87.

Ali, W. and Rizwan, M. (2013), *"Factors influencing corporate social and environmental disclosure (CSED) practices in the developing countries: An institutional theoretical perspective",* International Journal of Asian Social Science, 3(3), pp.590-609.

Banerjee, A. (2018), "Blockchain technology: supply chain insights from ERP. In Advances in computers", Elsevier, Vol. 111, pp. 69-98.

Baralla, G., Pinna, A., Tonelli, R. and Marchesi, M., (2023), *"Waste management: A comprehensive state of the art about the rise of blockchain technology"*, Computers in Industry, 145, p.103812.

Bendiek, A. and Römer, M. (2019), *"Externalizing Europe: the Global Effects Of European Data Protection"*, Digital Policy Regulation and Governance, 1(21), pp. 32-43.

Berg, H., Bendix, P., Jansen, M., Le Blévennec, K., Bottermann, P., Magnus-Melgar, M., Pohjalainen, E., & Wahlström, M. (2021), *"Unlocking the potential of Industry 4.0 to reduce the environmental impact of production (Eionet Report ETC/WMGE 2021/5)"*, European Environment Agency, European Topic Centre on Waste and Materials in a Green Economy.

Bhuniya, S., Pareek, S. and Sarkar, B. (2021), *"A supply chain model with service level constraints and strategies under uncertainty"*, Alexandria Engineering Journal, 60(6), pp.6035-6052.

Bruntland, G. H. (1987), *Report of the World Commission on Environment and Development: Our Common Future*, p.300.

Carter, C.R. and Rogers, D.S. (2008), *"A framework of sustainable supply chain management: moving toward new theory"*, International journal of physical distribution & logistics management, 38(5), pp.360-387.

Çetin, S., Wolf, C., Bocken, N. (2021), *"Circular Digital Built Environment: An Emerging Framework"*, Sustainability, 11(13), 6348.

Crosby, M., Pattanayak, P., Verma, S. and Kalyanaraman, V. (2016), *"Blockchain Technology: Beyond bitcoin"*, Applied Innovation, 2(6-10), p.71.

De Camargo Fiorini, P. and Jabbour, C.J.C. (2017), *"Information systems and sustainable supply chain management towards a more sustainable society: Where we are and where we are going"*, International Journal of Information Management, 37(4), pp.241-249.

Deegan, C.M. (2019), *"Legitimacy theory: Despite its enduring popularity and contribution, time is right for a necessary makeover"*, Accounting, Auditing & Accountability Journal, 32(8), pp.2307-2329.

Dong, F., Zhou, P., Liu, Z., Shen, D., Xu, Z. and Luo, J. (2017), *"Towards a fast and secure design for enterprise‐oriented cloud storage systems"*, Concurrency and Computation: Practice and Experience, 29(19), p.e4177.

Duker, J., Olugunna, M. (2014), *"Corporate environmental responsibility (CER): a case of logistics companies in Sweden"*.

European Commission (2019), *Towards an EU Product Policy Framework contributing to the Circular Economy Roadmap*.

European Commission (2020), *A new Circular Economy Action Plan For a cleaner and more competitive Europe*.

European Commission (2022), *EU Directorate-General for Environment. Proposal for a Regulation Establishing a Framework for Setting Ecodesign Requirements for Sustainable Products and Repealing Directive 2009/125/EC*. COM 2022, 142, 122

European Committee for Standardization (2013), *Standards and your business How your business can benefit from standards and participate in standardization activities*.

Freeman, R.E. and Reed, D.L. (1983), *"Stockholders and stakeholders: A new perspective on corporate governance"*, California management review, 25(3), pp.88-106.

Gligoric, N., Krco, S., Hakola, L., Vehmas, K., De, S., Moessner, K., Jansson, K., Polenz, I., van Kranenburg, R. (2019), *"IoT Product Passport for Circular Economy Based on Printed Sensors and Unique Item-Level Identifiers"*, Sensors, 19, pp. 586.

Jansen, M., Gerstenberger B., Bitter-Krahe J., Sebestyén J., Schneideret J. (2022), *"Current approaches to the digital product passport for a circular economy: An overview of projects and initiatives"*, Wuppertal Papers, Wuppertal Institut für Klima, Umwelt, Energie, Wuppertal No.198.

Jia, F., Blome, C., Sun, H., Yang, Y. and Zhi, B. (2020), *"Towards an integrated conceptual framework of supply chain finance: An information processing perspective"*, International Journal of Production Economics, 219, pp.18-30.

Kamalam, S. (2017), *"Transforming Our World: the 2030 Agenda For Sustainable Development"*, Pondicherry Journal of Nursing, 2(10), pp. 42-49. https://doi.org/10.5005/pjn-10-2-42

King, M.R., Timms, P.D. and Mountney, S. (2023), *"A proposed universal definition of a Digital Product Passport Ecosystem (DPPE): Worldviews, discrete capabilities, stakeholder requirements and concerns"*, Journal of Cleaner Production, 384, p.135538.

Koh, S.L., Gunasekaran, A. and Goodman, T. (2011), *"Drivers, barriers and critical success factors for ERPII implementation in supply chains: A critical analysis"*, The Journal of Strategic Information Systems, 20(4), pp.385-402.

Koppelaar, R.H.E.M., Pamidi, S., Hajósi, E., Herreras, L., Leroy, P., Jung, H.-Y., Concheso, A., Daniel, R., Francisco, F.B., Parrado, C. (2023), *"A Digital Product Passport for Critical Raw Materials Reuse and Recycling"*, Sustainability, 15, 1405. https://doi.org/10.3390/su15021405

Kouhizadeh, M., Sarkis J. and Zhu Q. (2019), *"At the Nexus of Blockchain Technology, the Circular Economy, and Product Deletion"*, Applied Sciences, 9.

Kshetri, N. (2017), *"Can blockchain strengthen the internet of things?"*, IT professional, 19(4), pp.68-72.

Liu, X.L., Wang, W.M., Guo, H., Barenji, A.V., Li, Z. and Huang, G.Q. (2020), *"Industrial blockchain based framework for product lifecycle management in industry 4.0"*, Robotics and computer-integrated manufacturing, 63, pp.101897.

Lövdahl, J. (2023), "Implications of Eu Instruments On Company Capabilities To Design More Sustainable Solutions–product Environmental Footprint and Digital Product Passport", *Proceedings of the Design Society*, (3).

Mathews, M.R. (1997), *"Twenty-five years of social and environmental accounting research: is there a silver jubilee to celebrate?"*, Accounting, Auditing & Accountability Journal, 10(4), pp.481-531.

Muench, S., Stoermer, E., Jensen, K., Asikainen, T., Salvi, M. and Scapolo, F. (2022), *Towards a green and digital future*, EUR 31075 EN, Publications Office of the European Union, Luxembourg.

Mulhall, D.; Ayed, A.-C., Schroeder, J., Hansen, K., Wautelet, T. (2019), *"The Product Circularity Data Sheet - A Standardized Digital Fingerprint for Circular Economy Data about Products"*, Energies 2022, 15, 3397.

Nayak, G. and Dhaigude, A.S. (2019), *"A conceptual model of sustainable supply chain management in small and medium enterprises using blockchain technology"*, Cogent Economics & Finance, 7(1), pp.1667184.
Niranjanamurthy, M., Nithya, B.N. and Jagannatha, S.J.C.C. (2019), *"Analysis of Blockchain technology: pros, cons and SWOT"*, Cluster Computing, 22, pp.14743-14757.
Papadakis MN. (2015), *Traceability systems and techniques for the modern supply chain*, University of Piraeus Dissertation, Piraeus, pp. 45-120.
Papadakis MN. (2020), *Management and standardization of business operations through blockchain technology*. University of Piraeus Dissertation, Piraeus, pp. 243-250.
Papadakis MN., Kopanaki E. (2022), "Standardization and blockchain technology in the maritime industry" in *ITS European Congress Toulouse, 2022*, pp. 426-436.
Patorska J., Łaszek A., Leoniewska-Gogola J., Maciborski D., Fusiara A. (2022), *Impact of international, open standards on circularity in Europe*, Deloitte, Poland.
Plociennik, C., Pourjafarian, M., Nazeri, A., Windholz, W., Knetsch, S., Rickert, J., Ciroth, A., Lopes, A.C.P., Hagedorn, T., Vogelgesang, M. (2022), *"Towards a Digital Lifecycle Passport for the Circular Economy"*, Procedia CIRP, 105, pp. 122–127.
Roberts, P.W. and Dowling, G.R. (2002), *"Corporate reputation and sustained superior financial performance"*, Strategic management journal, 23(12), pp.1077-1093.
Saberi, S., Kouhizadeh, M. and Sarkis, J. (2019), *"Blockchains and the supply chain: Findings from a broad study of practitioners"*, IEEE Engineering Management Review, 47(3), pp.95-103.
Shojaei, A., Ketabi, R., Razkenari, M., Hakim, H. and Wang, J. (2021), Enabling a circular economy in the built environment sector through blockchain technology. Journal of Cleaner Production, 294, pp.126352.
Sidjabat, F. and Febrian, P. (2020), *"The Comparison of ISO 14001 Implementation In Indonesia Construction Companies (Case Study: Pt. Waskita Karya Tbk, Pt. Wijaya Karya Tbk, Pt. Pp (Persero) Tbk)"*, Jie Scientific Journal on Research and Application of Industrial System, 2(5), 120.
Smith W. K., Nelson E., Johnson J. A., Polasky S., Milder J. C., Gerber J. S., West P. C., Siebert S., Brauman K. A., Carlson K. M., Arbuthnot M., Rozza J. P., and Pennington D. N. (2018), *"Voluntary sustainability standards could significantly reduce detrimental impacts of global agriculture"*, Biological Sciences, 116 (6), pp. 2130-2137.
Stroumpoulis, A. and Kopanaki, E. (2022), *"Theoretical perspectives on sustainable supply chain management and digital transformation: a literature review and a conceptual framework. Sustainability"*, 14(8), pp.4862.
Stroumpoulis, A., Kopanaki, E. and Karaganis, G. (2021), *"Examining the relationship between information systems, sustainable SCM, and competitive advantage"*, Sustainability, 13(21), pp.11715.
Stubbs, W. (2019), *"Strategies, Practices, and Tensions in Managing Business Model Innovation For Sustainability: The Case Of An Australian Bcorp"*, Corporate Social Responsibility and Environmental Management.
Walden, J.; Steinbrecher, A.; Marinkovic, M. (2021), *"Digital Product Passports as Enabler of the Circular Economy"*, Chem. Ing. Tech., 93, pp. 1717–1727.
Wang, Y., Chen, Y. and Benitez-Amado, J. (2015), *"How information technology influences environmental performance: Empirical evidence from China"*, International Journal of Information Management, 35(2), pp.160-170.

CHALLENGES OF CIRCULAR SUPPLY CHAINS IN DEVELOPING COUNTRIES: THE EXAMPLE OF ZAMBIA

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ABSTRACT

Purpose: In a global approach to reduce the use of natural resources, international conventions, protocols, and agreements were introduced. In implementing these international approaches, developing countries were facing challenges such as war, instability, and economic weakness. As a result, introducing sustainable strategies, such as circular supply chains, remain relatively immature compared to more developed regions. This paper explores the challenges in the implementation of circular supply chains in developing countries and investigates these challenges using the example of Zambia, a developing African country.
Design/methodology/approach: In the first phase, a literature review was conducted to evaluate, critique, and synthesize the challenges of circular supply chains in developing countries. The literature review covered research articles, reviews, and concept papers from the research databases Scopus, and Science Direct. Studies combining 'circular supply chain,' 'sustainable supply chains,' 'supply chains and circular economy,' and 'circular supply chains and challenges of implementation' and focussing on 'developing countries' were considered for review. In the second phase of this research, a comparative analysis was performed contrasting the findings in the implementation of circular supply chains in developing countries with today's circular supply chain strategies in Zambia in order to reflect implementation challenges.
Findings: This research maps challenges developing countries are facing in the implementation of circular supply chain strategies and demonstrates them using the example of Zambia. It provides recommendations to relevant groups of stakeholders both in the public and private sectors.
Research limitations: Performing a literature review limits findings to secondary sources, potentially influencing the timeliness of data in this fast-changing research area.
Practical implications: This research provides a basis for formulating policies and theoretical framework.
Originality/value: Circular supply chain strategies have been widely explored. This research provides additional insight into the status and specific challenges faced by developing countries in the implementation phase.

Keywords: Circular supply chains, Sustainability, Remanufacturing, Recycling, Developing countries, Zambia

1. Introduction

Natural resources are being consumed at a rapid rate worldwide. A key driver for the unsustainable consumption of raw materials is waste management, which includes generating non-segregated waste, disorganized recycling concepts, missing reuse strategies, inadequate waste treatments, and inappropriate final disposals in landfills (Mangla, et al., 2018). Resource recovery initiatives are set up to create and maintain circular strategies in order to solve these issues. A circular supply chain (CSC) involves a theoretically endless cycle of reuse, remanufacturing, and recycling after the phase of the initial product usage (Low, et al., 2016). A CSC is a component of the circular economy, which aims to implement concepts to make product usage more sustainable over the complete lifecycle of a product, for example by adding concepts of reusing and remanufacturing (Mangla, et al., 2018). CSC provides businesses with the chance to reuse resources that would otherwise be considered waste. Its goal is to convert used and worn-out products into new products. This is a new perspective differing from the traditional linear supply chains, which disposed the product after the period of usage (McCloud, 2023). Implementing CSC demands having an insight into the challenges impeding its development. Such challenges can be divided into governmental,

financial, technological, knowledge-related, managerial, legal, social, and marketing-related challenges (Saroha, et al., 2018). Due to limited institutional capacities, a lack of access to sufficient financial resources, and a lack of technological innovation, these difficulties are often of higher relevance in developing countries than in developed countries (Wellesley, et al., 2019). According to Dora et al (2016), implementing CSC models is challenging and requires an understanding of the barriers.

Researchers and practitioners have addressed the challenges connected with CSCs (Genovese, et al., 2017; Millettea, et al., 2019; Bhatia, et al., 2022). Several studies have attempted to look at the challenges of CSC in developing countries (Okafor, et al., 2020; Ahmed, et al., 2022; Sohal, et al., 2022; Yadav, et al., 2023). It has been observed that the challenges of CSC implementation particularly in developing countries require to be distinguished accurately (Mangla, et al., 2018), as there is still limited research that has attempted to bring together the various studies focusing on this matter. To address this gap, this research explores the challenges developing countries are facing when implementing CSCs. Moreover, it aims to identify country-specific challenges in the example of the developing country Zambia. To achieve this, this research is exploring the following two research questions:

1. What challenges do developing countries face when implementing CSCs?
2. How do the challenges of implementing CSC in Zambia relate to those in other developing countries?

To answer these research questions, this paper provides the applied methods in Section 2. Section 3 reviews the literature on challenges in the implementation of CSCs in developing countries. In Section 4 the country-specific challenges for Zambia are explored. Section 5 discusses the findings before a conclusion is provided in Section 6.

2. Methodology

The literature review was chosen as the research method for this study, and it was conducted between May 2023 and July 2023. A literature review is used as a research method to describe research trends and understandings on a particular topic. Tranfield, et al. (2003) state in their research that a literature review can systematically collect and synthesize previous studies. It can provide a solid basis for developing theory and enhancing knowledge. (Webster & Watson, 2002). For example, a study by Sharma, et al (2019) used a literature review approach to identify the CSC-related challenges in the food supply chains. Mangla (2018) used a literature review approach to establish the barriers to effective CSC management in developing economies. Moreover, Khan & Haleem (2021) investigated circular economy activities in emerging economies using a literature review methodology. Further, Orji, et al (2022) established determinants of CSC implementation in manufacturing industries from Nigeria using a literature review approach. This study applies the literature review approach to establish the CSC challenges by considering Zambia as an example.

To effectively conduct the literature review, a five-step approach was performed (Figure 1). Step one involved the search for articles by using research databases such as Elsevier, Science Direct, Springer, Emerald Insight, Wiley, Scopus, and Taylor & Francis. The search for published articles was limited to abstracts, keywords, and titles in the area of CSC management. Emphasis was made to include articles on CSC management and implementation challenges in developing economies in which Zambia was considered. The following keywords were used; ‘’circular supply chains’’, ‘’challenges’’, “implementation”, “developing economies”, and “Zambia” and a total of 208 articles were identified and considered.

In step two, the articles were analyzed to filter duplicates as well as to consider only the articles meeting the focused area of research. As a result of this, 96 articles were chosen. At this stage, 112 articles did not meet the criteria and were not considered for abstract analysis.

In step three, abstract analysis was conducted to ensure that all articles that included the keywords and key phrases, “circular supply chains’’, ‘’challenges’’, “implementation”, “developing economies”, and “Zambia”

were considered for full-text analysis. Articles that did not have the keywords and key phrases in the abstracts were eventually excluded and 36 articles were chosen to undergo a full-text analysis.
In step four, full-text reading was conducted on the 36 articles, and research questions were developed during this phase. The structure of the literature review and its analysis were based on the previously defined research questions.

In step five, an analysis of the articles was conducted to establish the challenges of implementing CSCs in developing economies and Zambia. To present the challenges of circular supply chain implementation from developing countries' perspective and Zambian's perspective as per the research questions, the articles were categorized into two groups, 'those focusing on developing countries' circular supply challenges' and 'those focusing on Zambia.' To present a comprehensive analysis of the challenges, a subsection for each challenge was scrutinized relative to the reviewed articles.

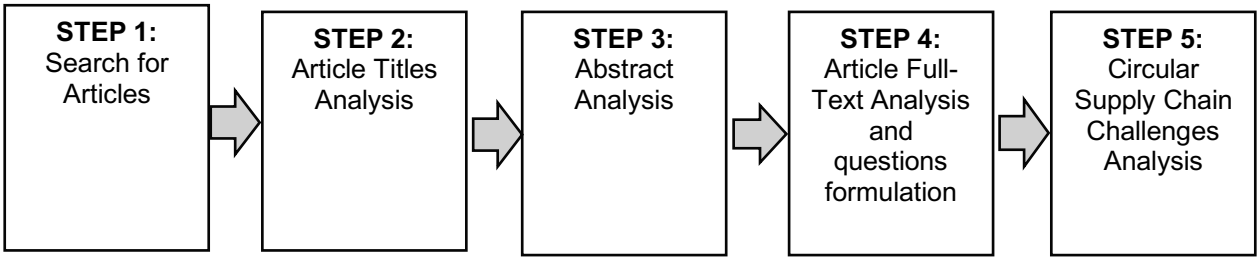

Figure 1: Research Design

3. Circular Supply Chain Challenges in Developing Countries

According to Saroha, et al. (2018), the challenges of CSCs in developing countries can be divided into governmental, financial, technological, knowledge- or skill-related, managerial, regulatory framework, social, and marketing-related challenges. The qualities of each challenge are examined in the following sub-sections.

3.1 Government-Related Challenges in Developing Countries

Government challenges of a CSC in developing countries relate to the lack of vision, laws, and policies (Hull, et al., 2021; Yadav, et al., 2023; Karuppiah, et al., 2021). A lack of government CSC vision presents a challenge in developing countries. Government vision on the CSC is required to boost participation and to develop and establish agreements with cooperating partners (Hull, et al., 2021). Similarly, the lack of strict government laws and policies represents an additional challenge to overcoming the challenge of implementing CSCs (Yadav, et al., 2023), as stringent laws regarding recycling and remanufacturing practices are ineffective (Karuppiah, et al., 2021). Further, developing countries lack policies to enforce extended producer responsibility, taxes, and charges for waste disposal. This is leading to more environmental degradation, as producers are not held accountable for generating waste (Okafor, et al., 2020).

3.2 Financial-Related Challenges

The financial challenges of a CSC relate to the lack of funding (Karuppiah, et al., 2021; Ngu, et al., 2020). A transition to a CSC requires investment in CSC projects. As a result, huge upfront financial resources are required (Karuppiah, et al., 2021). This can be a serious blocking point for developing countries, as most companies in developing countries are small and medium-sized enterprises (SMEs) and therefore cannot afford to finance huge projects. Further, the limited cash flows make it difficult for SMEs to mobilize the

resources required to acquire circular economy technologies such as industrial symbiosis to improve resource efficiency (Sohal, et al., 2022; Cezarino, et al., 2021).

3.3 Technological-Related Challenges in Developing Countries

The technical challenges of CSC implementation in developing countries relate to the lack of technology and information sharing, (Yusop, et al., 2016; Millettea, et al., 2019). In developing countries, the majority of industries are not equipped with the latest technologies to enable a smooth transition to CSCs (Karuppiah, et al., 2021; Ahmed, et al., 2022). Similarly, information sharing is also a challenge. For instance in India, CSCs lack information systems channels to coordinate members in complex supply chain processes (Mangla, et al., 2018). Further, developing have difficulties accessing specific information, tools, and standards from original equipment manufacturers in developed countries to help with CSC implementation in developing countries (Ngu, et al., 2020).

3.4 Knowledge-Related Challenges in Developing Countries

Knowledge-related challenges of CSCs in developing countries usually involve the lack of awareness and lack of skilled manpower (Hull, et al., 2021; Yadav, et al., 2023). In developing countries, most people are not well informed about CSCs. The majority of people are only aware of traditional waste management practices such as recycling and landfilling and lack knowledge of better circular economy practices such as prevention, reuse, and remanufacturing (Hull, et al., 2021; Yadav, et al., 2023). Further, most manufacturers are not conscious of CSC strategies (Karuppiah, et al., 2021). Likewise, the lack of skilled manpower, such as specialist labor to manage CSC processes in remanufacturing, is a challenge for developing countries (Ngu, et al., 2020; Ahmed, et al., 2022).

3.5 Management-Related Challenges in Developing Countries

The management challenges of CSC implementation in developing countries relate to a lack of managerial commitment and CSC responsibilities (Mangla, et al., 2018; Silva & Morais, 2021). The absence of strict laws and policy guidelines for CSCs results in less commitment by the management of business organizations to promote CSCs (Hull, et al., 2021; Karuppiah, et al., 2021). Equally, the lack of structured CSC management such as the absence of mechanisms for defining responsibilities for various segments involved in waste management, remains a management challenge of CSC implementation in developing countries (Silva & Morais, 2021). Thus, governments require private-sector commitment and support to actualize an agenda for CSCs. Mangla et al. (2018), observed that the concept of a CSC in developing countries is significantly aided by raising the acceptance of managers at all levels of the organization.

3.6 Regulatory Framework-Related Challenges in Developing Countries

The regulatory framework challenges of CSCs in developing countries relate to ineffective frameworks (Okafor, et al., 2020). The regulatory frameworks regulating, promoting, and monitoring the transition to CSCs in most developing countries are ineffective (Ahmed, et al., 2022; Okafor, et al., 2020). During the transition to CSCs, there are fundamental shifts in government regulations, business practices, and consumer behavior. In India for instance, the shift to cleaner energy and circular economy requires the presence of stringent environmental and regulatory frameworks. Compared to developed countries, India lacks a robust environmental regulatory framework for adopting circular supply models (Goya, et al., 2016).

3.7 Social-Related Challenges in Developing Countries

The social challenges of CSCs in developing countries relate to the negative perceptions of recycled, reused, and remanufactured products (Sharma, et al., 2016; Cezarino, et al., 2021). Customers have quality

concerns in respect of remanufactured products. This discourages companies to implement CSC principles (Sharma, et al., 2016). Similarly, Karuppiah et al. (2021), confirm also that a low consumer perception of products from circular business creates uncertain demand and reduces the manufacturers' motivation to implement CSC practices. Further, structural problems in developing countries such as water and energy supply present an additional challenge (Cezarino, et al., 2021).

3.8 Marketing-Related Challenges in Developing Countries

The marketing-related challenges of CSCs in developing countries relate to the creation of market and customer demand for circular products (Sohal, et al., 2022; Ngu, et al., 2020). Challenges, such as a lack of an established market for circular products, impede the implementation of CSCs in developing countries (Sharma, et al., 2016). Likewise, competition between new products and circular products affects the implementation of CSCs (Ngu, et al., 2020), as consumers often have a preference for the new products (Karuppiah, et al., 2021).

A summary of the challenges in the implementation of CSCs identified in this research is provided in Appendix A.

4. Circular Supply Chain Challenges in Zambia

Zambia, like other developing countries, faces challenges in the implementation of CSCs on the governmental, financial, technological, knowledge-related, managerial, regulatory framework, social, and market-related level (Banda, et al., 2023; Sichiweza, 2017; Mwanza & Mbohwa, 2019). The following subsections explore the specific challenges in the implementation of CSCs Zambia is facing.

4.1 Government–Related Challenges in Zambia

Concerning the government, studies such as Banda et al. (2023) reported a lack of investment incentives by the Zambian government on waste technologies that would support a circular economy. On the other hand, a lack of regulatory enforcement on waste management stands in the way of the creation of a CSC in Zambia. For example, research performed by Mwanza et al. (2016) summarizes the ineffectiveness of the Zambian government in enforcing already-existing environmental legislation on waste streams such as plastic waste. Similarly, Sakanyi and Kooma (2022) identify comparable issues traced back to a lack of legislative and administrative enforcement of environmental regulations. Banda et al. (2023) state that the inability of the Zambian government to sanction or convict lawbreakers abrogating waste management regulations is another obstacle that is hampering Zambia’s path toward a CSC. Furthermore, ineffective enforcement of extended producer responsibility (EPR) to management control waste, is a government-related challenge Zambia is facing (Mwanza & Mbohwa, 2019).

4.2 Financial–Related Challenges in Zambia

Financial challenges are among the major challenges to CSC actualization in Zambia. For instance, Hambulo (2014), points out financial failures by municipalities to procure waste bins meant to facilitate the segregation of waste streams discouraging households' participation in waste management. Sichiweza (2017) observed a lack of funding for municipalities which causes them to be unable to adequately deliver waste management services to the public. The lack of funds to finance waste management projects hinders the implementation of a CSC in Zambia as observed by Sambo et al. (2020). A lack of financial resources has also been observed to impede innovative initiatives. For example, improvements in waste recovery projects, efficient solutions in waste management, and concepts to implement CSCs in Zambia (Gweme, et al., 2016).

4.3 Technological–Related Challenges in Zambia

The lack of technical expertise is a challenge in implementing CSCs in Zambia. For instance, Nalwamba (2022) describes that the level of technical training on the handling of electronic waste (“E-waste”) in Zambia is not adequate. Demonstrating that communities in Zambia are not fully aware of the handling of E-waste.

A similar finding is made by Sichiweza (2017), who found a shortage of technically qualified staff in the management of solid waste. Insufficient technical skills in waste management have been highlighted as a key barrier to the actualization of CSCs in many developing countries (Ahmed et al., 2022; Yusop et al., 2016). In other studies, such as Mwanza and Mbohwa (2019), it has been concluded that Zambian businesses do not make use of the most up-to-date recycling technology to recycle plastic waste.

4.4 Knowledge–Related Challenges in Zambia

There is a noticeable lack of knowledge within CSCs in Zambia. Hambulo (2014) describes in his research focusing on the engagement of stakeholders in waste management, that education on environmental topics is insufficient in schools, which goes along with a lack of public awareness in communities. Sichiweza (2017) describes inefficient attempts of local authorities to educate households on correctly dealing with solid waste and meeting requirements to achieve a CSC. Madekivi (2017) concludes that Zambian people consist of a low understanding of the value of their waste and the need to separate waste. In addition, research conducted by Banda et al. (2023) and Sakanyi & Kooma (2022) mentions the lack of knowledge of CSC practices among the people in Zambia as a barrier to CSC implementation.

4.5 Management–Related Challenges in Zambia

The management-related challenges of CSC implementation are described by Gweme et al. (2016). They describe a low level of participation in CSC projects among senior managers of institutions tasked with environmental protection. Such managers lack the motivation to sustain and promote CSC initiatives in communities. Similarly, Banda et al. (2023) observed that waste management agencies in Zambia lack top management commitment towards waste control and management.

4.6 Framework–Related Challenges in Zambia

Framework-related challenges to CSC implementation in Zambia are mainly related to ineffective regulations. For example, Hambulo (2014) found that the regulations for the disposal of waste are lax and that violators are most often not subject to any kind of punishment for their illegal actions. In addition, Sichiweza (2017) verifies that there is no legislative framework to facilitate community involvement in managing waste. Likewise, Mwanza and Mbohwa (2017) found that the absence of laws on collecting and treating waste is a barrier to the development of CSC practices in Zambia. Further, Mwanza and Mbohwa (2019), observed that the Zambian government does not have sufficient laws or rules in place for the efficient handling of plastic waste.

4.7 Social–Related Challenges in Zambia

Social challenges of CSCs in Zambia, relate to the attitude and culture of people in Zambia and their perception towards circular supply chain principles. For instance, Sichiweza (2017), observed a poor attitude and culture among communities in Zambia towards waste reduction. Equally, Mwanza & Mbohwa (2019), observed similar challenges among local communities. For instance, a lack of participation by Zambian households in plastic recycling schemes has been identified. Sambo et al (2020) summarize that waste separation processes within Zambian communities are hardly existing.

4.8 Marketing–Related Challenges in Zambia

Market challenges have been described by researchers as a lack of customer demand for remanufactured and recycled products (Genovese, et al., 2017). In Zambia, there are not many marketing challenges associated with a CSC implementation. However, Mwanza & Mbohwa (2017), observed in their reverse logistics barriers study a weak demand for recycled resin products in Zambia. The lack of demand for recycled products hinders the development of a CSC in Zambia (Mwanza & Mbohwa, 2017).

A summary of the challenges of the circular economy in Zambia identified from the literature is provided in Appendix B.

5. Discussion

5.1 Challenges facing developing countries when implementing circular supply chains

From the literature, governments in developing countries lack the vision, rules, or policies necessary to enable CSCs. There is also a lack of enforcement on the part of governments on pre-existing rules and regulations regarding CSCs. This conclusion is related to the findings that Hull et al. (2021) and Sakanyi & Kooma (2022) arrived at, in which they found that the lack of support from the government was a barrier to the adoption of CSCs in developing countries**.** Further, due to a shortage of funds to finance CSC projects, developing countries are limited to successfully implementing CSCs. This inference is supported by the findings of Sohal et al. (2022), who pointed out that the majority of firms in developing nations are small to medium enterprises (SMEs), and as a consequence, they do not have the funds to engage in CSCs. In the same way, there is a significant shortage of technical know-how on the most recent technology, and information exchange is very limited. These challenges have been highlighted by Sichiweza (2017) and Mwanza and Mbohwa (2019), who also reported a lack of access to new circular economy technology, as well as information exchange and a lack of technical competence.

As a result from the low level of knowledge and awareness on CSC concepts, the majority of people in developing countries do not have in-depth knowledge of practices associated with CSCs, such as the reuse and remanufacturing of items. Madekivi's (2017) findings align with this finding since the author also observed knowledge gaps related to a lack of environmental education and CSC in developing countries. Additionally, management in public waste management institutions is less dedicated to supporting the implementation of CSCs. The unwillingness to assume additional responsibilities and the fear of financial burdens are the primary motivating factors behind the lack of commitment. This view is consistent with that made by Gweme et al. (2016), Banda et al. (2023), and Hull et al. (2021), who acknowledged the lack of managerial commitment among key environmental institutions in developing countries. The absence of regulatory frameworks to govern the adoption of CSCs is another barrier. This finding is corroborated by Sichiweza, (2017), who also highlighted the absence of regulatory frameworks to oversee the treatment of waste in Zambia. In addition, Ahmed et al. (2022) and Okafor et al. (2020) come to the same conclusion when they noted the absence of regulatory frameworks in developing countries to lead changes in law, company practices, and consumer behaviors when transitioning to a CSC.

Furthermore, people have unfavorable attitudes about recycled, reused, and remanufactured items socially owing to worries about the product's quality, and they have a low preference for products that fall into these categories. Likewise, people have a negative attitude and culture toward CSCs, which is a major barrier to their adoption. These findings are also disclosed by Karuppiah, et al., (2021); Sambo, et al., (2020) in which similar people's perceptions of reusable and remanufactured products were observed by the authors in developing countries. Equally, in developing countries, there is a lack of consumer demand for reused or remanufactured products. The development and implementation of CSCs are hindered as a result of this. Further, the presence of new items in the market acts as a barrier to the implementation of CSCs in developing countries, as pointed out by Ngu et al.(2020); Sharma et al., (2016).

5.2 Circular Supply Chain Implementation Challenges in Zambia and Developing Countries

The lack of government support due to a lack of vision, laws, and policies is a challenge that exists in other developing countries (Hull, et al., 2021) while in Zambia laws and policies exist what lacks is government enforcement (Mwanza, et al., 2016). Insufficient funding for CSC projects is common in all developing countries including Zambia. This finding corresponds to Sohal, et al (2022) findings on the lack of financing CSC projects in developing countries and Sichiweza, (2017) findings which highlight financial failures by

municipalities in Zambia. Likewise, insufficient levels of knowledge of the latest technologies are common both in Zambia and in developing countries. This finding is affirmed by Yusop, et al., (2016) and Mwanza & Mbohwa (2019) findings in which technical challenges in Zambia and developing countries were spotted. The lack of awareness and education is another common implementation challenge facing Zambia and developing countries. In both cases, people are not fully informed and education on the CSC is limited (Yadav, et al., 2023; Ngu, et al., 2020; Madekivi, 2017). In Zambia and developing countries, top management commitment remains a common challenge to effectively implement CSCs. Gweme, et al., (2016) findings were analog to this research finding. In their study, the authors witnessed low participation and a lack of drive among senior managers in the public and private sectors to support CSC implementation in developing countries. Similarly, ineffective legal framework barriers are observable in Zambia and developing countries (Kazancoglu, et al., 2021)). Unlike developing countries, in Zambia, regulatory frameworks encouraging community engagement in waste management are also non-existence (Hambulo, 2014). Further, a contradiction in people's social behavior in Zambia and developing countries was observed. That is, people in Zambia have a poor attitude and culture towards CSCs while in developing countries, people usually have negative perceptions of reusable and remanufactured products. These findings align with Karuppiah, et al., (2021); Sambo, et al., (2020) research findings. However, the lack of market demand for reusable/remanufactured products is consistent in developing countries. Consumers prefer new products to reusable/remanufactured as a result demand is low in Zambia and developing countries.

Based on the above, the findings confirm that most of the CSC implementation challenges in Zambia relate to those in other developing countries. However, only a few specific challenges such as government, regulatory framework, and social challenges have been noted to be different and do not relate to those in other developing countries.

6. Conclusion

The implementation of CSCs in developing countries is critical to advance sustainability and environmental opportunities. This research aimed to explore nd summarize the country-specific challenges of CSC implementation in the example of the developing country Zambia. To achieve this goal, a literature review of articles on CSC implementation were identified from online databases. The findings obtained from the targeted and reviewed articles, provided answers to the research questions. The challenges of CSC implementation facing developing countries with a specific focus on Zambia were noted and divided into different categories of challenges, such as governmental, financial, technological, knowledge-related, managerial, legal, social, and marketing-related challenges. Some challenges such as technology, knowledge, management, regulatory framework, and marketing were observed to relate to developing countries and Zambia. However, some specific challenges associated with the government, regulatory framework, and social challenges were different and do not relate to Zambia and developing countries.

Therefore, this research contributes to the existing knowledge of CSCs by bringing together existing literature on the challenges of CSC implementation and provides a structured analysis to enable a better understanding of the challenges of CSC implementation in developing countries. Further, based on the findings, the research recommends that governments in developing countries prioritize the implementation of current laws and regulations on CSCs. This is because CSCs are becoming more important. It is of the utmost importance that support be offered, not only in the form of commitment but also in the form of funding for CSCs. To enable the development of skills and a process of exchanging information within the phase of implementation, collaborative partnerships and technical training are required. People should also be

educated and made aware of the CSC, and leaders should establish CSC objectives as well as strategies within their organizations. Further, to facilitate the establishment of CSCs, governments should encourage the use of items that can be reused and remanufactured.

Despite the contribution provided by the research, it is still limited in some ways and offers future research with research avenues. Firstly, the study was carried out using a literature review of previous studies. Future research should consider conducting a survey or case study to facilitate an in-depth analysis of the research. Secondly, the research only involved secondary data. Future research should consider primary data to provide unique and original insights into the challenges. Lastly, the research used a single example approach of a developing country to compare the challenges of CSC implementation. Future research should consider a multiple-example approach of developing countries for better comparisons of country-specific challenges of CSC implementation.

References

Ahmed, Z., Mahmud, S. & Acet, H., 2022. Circular economy model for developing countries: evidence from Bangladesh. Heliyon, Volume 8.

Banda, K., Mwanaumo, E. M. & Mwanza, B. G., 2023. Circular Economy: An Antidote to Municipal Solid Waste Challenges in Zambia. In: Recycling Strategy and Challenges Associated with Waste Management Towards Sustaining the World. s.l.:Intech Open.

Bhatia, M. S., Jakhar, S. K. & Dora, M., 2022. Analysis of Barriers to Closed-Loop Supply Chain: A Case of the Indian Automotive Industry. IEEE Transaction on Engineering Management , 69(5).

Cezarino, L. O. et al., 2021. Diving into emerging economies bottleneck: Industry 4.0 and implications for circular economy. Management Decision, 59(8), pp. 1841-1862.

Dora, M., Manjot , B. S. & Gallear, D., 2016. Supply chain in a circular economy: a multidimensional research agenda. 3rd International Conference on Green Supply Chain.

Genovese, A., Adolf , A. A., Figueroa, A. & Koh, S. L., 2017. Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications. Omega, 66(PB), pp. 344-357.

Goya, S., Esposito, M. & Kapoor, A., 2016. Circular economy business models in developing economies: Lessons from India on reduce, recycle, and reuse paradigms. Thunderbird International Business Review, pp. 720-739.

Gweme, F., Maringe, H., Ngoyi, L. & Stam, G. v., 2016. E-Waste in Zimbabwe and Zambia. Chinhoyi, Zimbabwe, Conference: 1st Institute of Lifelong Learning and Development Studies International Research Conference, Chinhoyi University of Technology.

Hambulo, C., 2014. Stakeholder Participation in Solid Waste Management in Selected Zambian Urban Primary Schools of Lusaka, Lusaka: University of Zambia.

Hull, C. E., Millette, S. & Williams, E., 2021. Challenges and opportunities in building circular-economy incubators: Stakeholder perspectives in Trinidad and Tobago. Journal of Cleaner Production, Volume 296, pp. 1-12.

Karuppiah, K. et al., 2021. Inhibitors to circular economy practices in the leather industry using an integrated approach: Implications for sustainable development goals in emerging economies. Sustainable Production and Consumption, Volume 27, p. 1554–1568.

Kazancoglu, I., Sagnak, M., Mangla, S. . K. & Kazancoglu, Y., 2021. Circular economy and the policy: A framework for improving the corporate environmental management in supply chains. Business Strategy and the Environment, 30(1), pp. 590-608.

Low, J. S. C., Tjandra, T., Lu, W. F. & Lee, H. M., 2016. daptation of the Product Structure-based Integrated Life cycle Analysis (PSILA) technique for carbon footprint modelling and analysis of closed-loop production systems. Journal of Cleaner Production , Volume 120, pp. 105-123.

Madekivi, T., 2017. Effectiveness of Recycling Intiatives in the City of Lusaka Zambia-Case of Ng'ombe Compound , Turku and Salo: Turku University of Applied Sciences.

Mangla, S. et al., 2018. Barriers to effective circular supply chain management in a developing country context. Production Planning and Control., 29(6), pp. 551-569.

McCloud, C., 2023. shippingsolutions.com. [Online] Available at: https://www.shippingsolutions.com/blog/circular-supply chains#:~:text=A%20circular%20supply%20chain%20offers,where%20manufacturers%20discar %20product%20waste. [Accessed 7 August 2023].

Millettea, S., Williamsa, E. & Hullb, E. C., 2019. Materials flow analysis in support of circular economy development: Plastics in Trinidad and Tobago. Resources, Conservation & Recycling, Volume 150, pp. 1-8.

Mwanza, B. G. & Mbohwa, . C., 2017. Major Obstacles to Sustainability in the Plastic Industry. Stellenbosch, 14th Global Conference on Sustainable Manufacturing, GCSM 3-5 October 2016, Stellenbosch, South Africa.

Mwanza, B. G. & Mbohwa, C., 2019. Reverse Logistics Barriers: A Case of Plastic Manufacturing Industries in Zambia. s.l., International Conference on Industrial Engineering and Engineering Management (IEEM).

Mwanza, B. G. & Mbohwa, C., 2019. Technology and Plastic Recycling: Where are we in Zambia, Africa?. s.l., International Association for Management of Technology IAMOT 2019 - Managing Technology for Sustainable and Inclusive Growth Conference Proceedings.

Mwanza, B. . G., Mbohwa, C. & Telukdarie, A., 2016. Reverse Logistics Framework for PET Bottles. s.l., Proceedings of the American Society for Engineering Management 2016 International Annual Conference.

Nalwamba, D. S., 2022. The Electronic Waste Management Crisis - A Situation Analysis of Zambia, Lusaka: Research Square .

Ngu, J. H., Lee, D. M. & Osman, M. S. B., 2020. Review on current challenges and future opportunities in Malaysia sustainable manufacturing: Remanufacturing industries. Journal of Cleaner Production, Volume 273, pp. 1-13.

Nnorom, I. C. & Osibanjo, O., 2011. Overview of Prospects in Adopting Remanufacturing of End-of-Life Electronic Products in the Developing Countries. International Journal of Innovation, Management and Technology, 1(3), pp. 328-338.

Okafor, C. et al., 2020. Implementation of circular economy principles in management of end-of-life tyres in a developing country (Nigeria). AIMS Environmental Science, 7(5), p. 406–433.

Sakala, W. D. & Moyo, S., 2017. Solid Waste Recycling and Job Market in Zambia. Sustainable Resources Management Journal, 2(6), pp. 1-9.

Sakanyi, G. & Kooma, E. . H., 2022. Challenges and Opportunities Associated with Solid Waste Management in Chililabombwe District, Zambia. Texila International Journal of Public Health, pp. 2520-3134.

Sambo , J., Muchindu , M., Nyambe , S. & Yamauchi , T., 2020. Sustainable Solid Waste Management: An Assessment of Solid Waste Treatment in Lusaka, Zambia. Sanitation Value Chain, 4(2), pp. 39-50.

Saroha, M., Garg, D. & Luthra, S., 2018. Key Issues and Challenges in Circular Supply Chain Management Implementation- A SystematicReview. International Journal of Applied Engineering Research, 13(9), pp. 91-104.

Sharma, V., Garg, S. K. & Sharma, P., 2016. Identification of major drivers and roadblocks for remanufacturing in India. Journal of Cleaner Production, Volume 112, p. 1882e1892.

Sichiweza, E., 2017. Participation of Households in Solid Waste Management and Circular Economy Towards Sustainability: A case study of Kabwe Town, Central Province of Zambia , Enschede: University of Twente.

Silva, O. W. D. & Morais, D. C., 2021. Transitioning to a circular economy in developing countries: A collaborative approach for sharing responsibilities in solid waste management of a Brazilian craft brewery. Journal of Cleaner Production, 319(128703).

Snyder, H., 2019. Literature review as a research methodology: An overview and guidelines. Journal of Business Research, Volume 104, pp. 333-339.

Sohal, A., Nand, A. A., Goyal, P. & Bhattacharya, A., 2022. Developing a circular economy: An examination of SME's role in India. Journal of Business Research, Volume 142, pp. 435-447.

Tranfield, D., Denyer, D. & Smart, P., 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review.. British Journal of Management, Volume 14, pp. 207-222.

Webster, J. & Watson, R. T., 2002. Analyzing the past to prepare for the future: Writing a literature review. Management Information Systems Quarterly, 26(3).Wellesley, L., Preston, F. & Lehne, J., 2019. Chatthamhouse.org. [Online] Available at: https://www.chathamhouse.org/2019/05/inclusive-circular-economy/2-challenges-scaling-circular-economy-developing-countries[Accessed 1 June 2023].

Yadav, H., Soni, U. & Kumar, G., 2023. Analysing challenges to smart waste management for a sustainable circular economy in developing countries: a fuzzy DEMATEL study. Smart and Sustainable Built Environment, 12(2), pp. 361-384.

Yusop, N., Wahab, D. & Saibani, N., 2016. Realising the automotive remanufacturing roadmap in Malaysia: challenges and the way forward. Journal of Cleaner Production, Volume 112, pp. 1910-1919.

CONSEQUENCES OF NATURAL GAS SHORTAGE ON SUPPLY CHAINS IN AUSTRIA

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ABSTRACT

Purpose: The scarcity of natural gas as a significant threat became highly evident since the beginning of the Russia-Ukraine conflict. It is essential to understand the impact on national supply chains (SC) in case of import restrictions or any other disruptions. A holistic approach is vital to identify the most affected sectors or businesses. Additionally, it is necessary to investigate and understand indirect consequences caused by cascading effects in SCs.
Methodology: The study modelled the natural gas dependency of SCs in Austria, from the national interconnection hub to gas customers in a business context, and visualized it through a graph to enhance awareness of interdependencies. Based on the graph, a simulation was designed to mimic the potential reaction to a shortage of specific nodes in the SC.
Findings. The dataset included nodes, edges, and characteristics based on natural gas usage (as a material source for production or for the operation of machines or heating) to enhance the understanding of the SC. The simulation identified the independencies and nodes most strongly affected.
Limitations of the research: This study has limitations because it is focused on a national and, therefore, geographically limited context. Although the simulation did not consider the available storage volumes in the natural gas network, it showed significant interdependencies between sectors.
Practical implications: The research indicated that there was insufficient information and data available to monitor potential natural gas shortages and their effects on national SCs at the state level.
Originality/Value: This study provides an initial holistic overview of the natural gas SC in Austria to increase awareness of existing dependencies. The simulation improved the understanding of the aftermath of a shortage, supporting the estimation of impacts, complementing existing practices in managing system infrastructure, and ensuring a continued national supply. Engaging in discussions with domain experts further increased the validity of the approach.

Keywords
Impact estimation, Interdependencies, Simulation, Natural Gas Shortage, SC

Introduction

Due to its essential role in various sectors of the economy, a shortage of natural gas can pose a significant threat and cause severe disruption to national businesses. Natural gas is a vital energy source used for generating electricity, industrial processes, heating, and as a feedstock for petrochemicals. Manufacturing, agriculture, and transportation industries heavily depend on a consistent supply of natural gas. Any shortage leads to surging energy prices, rising operational costs, reduced profitability, and potential production cutbacks or shutdowns. Furthermore, the scarcity of natural gas can unveil interdependencies among sectors as SC disruptions in one industry can affect others through a cascading effect. For example, a shortage of natural gas could have an impact on power generation, which in turn could have an impact on communication networks, and essential infrastructure, thereby amplifying the economic and societal consequences (Dujak et al., 2019).

As a result, the accessibility of natural gas is closely linked to the stability and resilience of the economy. To be more holistic, this accessibly is an issue of raw material resilience and at the core of the EU Commission's "Raw Materials Initiative - Securing Europe's Supply of Goods Needed for Growth and Jobs" (European Commission, 2008) and the Communication "Commodity Markets and Raw Materials: Challenges and Solutions" (European Commission, 2011). As early as 2008, the Commission recognized

the strategic importance of the Raw Materials Initiative. It also formulated the desirability of defining an appropriate policy in this direction. Subsequently, the framework for issues such as sustainable access to raw materials inside and outside the EU, resource efficiency, and recycling was established. The demand for raw materials has increased both in the EU and in many of its member states – also in Austria, which serves as the research geographic context. Processes of extraction, processing, reuse, and recycling have evolved. In order to respond to changing conditions and at the same time be in line with international strategies and goals. Austria's efforts to continue to play a leading and stable role in Europe in the field of raw materials and the raw materials and basic materials industry entails the following: international planning and supporting activities in order to strengthen the resilience of the raw materials sector along the value chains and to reduce future supply risks (European Commission, 2008; European Commission, 2011; BLMFUW, 2011).

SCs within a country can be significantly affected by a shortage of natural gas. Numerous industries depend on natural gas for various purposes, including manufacturing, heating, and transportation. With reduced availability and rising prices caused by a shortage, businesses could experience difficulties in obtaining the needed energy supply, resulting in production delays, higher operational costs, and potential disruptions in logistics and distribution processes. Such a situation can trigger a ripple effect, affecting interdependent industries such as manufacturing, electricity, transportation logistics, agriculture, petrochemicals, and retail (Zamanian, 2020).

Companies that operate within interconnected networks aim to focus on managing a system, which comprises various economic actors, including suppliers, partners, allies, or customers (Iansiti and Levien, 2004). Within these networks, resilience is the ability to absorb risks by acting and using the resulting new knowledge to one's advantage (Lengnick-Hall et al., 2011). SC networks are highly vulnerable since disruptions can lead to costly downtime. Such failures can be caused by influencing factors such as technological change, crises, and shortages of raw materials. Adapting resilience to the value chain can prevent damage and at the same time open up new opportunities (Schrems, 2021). For these reasons, the improvement of the resilience of SC networks in the face of crises is all the more important. Value chain resilience refers "*to the capability of planning and designing the SC network in advance to anticipate unforeseen events and respond to them dynamically, while retaining control over the structure and functioning of the SC. The goal after such events is to achieve a robust operational state that is, if possible, more favourable than the pre-event scenario, resulting in a competitive advantage"* (Ponis and Koronis, 2012, p. 921). In the context of resilience, visibility is a crucial aspect because it provides the necessary insights and information for organizations to effectively anticipate, mitigate, and respond to disruptions. When managing SCs, visibility refers to the ability to track and monitor the movement of goods, information, and resources across various stages of the SC network.

Given that SCs undergo continuous change and visibility cannot be assumed, it is crucial to find approaches to investigate, simulate and analyse network vulnerabilities using a standardized process and methodology. Moreover, a standardized approach facilitates not only temporal comparisons between analysis of the same SCs but also comparisons between analysis of different SCs. Modelling the components involved (e.g., SC partners, critical infrastructures, and individual subsystems) and their interdependencies helps analyse and assess vulnerabilities. This type of abstraction also represents the dependencies between different areas, which are traditionally considered separately, and then estimates and visualizes potential impacts and cascade effects (Wei and Wang, 2010). This research illustrates this process, and aims to develop associated risks in scenarios within the context of natural gas shortage in the country of Austria.

The remainder of the paper is organized as follows. In section 2, the literature review describes the natural gas issue in the national context and the SC literature on risk management, disruptions, and resilience. Section 3 introduces the methodology and the steps taken to model the natural gas dependency of SCs in Austria based on scenario and data description and data analysis. Sections 4 and 5 present the findings

and discussion while section 6 concludes the paper with theoretical and managerial implications and future research avenues.

Literature Review

Alongside oil and coal, natural gas is one of the most important energy sources worldwide, accounting for 23.5% of global primary energy consumption in 2022 (Statista, 2022). In addition to the use of natural gas for heating, natural gas is used for electricity generation and industrial production processes (Emenike and Falcone, 2020), which is why the industrial sector, in particular, is an important customer, including in Austria (FGW - Fachverband der Gas- und Wärmeversorgungsunternehmungen, 2022). Natural gas supply is ensured by a supply consisting of numerous nodes responsible for individual components in the SC, which increases operational complexity. In addition, long lead times, insufficient communication between nodes and dependencies due to single source constellations further add to the complexity of the natural gas SC (Emenike et al., 2022). Adding to that, various events disrupted the natural gas SC, such as the most recent Russian invasion of Ukraine in 2022 (Chen et al., 2023). Reoccurring events like those show why resilience is needed in the natural gas SC.

Risk management created several strategies to minimize the negative consequences of disruptions. However, in response to the increasing frequency of interruptions, these consequences cannot be avoided entirely by risk management as these strategies focus only on known risks. This is why resilience in SC is needed to tackle prior unknown risks regarding the probability of occurrence and magnitude (Kayikci, 2021). Former literature in SC management defined resilience as the ability to bounce back after disruptions (Kamalahmadi and Parast, 2016). In particular, the former definition of resilience is no longer suitable for complex systems with numerous components since these systems and their components may often not be comparable to their prior states after a disruption. Therefore, the capacity to withstand, adapt to, and transform in the face of short-term disruptions and long-term changes is the definition used for this paper (Béné et al., 2016; Wieland and Durach, 2021).

Resilience thereby becomes an essential factor in the natural gas SC. As mentioned earlier, the availability of the natural gas SC is frequently impaired by disruptions. Not only the Russian invasion of Ukraine but also natural disasters disrupt the SC, such as Hurricane “Michael” in October 2018, which affected 400,000 consumers (Li and Hao, 2022). Primarily due to the extensive usage of natural gas in various SCs, it is necessary to build resilience. Previous studies found that resilience can be achieved mainly through a buildup of storage facilities, supplier diversification or the establishment of alternative suppliers (Zamanian, 2020), decentralization of SC structures, or optimization of transportation pipelines, to mention a few. However, it is necessary to analyze various risks and their impacts to implement and establish these resilience factors in the long term (Emenike and Falcone, 2020).

Methodology

To determine the consequences of a gas shortage in Austria in the form of a simulation model, it was first necessary to map dependencies in the network into a graph. By using a stochastic approach (König et al., 2019), it was thus possible to map the critical partners and systems to create awareness of the dependencies. Not only could this create visual mappings, but it also served to formalize a mathematical layer. To integrate the behavioural patterns of the respective organisations and components within the SC under consideration into the dependency graph model, the individual nodes in the graph are based on the mathematical model of a probabilistic Mealy automaton. A probabilistic Mealy automaton is an abstract concept of a machine with finitely many states; this machine can compute an output for an input (from a predefined set of symbols) based on its current state.

The simulation of dependency effects starts with one or more initial events that affect one or more nodes. The respective nodes behave according to their current state, and a state change is triggered in the node based on the transition function and the transitions defined in it. This state change generates an output

event, which is then formally sent out via the node's outgoing edges to all neighbouring nodes that depend on the initial node. In this way, the dependence graph represents the cascade effects and their further propagation in each simulation step. Simulating a sufficient number of times can produce a comprehensive overview that highlights the partners in the SC who are most impacted by an incident and the crucial points in the SC where such an incident could occur.

The initial event is assumed to be a shortage in the supply of natural gas. This shortage appears in the natural gas SC to Austria, but has its origin beyond Austria. For the model, therefore, the event "natural gas shortage" is used, which affects the node in the natural gas SC in Austria that is connected to the international network. Due to dependencies in the network, these states propagate throughout the network with time delays as individual natural gas storage and distributors were considered.

The initial stages, as well as the transition functions, were defined using qualitative and quantitative primary and secondary data in several sub-steps. In the first sub-step, the most important industrial natural gas consumers in Austria were identified based on published emission figures of companies in specific industries. An analysis of annual and sustainability reports enabled the additional concretization of these figures. In the second sub-step, these data were further expanded with qualitative and quantitative primary data. The secondary data research was sourced from reports, databases, and statistics, and the data collected through semi-structured interviews and collaborative workshops spanned five months, from January to May 2022. In the form of direct exchange rounds with companies and representatives of industry organizations (e.g. the Austrian Chemical Industry Association) as well as the preparation and implementation of an Austria-wide survey concerning the dependence of Austrian companies on natural gas and the recording of effects of supply interruptions or complete natural gas supply stops, further important insights were gained, which were taken into account in the simulation.

Findings

From a state perspective and in the case of a potential supply disruption in natural gas supply, that has not yet taken place, the available pre-emptive measures include both general preparedness measures established by the government, as well as specific preparations undertaken in response to any indicative signs of impending disruption. The primary precautionary measure involves close monitoring and observation of the national market, particularly the key SCs. This involves, most importantly, the acquisition and analysis of data and information from Austria's pivotal industries to detect any inconsistencies or disruptions in the affected value chains as early as possible, and if necessary, address them with diplomatic measures.

The following table (Table 1) displays an overview of interconnected industries in a natural gas shortage consideration – gathered from the empirical work and secondary data analysis – and emphasized the intricate network of dependencies that support a nation's economic stability.

Industry	Narrative description
Manufacturing	Manufacturing Industries, such as those related to chemicals, plastics, and metals, heavily rely on natural gas as an energy source and as a raw material. Shortages can cause production stoppages, which can affect the availability of essential goods.
Electricity	Natural gas is commonly used by power plants to generate electricity. Shortages may result in decreased power generation, which can have an impact not only on households, but also on critical infrastructure such as hospitals, data centres, and communication networks.
Heating and Cooling	Residential, commercial, and industrial heating systems depend on natural gas. Any shortages can affect comfort and cause operational disruptions, particularly in cooler regions.
Transportation Logistics	Natural gas is utilized as fuel for vehicles, especially in certain commercial fleets. The shortage can cause disruptions in the SC and an increase in transportation expenses.

Agriculture	The use of natural gas in the agricultural sector is fundamental for processes such as the production of fertilizers and crop drying. Shortages can impact both the production and distribution of food.
Petrochemicals	The petrochemical industry utilizes natural gas as a feedstock for the production of materials such as plastics, chemicals, and synthetics. Shortages of natural gas can result in decreased availability and increased costs of these products.
Construction	The use of natural gas in the construction industry includes heating, hot water, and drying processes. Shortages can impact project timelines and costs.
Retail	Due to manufacturing and distribution disruptions caused by the shortage, retailers might face challenges securing products. In the upstream process view, food production may be affected by fertilizer availability.
Finance and Technology	Disruptions can have economic impacts on financial markets, investor confidence, and overall economic stability. A stable energy supply is also critical for the operations of data centres and tech industries meaning that shortages of natural gas may cause power interruptions, which can impact digital services and operations.

Table 1 - Interconnected industries in natural gas shortage settings

To analyse and evaluate vulnerabilities between interconnected industries within the given natural gas SC, it was important to model the various players involved, from the origin national interconnection hub to gas customers in the business context including their interdependencies. This data generation and analysis approach facilitated the representation of dependencies among different areas that are traditionally analysed separately.

In a nutshell, the developed data set covers nodes, edges and entails characteristics based on natural gas usage (as a material source for production; for the operation of machines, or heating) for an enhanced interpretation of the SC. The simulation allowed to identify who is most strongly affected. Based on this analysis, actions are proposed that increase the resilience of the gas SC against shortages.

The simulation component utilized in the study and underlying context is constructed based on an abstract depiction of the natural gas SC (for example a generic and theoretical outline of Austria's national gas network). This rough representation models the relevant organizations and components along with their interdependencies through a directed graph called the "dependency graph". It generally consists of the following components: nodes and directed edges.

Nodes represent the various parts of the SC relevant for analysis. This includes SC partners, critical infrastructure, industrial customers, and diverse actors related to them. Additionally, the term nodes encompass actors, goods, and abstract components, such as an attacker.
The SC model developed describes the various functional states of a node in the SC. A representation consisting of three possible states could be defined as:

- State 1 signifies the situation when the node is functioning as expected without any issues.
- State 2 refers to the node functioning with certain limitations.
- State 3 represents severe problems where the node is no longer operating.

The behavior of a node in response to an event (e.g. a threat or a disruption problem), depends on its current state, which is defined by the transition function. In general, an incident or external influence causes the node to transition to a particular state as defined by the transition function. For instance, the occurrence of "power failure" causes a node to change from state 1 (fully functional) to state 3 (non-functional), as per the transition function. Nevertheless, the new state of the node depends on not only the initial problem but also its current state. In addition, the availability and the expected damage in nodes are included in the interpretation to provide a consistent overview of the situation of the entire SC.

Directed edges describe the dependencies between nodes and indicate the direction in which resources or goods are exchanged. They mainly represent the national natural gas pipelines including the respective branch pipelines. They also include supply pipelines representing the connection between a branch point and an industrial customer or a specific region. The authors opted for this abstracted representation of edges due to the networks' complexity and lack of data.
It is key for the approach, that the direction of directed edges also indicates the direction in which the effects of an incident can propagate within the dependency graph. This means that a disruption in one node can escalate along edges and have effects on another node and potentially lead to further problems there.

The developed graph enabled the visual processing of relationships within the natural gas SC. Additionally, formal (mathematical) capture of these relationships is possible. The graph primarily facilitated an initial analysis of the natural gas SC concerning its critical nodes. These could be nodes that have a large number of outgoing edges, thereby, supplying many organizations, or evolved as neuralgic points, which represent the only supplier in a specific part of the natural gas SC under consideration. Certain industrial consumers (such as those related to critical infrastructure) were explicitly identified in this graph. As this diagram is a formally described directed graph, further analysis of highly complex and strongly interwoven SCs can be achieved through certain metrics from graph theory, such as the inner and outer degrees of nodes.

The analysis of an incident in the natural gas SC followed two steps: First, the local reaction of each node is described by changes in state. Second, if the state of a node changes, it informs all its neighbours about it. Neighbouring nodes in turn react to the received message about state changes of the predecessor node and in turn, send messages to their neighbours. In this way, the propagation of a problem through the entire network is simulated and cascading effects are explicitly taken into account. The effects of shortage in the natural gas network were estimated based on a simulation of cascade effects (König et al., 2023). For the simulation, the nodes were divided into different types and qualitatively described for their potential states to make their change and the probability of this change from one state of the node to another comprehensible.

The initial event is assumed to be a shortage in the supply of natural gas. This arises in the SC to Austria but originates outside of Austria. For the model, therefore, the event "natural gas shortage" is used, which affects the node in the natural gas SC in Austria. The importance of the key network node (natural gas import node in the Eastern part of the country) evolved immediately. The simulated shortage corresponded to a reduced flow rate and interruptions or delays in the gas supply and changed the states of nodes in close connection with the key network node. With multiple runs, state transitions naturally changed, resulting in a distribution over all possible states at the end, which allowed a conclusion about the average impairment of a node.

Discussion

At the beginning of the underlying research investigations, there was significant emphasis on the natural gas supply topic, including the SC and the “natural gas as a product”. Since the onset of the COVID-19 pandemic, there have been consistent bottlenecks and supply issues. However, the situation regarding natural gas supply had been surpassed by reality, metaphorically speaking, and further escalated by the Russia-Ukraine conflict.

To identify dependencies among industrial customers and sectors, it was necessary to record affected companies and their industry classification. To define real dependencies and document the actual use of natural gas as a "product", it was necessary to link the natural gas consumption of these companies with its actual use. The research process of analysing data on the dependencies, production, and application areas of natural gas not only focused on individual business models and product specifications but especially on the interdependencies of companies and their partners throughout the SC. This study also took into account how natural gas is used and applied in other companies and industries in this specific

Austrian SC context. The approach allowed the team of researchers to consider the use and application of the product and to set the database for the simulation and the rough representation models.

Natural gas distribution networks can be described as systems consisting of hundreds or thousands of kilometres of lines and production facilities, including pipelines, storage and distribution centers, compressor stations, valves, and regulators. The developed model in this research does not include any detailed analysis of individual network elements or their configuration. The simulation's primary aim, including the data model developed within the scope of the study, is to illustrate the potential impacts of disturbances, to display transitive dependencies and cascading effects resulting from such disturbances, and thus gain a deeper understanding of the natural gas SC in Austria.

Conclusion

The research contributed to the European natural gas SC literature and evidently showed that there was insufficient data and information available for monitoring potential natural gas shortages and their effects on national SCs at the specific state level.

A first step of a holistic overview of the natural gas SC in Austria was provided to raise awareness of existing dependencies. The key contribution was an analysis of a rough representation of a natural gas SC about potential cascading effects due to natural gas shortages or supply interruptions. Simulations increased the understanding of the aftermath of a shortage to support existing best practices to protect infrastructures and the supply of businesses. Discussions with domain experts increased the validity of the theoretic approach.

It was problematic that the extent of natural gas required for the production of downstream products could not be recorded due to the limited data from basic statistics, and could only be estimated through technological inferences. By collecting more data through expert discussions, workshops, and a nationwide survey directly addressed to companies, deeper insights into the overall natural gas system were gained and a more solid basis for further analysis steps was established. The analysis steps involved surveying critical actors in the overall national natural gas network, identifying relevant industries affected by natural gas shortages, and presenting cascade effects in connection with supply bottlenecks.

To conclude, the outlook for both the national and European natural gas markets is expected to remain uncertain. This is due in part to the ongoing situation in Russia and Ukraine, which has damaged Russia's reputation as a dependable natural gas supplier. There is considerable evidence to suggest that the natural gas markets will remain highly competitive until at least 2023 and 2024, and likely beyond. Therefore, it is necessary to develop comprehensive strategies and viewpoints that provide an overview of the entire natural gas system. To achieve this aim, it is crucial to have shared data, a transparent understanding of the interconnectivity of individual economic sectors, and comprehensible mechanisms for decision-makers. These measures will help in handling the times of natural gas and other energy sources' disruptions and shortages, assessing their criticality, and reducing dependencies.

The study’s limitation concerns a national and thus regional limited context. Although the simulation does not consider available storage volumes in the natural gas network, the interdependencies of sectors were drastically shown – irrespective of the gas usage. In this study, the industries and companies identified by their consumption of natural gas were aligned and demonstrated by their individual significance and systemic importance. Yet, a comprehensive evaluation of natural gas dependency and criticality necessitates additional factors. Future research might delve into this issue as at present, the criticality of a company is primarily determined by its industry's criticality.

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References

Béné, C.; Headey, D.; Haddad, L.; Grebmer, K. (2016), "Is resilience a useful concept in the context of food security and nutrition programmes? Some conceptual and practical considerations", *Food Sec*, Vol. 8, No. 1, pp. 123–138.

BMLFUW, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Sektion II Nachhaltigkeit und ländlicher Raum. (2012), "Ressourceneffizienz Aktionsplan (REAP) – Wegweiser zur Schonung natürlicher Ressourcen", available at https://www.bmk.gv.at/themen/klima_umwelt/nachhaltigkeit/ressourceneffizienz/publikationen/aktionsplan_ressourceneffizienz.html (accessed 14 August 2023).

Chen, S.; Bouteska, A.; Sharif, T.; Abedin, M. Z. (2023), "The Russia–ukraine war and energy market volatility: A novel application of the volatility ratio in the context of natural gas", *Resources Policy*, Vol. 85, p. 103792.

Dujak, D.; Šebalj, D.; Koliński, A. (2019), "Towards Exploring Bullwhip Effects in Natural Gas SC", *Scientific Journal of Logistics*, Vol. 15, No. 4, pp. 557-569.

Emenike, S.N. and Falcone, G. (2020), "A review on energy SC resilience through optimization", *Renewable and Sustainable Energy Reviews*, Vol. 134, p. 110088.

Emenike, S.N., Ioannou, A. and Falcone, G. (2022), "An integrated mixed integer linear programming model for resilient and Sustainable Natural Gas SC', *Energy Sources, Part B: Economics, Planning, and Policy*, Vol. 17, No. 1.

European Commission. (2008), "Die Rohstoffinitiative — Sicherung der Versorgung Europas mit den für Wachstum und Beschäftigung notwendigen Gütern: MITTEILUNG DER KOMMISSION AN DAS EUROPÄISCHE PARLAMENT UND DEN RAT", available at https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0699:FIN:de:PDF (accessed 14 August 2023).

European Commission. (2011), "Grundstoffmärkte und Rohstoffe: Herausforderungen und Lösungsansätze", available at https://www.europarl.europa.eu/meetdocs/2009_2014/documents/com/com_com(2011)0025_/com_com(2011)0025_de.pdf (accessed 14 August 2023).

FGW - Fachverband der Gas- und Wärmeversorgungsunternehmungen. (2022), "Zahlenspiegel 2022 – Gas und Fernwärme in Österreich", available at https://www.gaswaerme.at/media/medialibrary/2022/09/zasp22_hi.pdf (accessed 11 August 2023).

Isanti, M. and Levienm R. (2004), "Strategy as Ecology", *Harvard Business Review*, Vol. 82, No. 126, pp. 68-78.

Kamalahmadi, M.; Parast, M. M. (2016), "A review of the literature on the principles of enterprise and SC resilience: Major findings and directions for future research.", *International Journal of Production Economics*, Vol. 171, pp. 116–133.

Kayikci, Y. (2021), "Stream processing data decision model for higher environmental performance and resilience in sustainable logistics infrastructure", *Journal of Enterprise Information Management*, Vol. 34, No. 1, pp. 140–167.

König, S., Rass, S., Rainer, B. & Schauer, S. (2019), „Hybrid Dependencies Between Cyber and Physical Systems". In: Arai, K., Bhatia, R., Kapoor, S. (eds) *Intelligent Computing. CompCom 2019. Advances in Intelligent Systems and Computing*, Vol 998. Springer, Cham.

König, S.; Connolly, L.; Schauer, S.; O'Connor, A.; Carroll, P.; McCrum, D. (2023), "Combining Cascading Effects Simulation and Resilience Management for Protecting CIs from Cyber-Physical Threats". in *Proceedings of the 32nd European Safety and Reliability Conference (ESREL 2022).* pp. 2741-2748, ESREL 2022, Dublin, Ireland, 28/08/22.

Lengnick-Hall, C. A.; Beck, T. E.; Lengnick-Hall M. L. (2011), „Developing a capacity for organizational resilience through strategic human resource management", *Human Resoure Management Review,* Vol. 21, No. 3, pp. 243-255.

Li, S. and Hao, Y. (2022), „Research on the cooperation of emergency response subjects for the shortage of Urban Natural Gas Energy", *Mathematical Problems in Engineering*, pp. 1–26.

Ponis, S. and Koronis, E. (2012), „SC Resilience: Definition of concept and its formative elements.“, *Journal of Applied Business Research,* Vol. 28, No. 5, pp. 921-935.
Schrems, A. (2021), “*Resilienz - Die organisationale Widerstandsfähigkeit“,* 1st version. Vienna.
Statista. (2022), “Energieverbrauch weltweit”, available at https://de.statista.com/statistik/studie/id/6691/dokument/energieverbrauch-weltweit/ (accessed 11 August 2023).
Wei, H.; Wang, E. T. G. (2010), „The strategic value of supply chain visibility: increasing the ability to reconfigure”, European Journal of Information Systems, Vol. 19, No. 2, pp. 238-249.
Wieland, A.; Durach, C. (2021), “Two perspectives on SC resilience”, *Journal of Business Logistics*, Vol. 42, No. 3, pp. 315–322.
Zamanian, M. R. (2020), “A Fuzzy Goal-Programming Model for Optimization of Resilience and Sustainable Natural Gas SC: A Case Study”, *Journal of Science and Engineering Elites*, pp. 135-156.

CONSUMER BEHAVIOUR IN CIRCULAR FOOD SUPPLY CHAIN

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ABSTRACT

Purpose: The objectives of this exploratory study are to understand the role of consumer behaviour in the circular economy to reduce food waste and identify alternatives to encourage consumers' contribution to the subject. The study is focused on Singapore, where the high population density and limited resources make the Circular Economy a key tool for reducing waste, improving resource management, and enhancing resource usage.
Design: First, an extensive literature review was conducted to get insights on food waste, consumer behaviour, and the circular economy. Secondly, a comprehensive survey questionnaire was created and distributed via social media platforms to collect qualitative and quantitate data from potential respondents. The collected data was categorised by relevant topics and analysed using descriptive statistics. Based on findings, key recommendations are made.
Findings: Results indicate that Singapore residents are conscious of the impacts of food waste and are willing to take steps to reduce it. However, gaps in knowledge and practical approaches to achieving this goal were also identified. Raising awareness, encouraging appropriate behaviour, enabling sustainable behaviour, and collaborating with stakeholders are strategies proposed and discussed in this study to influence consumer behaviour towards the circular food supply chain in Singapore.
Research limitations: By increasing the pool of respondents and gathering target data for each recommendation presented, a detailed framework for measuring the impact of consumer behaviour and creating targeted measures in the local and international context could be outlined. Perspectives from other stakeholders in the food supply chain may also be explored in future studies.
Practical implications: By understanding the impact of consumer behaviour on the circular economy, policymakers and industry stakeholders can develop more targeted and effective strategies to reduce food waste and promote the adoption of circular economy principles. Identifying gaps in existing measures also presents an opportunity to refine current approaches and achieve better outcomes.
Value: Amidst the current push by several companies, consumers, and authorities to improve sustainability and optimise resource utilisation, this study presents insights on how the circular food supply chain can be leveraged towards these goals.

Keywords: Circular Economy, Consumer Behaviour, Food Waste Reduction, Resource Management, Singapore

Introduction

In the Circular Economy, the supply chain model operates differently from the traditional linear supply chain. Rather than following the "Take, Make, Use, and Throw" strategy, the circular supply chain model follows a "Make, Use, Recycle or Reuse" strategy. In this latest model, the aim is to reduce waste and generate added value for products reaching the end of their useful life, this is achieved by reusing or recycling the materials and reintegrating them into the production cycle (De Angelis et al., 2018; Lavelli, 2021). A circular supply chain model in the food industry enables food waste to be recycled or repurposed, creating new value within the supply chain (Kabadurmus et al., 2022). Globally, different industries, consumers, and authorities are pursuing sustainability and optimised resource utilisation, with many adopting a circular strategy (Zhou et al., 2023; Rojas Lopez and Loh, 2023; MEWR & NEA, 2020; Gu, et al. 2020). This study, which focuses on Singapore, presents insights into how the circular food supply chain can be leveraged towards these goals and what could be the role of consumer behaviour and existing policies in the process.

Singapore has been globally lauded for its economic, urban, logistics and transport developments(LTA, 2019; Rojas Lopez et al., 2020). However, there is still room for improvement in the area of food waste

management. Food waste is one of the largest waste streams in the country, the generation has increased by 20% over the last decade. In 2020 and 2021 alone, the amount of food waste generated was 665,000 tonnes and 817,000 tonnes (23% increase), respectively, with a recycling rate of only 19% on average (Grandhi & Appaiah Singh, 2016; MEWR & NEA, 2020; Siow & Lee, 2020). Hence, there is a need to prioritise sustainability while balancing economic development and consumption needs, it is important to prioritise. By implementing a circular food supply chain, Singapore could not only reduce the waste sent to the landfill (hence reducing greenhouse emission and promoting environmental sustainability), but also strengthens food security and maximise overall usage of resources (NEA, 2023; Rezvani Ghomi et al., 2021).

Despite the growing interest in food waste in Singapore among both authorities and the public (consumers), research publications on the topic have not kept up with this trend, let alone on the overall circular food supply chain. Singapore recognises the importance of implementing a circular economy model to reduce waste generation, enhance resource management, and optimise resource usage (NEA, 2023). Research has indicated that sustainability transition is a collective effort of society (Rut et al., 2020). While transitioning towards a circular economy presents novel ways to generate value through various circular offerings, not all consumers have embraced circular behaviour in their consumption patterns (Chai et al., 2023; Rut et al., 2020). Understanding how consumer behaviour fits into the circular food supply chain, as aimed in this study, can help with the implementation of a top-down approach.

This study is a preliminary study that reviews existing policies or strategies in Singapore from the consumer perspective. Based on findings, suggestions for the government and private organisations to refine existing policies and/or develop targeted strategies enabling circular behaviour among consumers for better outcomes are proposed. The remainder of this manuscript is organised as follows, an overview of the Singapore context is provided next, including some of the current food waste management practices. Then, the methodology for data collection on consumer behaviour is outlined, followed by the presentation of the main results and discussion. Some concluding remarks, including study limitations and possible directions for future research, finalise the manuscript.

The Singapore Context

Located in Southeast Asia, Singapore is a densely populated island country with a strong economy (DoS, 2022). Considering its limited land and resources, sustainability is a key focus for the country. The government has implemented initiatives to promote sustainability, such as efficient public transport, emission reduction approaches, and providing green areas (CLC, 2020, 2021). Singapore also aims to improve residents' digital literacy, making technology more accessible, and embracing a myriad of digital tools to become a Smart Nation. Technological developments can be seen in finance, healthcare, supply chain, and transport, among other areas, with the main goal of enhancing city efficiency and improving quality of life (SmartNation, 2023). At the same time, the government is also promoting social activities to increase liveability and to foster social support and cohesion – locally referred to as "the kampong spirit" (OurSG, 2022).

High-rise buildings characterise Singapore's landscape, several being residential (Rojas Lopez et al., 2020). These buildings are equipped with common trash chutes where households dispose of food and general waste. Research has indicated that the convenience and simplicity of disposing food waste may decrease each household's responsibility in managing food waste, and consumers might take this convenience for granted instead of actively doing their part to help reduce food waste (Low & Chen, 2023). In contrast, countries like Taiwan and South Korea, implement a pay-as-you-throw system. This system requires consumers to pay for the total waste that they dispose, and this has helped to reduce overall waste. Other research as indicated that Singapore faces major challenges related to the mismatch in supplies and demand for food consumption as well as inefficient inventory management at households, food providers, and retailers' level (Kabadurmus et al., 2022; Siow & Lee, 2020).

The majority of the waste produced at country level, including food waste, is incinerated at Pulau Semakau, the only offshore landfill in Singapore. The process reduces the volume of waste by about 90% and energy is recovered for electricity generation. Noticing that the landfilled is expected to reach total capacity by 2035 (Rezvani Ghomi et al., 2021) and the high amounts of food waste generated, a circular economy approach or a circular food supply chain is critical for the country's long-term subsistence. Herein, active steps have been taken by authorities, including the plan to achieve zero waste by 2030. As such, Singapore could also better optimise the usage of their limited resources and prevent future scarcity (Low & Chen, 2023; MEWR & NEA, 2020; NEA, 2023). In the country, The National Environment Agency (NEA) is a statutory board that oversees environmental-related measures and policies. The National Environmental Agency (NEA) has introduced a hierarchy of four different food waste management approaches as illustrated in Figure 1.

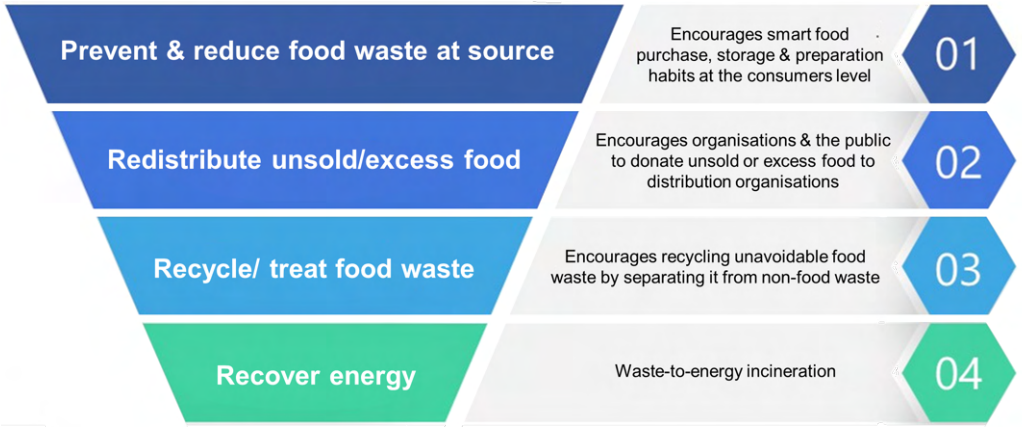


Figure 1: NEA Food Waste Management Hierarchy (adapted from MEWR & NEA, 2020).

The NEA food waste management approach targets stakeholders who commonly generate much food waste and can thus play a crucial role in enhancing the circular food supply chain. The top level of the hierarchy focuses on raising public awareness through education and outreach while encouraging Singaporeans to adopt healthy behaviours that minimise waste. The objective of this technique is to decrease food waste by using consumers. This is accomplished by implementing programs such as the Food Waste Reduction Outreach Program, which provides consumers with a recipe book with advice on food preservation. To encourage other consumers to reduce food waste, the NEA also trains ambassadors for the cause. At the second level, the aim is to encourage consumers and organisations to donate excess food to food distribution organisations and food banks. For this, NEA facilitates by providing guidelines to help consumers donate food responsibly. At the third level, unavoidable food waste is aimed to be reused. This is encouraged at a household level, as well as hawker centres, hotels, schools, and shopping centres. Waste is converted into compost, which is used mainly for compost. The fourth or lower level depicts the traditional or most often used approach in Singapore previously described, where energy is recovered from food waste through incineration.

This focus is not surprising, although food waste is common across the whole supply chain, much of it is generated by consumers, households, and restaurants, and here are plenty of opportunities to implement circular strategies and improve the overall food supply chain (Lavelli, 2021; Rut et al., 2020). Figure 2 depicts a linear food supply chain in Singapore, indicating in red the stakeholders mentioned. Besides these four level approaches, other alternatives or options that can help to close the loop on the food supply chain include developing and implementing on-site systems to treat food waste, building research & development (R&D) capabilities to test recycling innovation (e.g., using soya bean waste into useful food chain products), and legislations to require large industrial and commercial food waste generators to segregate their food waste for treatment and for developers to provide space for treating food waste on-site at new developments (MSE, 2023).

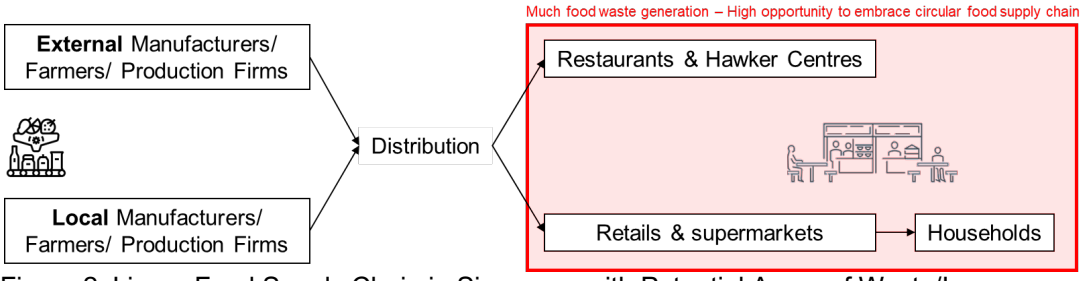


Figure 2: Linear Food Supply Chain in Singapore with Potential Areas of Waste/Improvement.

Data Collection

Data was collected through an online survey consisting of a combination of multiple-choice, ranking, and open-ended questions. The survey questionnaire was designed considering the online data collection approach and was thus kept simple and easy to complete. Questions were set based on information from the literature review and aimed to understand the role of consumer behaviour in the circular food supply chain and food waste management. The (possible) adoption of sustainability measures were also considered. The survey included questions aimed at evaluating the possible effectiveness and/or limitations of current measures to manage and reduce food waste in Singapore. Additionally, demographic information was collected from the respondents.

At this preliminary stage of the study, a chain-referral sampling approach was used, whereby the survey link was disseminated to the authors' personal and business contacts through messaging platforms and social media channels. After data cleaning and organisation, a total of 74 complete survey responses were used to analyse data for this study. Descriptive statistics are used to illustrate quantitative data. Qualitative data was organised by common themes. The data facilitated the identification of relationships between consumer behaviour and the circular economy principles, and it was discussed in relationship with existing measures. Based on identified gaps, possible (more targeted and effective) strategies to reduce food waste and promote a circular economy are proposed.

Results and Discussion

Out of the total 74 responses analysed, the gender distribution was almost equal, with close to 50% of the respondents being male and female. Nearly half the respondents (35 or 47%) were between 25 and 34 years of age, one young participant reported to be less than 16 years old (1%) and two participants were between 55 and 64 years of age (3%). At the time of the survey, three in five respondents (64%) held a university degree, and in slightly over one in five (20%) households, the average combined monthly income was reported to be more than 15,000 SGD or approx. 11,130 USD. Overall respondents' demographics are presented in Table 1. The group of respondents presents a good representation across various demographics. It comprised of individuals who, through their education, have been exposed to awareness of recycling, and also members from the older generation who offer varied perspectives. In terms of gender distribution, the group is also well-balanced. This comprehensive mix of respondents helps ensure a multidimensional understanding of the topic and provides perspectives from a spectrum of educational backgrounds, income levels and age. Based on responses and taking into consideration existing measures, some possible strategies are presented. The strategies are focused on raising awareness, encouraging and enabling sustainable behaviour, and collaborating with stakeholders. Being the main objective to influence consumers' behaviour and work towards improving the circular food supply chain in Singapore. These are explained in detail following the related findings.

Table 1. Survey Respondents' Demographics.

Age	Respondents (%)
Under 16 years	1 (1%)
16-24 years	22 (30%)
25-34 years	35 (47%)
35-44 years	4 (5%)
45-54 years	10 (14%)
55-64 years	2 (3%)

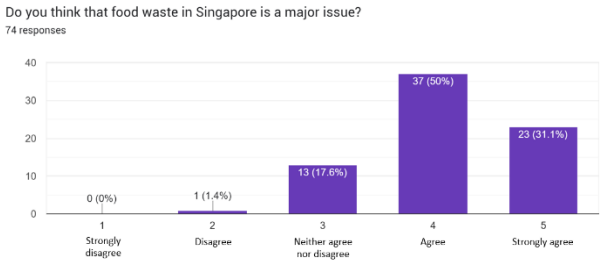
Gender	Respondents (%)
Male	39 (53%)
Female	33 (45%)
Prefer not to say	2 (2%)

Highest Education Level	Respondents (%)
Primary School	1 (1%)
Secondary School (A-levels)	2 (3%)
Diploma	18 (24%)
University Degree	47 (64%)
Masters	6 (8%)

Average combined monthly household income (SGD)*	Respondents (%)
Less than 3,000	9 (12%)
3,000 to 4,999	15 (20%)
5,000 to 6,999	9 (12%)
7,000 to 8,999	12 (16%)
9,000 to 10,999	6 (8%)
11,000 to 12,999	3 (4%)
13,000 to 14,999	3 (4%)
More than 15,000	17 (24%)

** 1 SGD = Approx. 0.74 USD*

Respondents were asked about their perceptions of their own knowledge regarding food waste in Singapore and their actions towards it using five points scale questions as shown in Figure 3. Most respondents (36 or 49%) reported having only an average understanding of the food wastage situation in Singapore. This indicates a potential gap that could be targeted with strategies focused on education to increase knowledge on the subject. They were also asked about their perception regarding food waste as a major/worrying issue in Singapore. In general, most respondents agreed or strongly agreed with it, with 50% (37) and 31% (21) responses, respectively. Furthermore, they were asked about their view or actions on aiming to reduce their own food wastage. A total of 34 respondents (46%) reported being very active in aiming to reduce it. However, when asked regarding how easy they find it to do so, the same number (34 respondents or 46%) presented a neutral answer, neither agreeing nor disagreeing with finding it easy. These responses indicate that while respondents are willing and actively taking action towards reducing food waste, more can be done to facilitate the process.



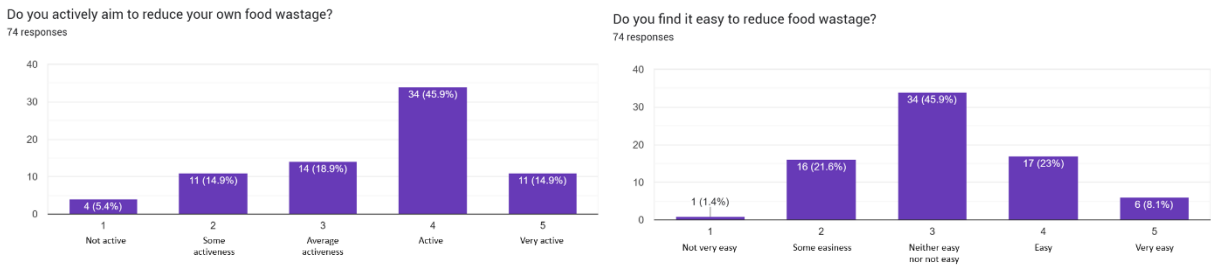


Figure 3. Perceptions of Knowledge and Actions Taken Regarding Food Waste.

Raising awareness can help overall consumers better know how to manage and reduce food waste. It is important for existing educational campaigns to be reviewed to bridge the gap in knowledge identified. Campaigns should be made appealing to the audience and possibly reflect local trends. Trends can help consumers to identify their role in the circular food supply chain, and this awareness could result in them becoming more mindful of their consumption and food waste habits. Leveraging Singapore's high internet access and tech-savvy population (DoS, 2022), Campaigns can be conducted through various social media channels, messaging platforms, or even dedicated apps. To reach a diverse audience, educational events at schools and organisations, as well as community outreach and engagement can also be considered. Being the aim to inform the public about the magnitude of the food waste issue in the country, its environmental and social impacts, and practical tips on reducing waste at home, during shopping, and dining out hence closing the supply chain loop.

Noticing that respondents consider being active in reducing their food waste, but the easiness of doing so is perceived at an average level, strategies to enable sustainable behaviour by improving the infrastructure and providing incentives to facilitate food waste reduction should be considered. In line with Singapore's efforts to become a smart nation and relying on its digital society (SmartNation, 2023), this could be achieved using innovative technology, such as smart refrigerators or meal-planning apps. Furthermore, promoting social/communal activities in residential areas like establishing edible community gardens and composting can also be considered. These would not only facilitate a circular food supply chain, but can contribute towards the kampung spirit of the country. Eventually, a more sustainable food system can be generated with the reduction in the environmental impact of food waste disposal.

In the survey, to identify the factors influencing the behaviour of respondents when buying groceries and food, they were asked to indicate ALL the factors/options they consider applicable from a list. In addition, they were also asked to indicate which of the selected factors is, in their view, the MOST IMPORTANT factor taken into consideration. The list of factors contained a total of 7 factors that were determined from the literature review and an "others" option as an open-ended answer for respondents to add any other factor they consider relevant. When purchasing food and groceries, the majority of respondents reported considering five key factors: Price, Flavour/Taste, Ingredients, Serving size, and Brand. It is noteworthy that, an equal number of respondents rated Flavour/Taste, Ingredients, and Serving size as important. Interestingly, upon analysing the responses regarding the factor of utmost importance, the majority of participants chose Price, Flavour/Taste, and Ingredients as their top choices. Only a few individuals selected the other available options, as indicated in Figure 4.

Note: the list was not presented in the above order in the survey, but instead in aleatory order was used for each response

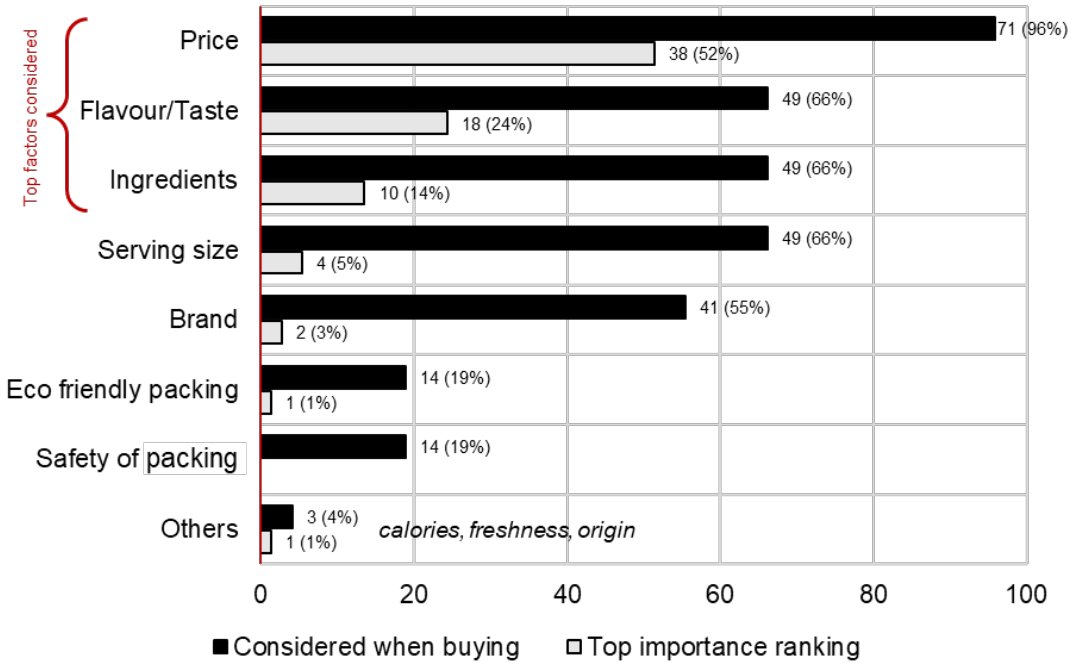


Figure 4. Factors Influencing Shopping Behaviour.

It is important to consider the mentioned shopping habits or factors that consumers value in the food waste management strategies, as this could help to enhance engagement and hence greater adoption of sustainable practices in reducing food waste. For example, in view that respondents (as consumers) prioritise price and flavour in their purchasing decisions, campaigns can highlight how reducing food waste can lead to cost savings and emphasize the support of flavourful sustainable brands. The strategies can consider include simple tips on meal planning (ingredients), portion control (serving size), and overall smart shopping choices. This can make the strategies relatable and actionable. Overall, it has been found that when consumers demand sustainable options and disposal alternatives (e.g. easy to compost food in case of any leftovers), organisations are motivated to adopt sustainable practices as well (Kabadurmus et al., 2022; Rut et al., 2020). This, in the longer term, can foster a collective responsibility and generate a better-informed society that makes positive decisions to improve the circular food supply chain.

The existing NEA Food Waste Management Hierarchy was presented to survey respondents, and they were asked to rank the strategies based on the frequency with which they implement it/them. A maximum of 4 points was assigned to the most commonly implemented strategy and 1 point to the least commonly implemented strategy. Interestingly, strategies across all 4 levels received a similar rating, with a grand average of 2.46 points. Respondents most commonly implement the top level of the pyramid strategy that focuses on “reducing food waste at the source” (average 2.55 points) and is related to education and increased awareness of food waste. The next frequently implemented strategy was reported to be “recycling food waste” (average 2.54 points), followed by “disposing of excess food” (average 2.43 points) – which is then recovered for energy, a strategy that is at the lowest level of NEA’s hierarchy. The least frequently adopted strategy was reported to be “donating excess food” (average 2.31 points). Herein, upon further review of the NEA website, it was noted that contact details of food distribution organisations and food banks are presented on the website. However, there is no address provided, and these are not categorised by location/region (NEA, 2023). Hence, this could be an indication that it is difficult for consumers to locate the closest organisation/food bank hindering food donation.

As part of the survey, respondents were also asked how they deal with excess perishable and non-perishable food, overall responses are summarised in Table 2. For excess (or left-over) perishable food, a large majority of respondents (49 respondents or 66%) indicated that they would keep it for the near future. Around one in four respondents (21 or 29%) indicated that they would discard the food, and a minority (4 respondents or 5% indicated that they would reuse the food for other purposes. The options of "sharing the food with friends or neighbours" and "donating it to food banks/less fortunate" were also presented. Interestingly, however, no respondents selected this option. This could be related to either food safety concerns, or to the mindset that sees sharing cooked food excess or leftovers as rude, which is often observed in the Asian culture. On the other hand, related to excess non-perishable food, it was also observed that most respondents (43 or 58%) indicated they would discard excess non-perishable food. This is an interesting observation, as excess non-perishable food could still be fit for consumption. For this category, sharing and donating were more selected as compared to excess perishable food with 11 (15%) and 9 (12%) respondents indicating it, respectively. Additionally, 10 respondents (14%) indicated that they keep the food for use in the near future. Similar to perishable food, a minority – in this case 1 respondent (1%), indicated that they reuse it for other purposes.

Table 2. Actions Taken on Excess/Leftover Food.

What do you do with excess/leftover food?	Perishable Respondents (%)	Non-perishable Respondents (%)
Discard	49 (66%)	43 (58%)
Share it with friends/neighbours	0	11 (15%)
Donate it to food banks/less fortunate	0	9 (12%)
Keep it for the near future	21 (29%)	10 (14%)
Reuse for other purposes	4 (5%)	1 (1%)

The reduced adoption of food donation strategies, especially for perishable food excess/leftovers, can be related to the inconvenience of locating (or accessing) food banks and food distribution organisations. One recommendation is to have a centralised portal providing detailed information on food distribution organisations, mainly on how to access them. In complement, collaborations between retailers, non-profit organisations, and government agencies can be leveraged to develop systems to collect and redistribute excess/leftover perishable and non-perishable food. This may include setting up accessible collection points for consumers (e.g. at supermarkets, food courts, and/or hawker centres) and partnering with delivery platforms to facilitate the distribution of excess/leftover food. Moreover, while the attitude towards and receiving food donations remains to be fully explored, it is important to showcase the potential benefits of sharing and donating food. Not only to collaborate with less fortunate individuals but also as an environmentally sustainable practice. An important consideration is to address misconceptions related to food safety concerns and cultural norms surrounding sharing cooked food excess. Community fridges and food-sharing platforms, coupled with success stories and positive impacts of food donation and food waste reduction efforts can motivate individuals to take action. These strategies can help Singapore to establish a more sustainable and efficient food circular supply chain with great community involvement.

Incentives and/or penalties could also be used to manage food waste, these might have a high impact considering that many respondents indicated price as the main factor considered with buying food. It is important for government agencies and organisations with thriving circular food supply chains to get involved in developing guidelines for incentives and penalties. This can ensure an ethical implementation, information tracking, exchanges of best practices and facilitation of peer-to-peer learning in the industry. Incentives can be considered for individuals/ households who donate and/or reuse excess food/leftovers. These may be provided in the form of rebates that has a direct impact on consumers' everyday lives and funding or support for organisations. On the other hand, penalties could be imposed on those with excess food waste generated. Herein, technology could be leveraged, for instance, the amount generated could be

tracked using tech-enhanced trash chutes. Noticing that implementing technological infrastructure can take time and cost considerations must be considered against the potential benefits.

Finally, while most of the above-mentioned strategies are mostly targeting individuals, different stakeholders must be involved and participate actively in their implementation. Authorities, supermarkets, restaurants, hawker centres, NGOs, and logistics companies play a crucial role. For instance, supermarkets can promote the sale of "imperfect" produce at discounted prices or using biodegradable packing, or food shops can offer smaller portion sizes, takeaway, and "doggy bag" options to help reduce overall food waste along the supply chain. An accessible and user-friendly platform can also help the dialogue and cooperation among various stakeholders involved in food waste management. Specialised task forces can also be created to assist in overseeing circular food supply chain undertakes and to establish specific guidelines to do so. Businesses may collaborate with research institutes to leverage technology and develop novel methods of creating waste-derived products and apply them to the industry. These strategies, among others, can aid Singapore in its quest to improve the circular food supply chain, reduce food waste, and foster a more sustainable and responsible food culture in the community.

Conclusion

This exploratory study has helped to shed light on consumers' knowledge and the role of their behaviour in the circular economy to reduce food waste. Based on the Singapore context, a survey was conducted. Responses were used to understand views on the food waste management situation in the country, consumer behaviour when grocery/food shopping, views and usage of current measures related to food waste management, and the most common approaches when dealing with excess/leftover food. Findings were used to point possible alternatives to encourage consumers' positive contribution to food waste management and the overall circular food supply chain.

Overall, respondents present a positive attitude towards working on reducing their own food waste, however, they admit to having only an average knowledge of the issue in the country. Price was the most commonly considered factor when shopping for groceries/food, followed by flavour/taste, and ingredients Regarding the existing NEA Food Waste Management Hierarchy, most respondents indicated taking actions related to the top of the pyramid that can be related to education and awareness and the least frequently adopted strategy was reported to be donating excess food. This was again reflected in respondents' answers for actions to deal with excess/leftover food, where a minority or no respondents mentioned sharing or donating non-perishable or perishable food, respectively. The most common approach for dealing with excess/leftover food was to discard it. The suggested strategies for food waste management and towards a circular food supply chain were in line with these findings.

It is proposed to raise awareness and knowledge on the topic through educational campaigns that clearly indicate the role that individuals play in it and some local trends. The utilisation of digital platforms that align with Singapore's digital advancements is suggested. This will aid to inform a broad public about the magnitude of the food waste issue and offer practical tips for minimising it. Strategies enabling sustainable behaviour through facilitation of the sharing/donation process, incentives/penalties, infrastructural, and technological solutions to facilitate food waste reduction are also presented. Some of these include smart refrigerators, tech-enhanced trash chutes, and meal-planning apps. Understanding that there are several players in the food supply chain, some collaboration strategies among the different stakeholders are presented. This collaboration is crucial for Singapore to towards an efficient and sustainable circular food supply chain.

While the current study provides valuable insights into consumer behaviour in the circular food supply chain in Singapore, there are certain limitations that should be acknowledged and that will be addressed in future research. First, the sample size might not be fully representative of the diverse population in Singapore due to the chain-referral sampling approach used and this will be addressed by expanding the sample size to different segments of the population. Second, the study focused on consumer behaviour in general, without

much differentiation on occasions, types of food, or types of food waste. Each of these might represent distinct challenges for circular practices. Future research can delve deeper to present tailored strategies addressing the unique characteristics associated with each category. Finally, the main focus of the study was on consumer behaviour in Singapore and other areas where food waste is generated in the supply chain were not investigated at this stage. A holistic approach encompassing all different – and possibly international – areas can be considered further on for a more comprehensive picture of a circular food supply chain.

References

Chai, G., Bte Abu Bakar, K. N., Lee, S., & Bajaj, T. (2023). Waste not, Want not: Understanding Online Public Concerns Toward Foodwaste Reduction in Singapore. Lee Kuan Yew Centre for Innovative Cities. https://lkycic.sutd.edu.sg/blog/waste-not-want-not/

CLC. (2020). Enhancing Liveability, Fostering Communities: Estate Management for Singapore's Public Housing. Centre for Liveable Cities, Singapore. https://www.clc.gov.sg/research-publications/publications/urban-systems-studies/view/enhancing-liveability-fostering-communities-estate-management-for-singapore-public-housing

CLC. (2021). Transport: Overcoming Constraints, Sustaining Mobility. Centre for Liveable Cities, Singapore. https://www.clc.gov.sg/research-publications/publications/urban-systems-studies/view/transport-overcoming-constraints-sustaining-mobility-(revised)

De Angelis, R., Howard, M., & Miemczyk, J. (2018). Supply Chain Management and the Circular Economy: Towards the Circular Supply Chain. Production Planning & Control, 29(6), 425–437. https://doi.org/10.1080/09537287.2018.1449244

Grandhi, B., & Appaiah Singh, J. (2016). What a Waste! A Study of Food Wastage Behavior in Singapore. Journal of Food Products Marketing, 22(4). https://doi.org/10.1080/10454446.2014.885863

Gu, Y., Loh, H. S., & Yap, W. Y. (2020). Sustainable port-hinterland intermodal development: Opportunities and challenges for China and India. Journal of Infrastructure, Policy and Development, 4(2), 228-248. http://dx.doi.org/10.24294/jipd.v4i2.1227

Kabadurmus, O., Kazançoğlu, Y., Yüksel, D., & Pala, M. Ö. (2022). A Circular Food Supply Chain Network Model to Reduce Food Waste. Annals of Operations Research. https://doi.org/10.1007/s10479-022-04728-x

Lavelli, V. (2021). Circular Food Supply Chains – Impact on Value Addition and Safety. In Trends in Food Science and Technology (Vol. 114). https://doi.org/10.1016/j.tifs.2021.06.008

Low, C., & Chen, J. (2023). Food Waste Management in Singapore: Envisioning the Possibilities of a Zero Waste Nation. Lee Kuan Yew Centre for Innovative Cities. https://lkycic.sutd.edu.sg/blog/food-waste-management-singapore-envisioning-possibilities-zero-waste-nation/

LTA. (2019). Land Transport Master Plan 2040. Land Transport Authority, Singapore. https://www.lta.gov.sg/ltmp2040

MEWR, & NEA. (2020). Zero Waste Masterplan Singapore. Ministry of the Environment and Water Resources (MEWR), Singapore and National Environment Agency (NEA), Singapore. https://www.towardszerowaste.gov.sg/zero-waste-masterplan/

MSE. (2023). Food Waste. Ministry of Sustainability and the Environment (MSE), Singapore - Towards Zero Waste. https://www.towardszerowaste.gov.sg/foodwaste/#:~:text=What%20is%20the%20government%20doing%3F,-Minimising%20food%20wastage&text=Ongoing%20food%20waste%20reduction%20publicity,them%20to%20minimise%20food%20wastage.

NEA. (2023). Food Waste Management. National Environment Agency (NEA), Singapore. https://www.nea.gov.sg/our-services/waste-management/3r-programmes-and-resources/food-waste-management#:~:text=The%20total%20amount%20of%20food,remained%20at%2019%20per%20cent.

OurSG. (2022). Rekindling the Kampung Spirit with Technology. Our SG - Singapore Together. https://www.sg/stories/sgkampung

DoS. (2022). Population Trends 2022. Department of Statistics, Ministry of Trade & Industry, Republic of Singapore. https://www.singstat.gov.sg/publications/population/population-trends

Rezvani Ghomi, E., Khosravi, F., Tahavori, M. A., & Ramakrishna, S. (2021). Circular Economy: a Comparison Between the Case of Singapore and France. Materials Circular Economy, 3(1). https://doi.org/10.1007/s42824-020-00016-w

Rojas Lopez, M. C., Toan, T. D., & Wong, Y. D. (2020). Transitioning different stages of transport planning in urban areas: Experiences of Singapore and Vietnam. In Lecture Notes in Civil Engineering (Vol. 54). https://doi.org/10.1007/978-981-15-0802-8_152

Rojas Lopez, M. C. & Loh, H. S. (2023). Last-Mile Delivery Innovations for Parcels Collection in Singapore. Sustainability, Economics, Innovation, Globalisation and Organisational Psychology (SEIGOP) 2023.

Rut, M., Davies, A. R., & Ng, H. (2020). Participating in Food Waste Transitions: Exploring Surplus Food Redistribution in Singapore Through the Ecologies of Participation Framework. Journal of Environmental Policy and Planning. https://doi.org/10.1080/1523908X.2020.1792859

Siow, L. G., & Lee, C. C. (2020, September). Singapore's 2030 Zero Waste Masterplan (ZMP): Is it Achievable? Proceedings of the International Conference on Environmental Science and Applications (ICESA'20). https://doi.org/10.11159/icesa20.125

SmartNation. (2023). Pillars of a Smart Nation. Smart Nation Singapore. https://www.smartnation.gov.sg/about-smart-nation/pillars-of-smart-nation#:~:text=Singapore%20has%20set%20its%20sights,businesses%20live%2C%20work%20and%20play.

Zhou, Q., Li, H., & Loh, H. S. (2023). A model for sustainable development of the ship recycling industry: Empirical evidence from China. Sustainable Development. (forthcoming) https://doi.org/10.1002/sd.2647

DIGITAL TRANSFORMATION IN LOGISTICS: THE NECESSITY OF THE NEW AGE

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ABSTRACT

Purpose: With the development of technology, change and transformation are now a given in any industry. It is common knowledge that utilizing information technology and good management are crucial for corporate success and creating a competitive advantage. Organizations may continue operating more quickly, more effectively, and competitively by providing a strategic framework for adopting digital advances and technological progress. The necessity of finding the correct balance between technological/digital efficiency and company innovation will be emphasized in this article. Additionally, it will go through how permitting safe innovation in response to the shifting demands of the commercial environment may help firms continue operating in a more rapid, effective, and competitive manner.
Design/methodology/approach: Our study intends to construct the architectural model of the job to be used for transformation utilizing the TOGAF architectural approach model and DDD (domain-driven design) as a guide. In our analysis of how to build a future journey by utilizing the existing applications/platforms in the company, we incorporate a logistics process that will ensure that every step in the supply chain is traceable and the logistics activities are automated.
Findings: Our findings include the absence of a workflow that can examine applications' processes holistically, the absence of a common language between the business unit and technology teams, the duplication of studies, and the inability to develop business processes because of the business execution's immaturity level.
Research limitations/implications (if applicable): It is a study where we aim to increase efficiency by using more innovative and technological solutions instead of conventional methods in logistics operations, to provide competitive advantage and to automate logistics processes.
Practical implications (if applicable): The foundation of our work is the development of a platform and procedure that will allow transportation functions to be managed from a single location while making use of global architectures and emerging technologies that can be used everywhere while maintaining a high level of security.
Originality/value: In this essay, we present the model of the requirement for an enterprise-wide technological and business-oriented transformation to occur simultaneously with a cultural shift toward greater security. By enabling a better understanding and efficient management of risks in transformation projects, this model raises the likelihood that projects will succeed.

Keywords: Digital Transformation, Logistics, Technology, Architecture, Culture

Introduction

Today, all standards and sanctions have changed as a result of technological advancements. It is common knowledge that efficient management and access to knowledge via technology are essential components of corporate success and a crucial instrument for attaining a competitive advantage. They are able to develop digital innovations and provide a strategic context for execution and direction more quickly, efficiently, and effectively in response to the solutions provided by the business environment.

This article will concentrate on the significance of striking the correct balance between corporate innovation and technological/digital efficiency on institutions. We'll talk about studies that let businesses innovate responsively to get a competitive edge.

We only have one strategy to deal with complexity and change, as John Zachman put it. “Management of enterprise architecture. Institutions that want to remain competitive and gain an edge have just one option given the growth and growth pace of growth. Enterprise architecture management "

The major challenge in architectural transformation is to swiftly decide what to do and how to do it in order to use time and money resources as efficiently as possible to meet the institution's goals in the face of the sector's complexity and rapid change. Identifying the institution's business operations, competencies, and knowledge capitals to be developed is the what question in this situation. Which enterprise architecture management will be used is the question at hand.

There is a Archtitecture structure of its company and an architecture of its behavior, which is why the transition occurs architecturally. Without carrying out the structuring of functional structures or the highlighting of capabilities in important organs, units of good or bad architecture pass. Enterprise architecture management is a comprehensive management discipline that offers the institution business benefits, technology, program and data processing in an architecturally sound manner, enhancing ways, risk and better management to help it reach strategic certainty.

The most frequently used corporate architecture technique in the world, TOGAF (The Open Group Architecture Framework), was used as a guide for creating this architectural discipline. DDD (Domain Driven Design), Micro Service design, BPM2.0 [6], and Event Storming techniques are some approaches we employ to construct this design.

The strategic target is clear, the desired point is clear, how to get there, how to deal with the Strategy/business/technology dimensions of the transformation journey, and how to reduce various cost items while increasing experience and efficiency are all addressed in this study under the umbrella of digital transformation. The research approaches employed and the findings that pertain to the management of the most significant cultural dimension are mentioned.

The main reasons for the need for this study are that there is no workflow in applications that can look at the processes holistically, that there are repetitive studies because there is no shared language between the business unit and technology teams, that business processes cannot be developed because of insufficient business execution maturity, and that there are similar processes that serve similar purposes because of application diversity. Enthusiasm started a major change process.

What is TOGAF (The Open Group Architecture Framework) methodology? [1]
It is a tried-and-true Enterprise Architecture framework and technique used to boost corporate productivity. Togaf Standard is a proven Enterprise Architecture methodology and framework used by the world’s leading organizations to improve business efficiency.

It is a foundation for comprehending, creating, organizing, and controlling the intricate business structures. To manage and enhance business architecture processes, particularly in large and complex businesses, TOGAF was created. As an open standard, TOGAF enables companies to incorporate their objectives into their technological foundation. In order to manage the digital twins of the institutions, the relationships between the layers, and to make decisions with a focus on process, risk, architecture, strategy, technology, data, cost, and efficiency, a new architectural model/framework was developed with reference to the TOGAF Model. No comparable model was found in the research done for a new architectural model that was constructed. The framework/model developed to oversee the institution's digital transformation was given the name EAM (Enterprise Architecture Model). The constructed architectural model has six dimensions or layers.

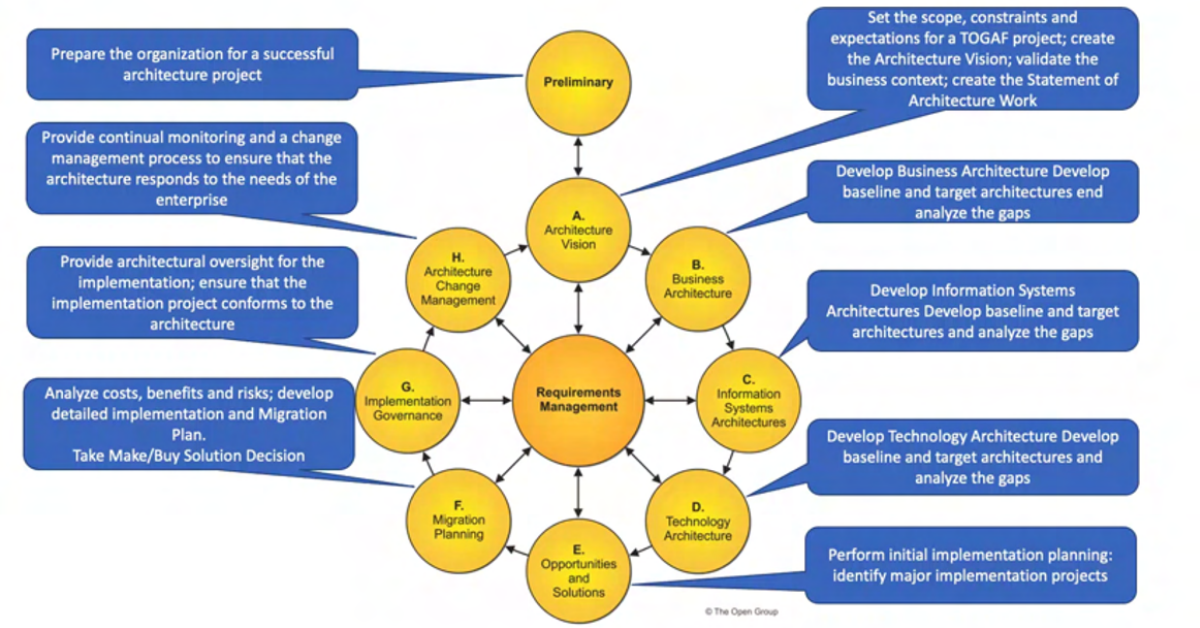

Table 1: ADM Phase (The Architecture Development Method)[2]

1.Business Architecture Layer
Business architecture is an architectural model used to align strategic goals with tactical demands about the organization. business architecture model; It consists of "Domain", "sub domain", "business functions", "organization", "product", "segment", "contract" and "Chanel", "capability", "processes".

2.Strategy Layer
There are models that can serve as a reference for institutions to achieve their strategic goals in line with their vision and mission. As a reference model in the strategy layer The Northan tiger [5] methodology is used. Layers (“Focus,” “Strategic Goal,” “Initiative,” “KPI”) are designated.

3.Portfolio Alignment Layer
Portfolio Allignment layer ("Demand Managment", "Project Management") was created with reference to PMI [7]standards in our metamodel, which was created by institutions for effective portfolio/project management.

4. Data Architecture Layer
Data Architecture Layer (Physical Data Component, Logical Data Compenent, Data Entity, Schema, Functions, Trigers, Table, Views, Stored Procedures) was created with reference to DAMA [3] Framework.

5. Application Architecture Layer
Application Architecture Layer (Micro Service, Logical Application Compenent, Physical Application, Application Module, Application Compenent) was created with reference to service/micro service oriented architecture.

6.Technology Architecture Layer
The Technology Architecture layer (Logical Technology Component, Physical Technology Component, Platform Services) was created.

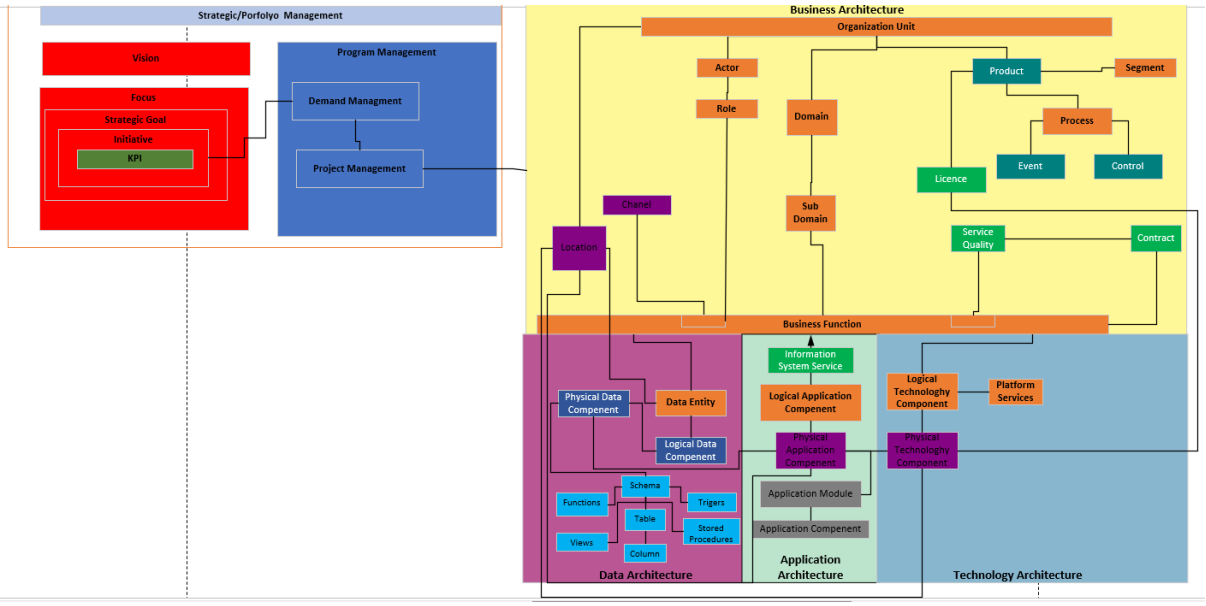

Table 2: EAM (Enterprise Architecture Methodology)

Developing a Workflow Methodology in Light of Event Storming and Agile Methods

During the software development process, complex business processes, events, and interactions are understood and modeled using the workshop and analysis technique known as event storming. This technique aids in a better understanding of business processes and the business environment, particularly when combined with the Domain Driven Design (DDD) methodology.

The major goals of event storming are to motivate participants to investigate the business processes and workflows associated with their jobs, to establish a common vocabulary, and to communicate complicated ideas in a clear and concise manner. This enables them to examine and discuss workshop, teamwork, and business components from many angles. Event storming aids in maintaining the company vision and clarifies specifics.

The term "agile methodology" refers to a collection of guidelines and practices that take a flexible, team-based, and client-focused approach to software development and project management procedures. Agile projects are designed to be quicker, more productive, and more responsive to client needs. By better adjusting to the variables, rather than relying on a rigid and static plan of business processes, it seeks to produce better results.

At order to realize the change/transformation of corporate business models with the Digital Transformation at institutions and to establish a shared goal, common target, and common language, agile/event storming working approaches have been used as references. The Domain Driven Design (DDD) approach, greater understanding of business processes, and the development of a common language approach used in event storming are seen as examples of how the working principles of the Agile methodology are faster, more effective, and can better adapt to customer requests. EBFM (Event-Based Flexible Method) is the name of the recently developed model. While developing the interest model, working approaches including Agile Methodology, PMI, SDLC, Event Storming, Kanban, and Waterfall were examined. Organizations and units have been established, RACI matrices have been made, and documentation requirements have been decided.

The following is how the institution used the chosen methodology.

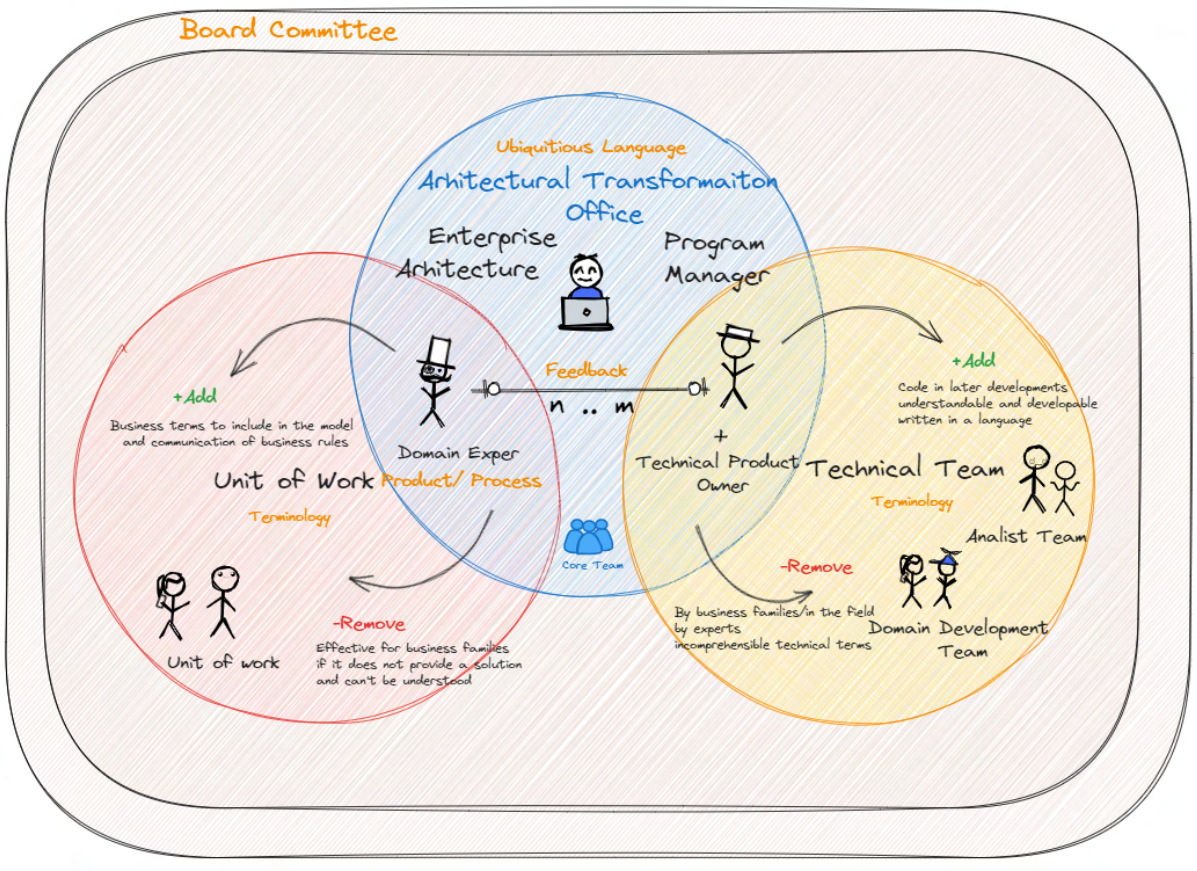

Table 3: EBFM (Event-Based Flexible Method)

Domain-based architecture using the DDD (Domain Driven Design)/ Micro Service Arhitectural Approach method

Domain Driven Design: What is it?
DDD is not a cutting-edge technology or a particular technique. In order to ensure the continuity of our applications once these large projects are done, DDD is a strategy that aims to offer solutions to the fundamental issues that are regularly encountered in the creation of big software systems.
In order to build domain-based organization, technology, and process setup, business activities/business services offered on 10 distinct platforms were compared to DDD.

For instance, using the DDD method, operational units that were previously controlled as application-based units within the institution were changed into domain-based operational processes. Deduplicating the order management for each application has resulted in the creation of a single order management unit.

Action was taken on the axis of culture, experience, and transformation at the same time that this operational, technological, and architectural transformation brought about by the digital transformation spread and became internalized. The following components are used as a guide in order to establish the established methodology and cultural transformation in a solid manner.

- Expressing our thoughts honestly and engaging in productive conflict.
- Setting up an autonomous management environment,
- Acting bravely,
- Fostering a culture of shared values and active participation,
- Acting in unison of value, respect, and love for one another, and taking action by putting our attention on how to improve by viewing the setbacks we have previously experienced as learning opportunities.
- Being us

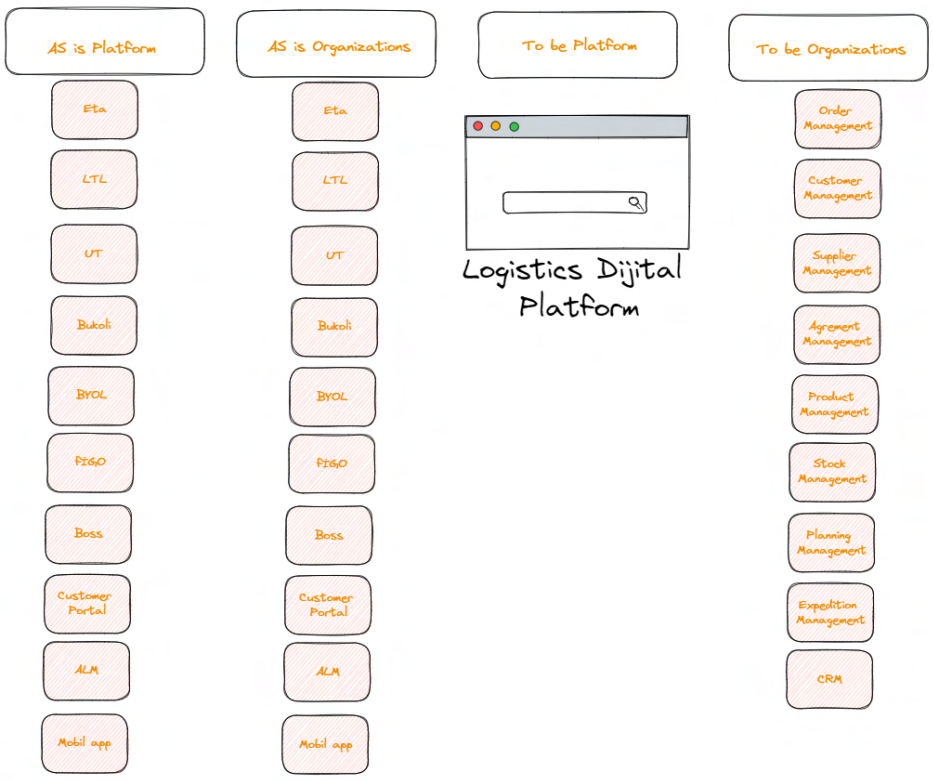

Table 4: Domain-Based Organization

What is the Microservice Architecture?

A modular structure known as a "microservice architecture" is a method of creating a single application that has mechanisms that can manage their own business and communication inside each service, are not overly complex, and are modest in size compared to other services. It is a framework with an automated distribution system that focuses on a specific task for which these services are accountable and capable of working independently. It ought to be comparatively free of central government institutions. It can be created using a variety of data-based technologies and programming languages.

By looking at the screens related to the application modules, the services associated with the screens, and the methods of the services, it has been concluded that there are 6400 services. The analyses lead to the conclusion that there is no software architecture. 1200 micro services were used in the construction of the new platform.

DBAM (Domain-Based Architectural Model)
Scalability, management independence, and business continuity are costs associated with the DBAM (Domain Based Architectural Model) [4]Microservice architectural model. A fresh model approach is the DDD model reference point. The fields associated with the Logistics Sector were eliminated when this model was created. Aggregate Root and Bounded Context have been eliminated from domains.

Domain

- Order management
- Customer/Supplier management
- Stock management
- Planning Management
- Payment System management
- Product management
- User management
- Contract Management
- Pricing Management
- Integration Management

DDD Model reference reference varies with Layered Architecture.

- Domain Layer
- Application Layer
- Presentation Layer
- Infrastructure Layer

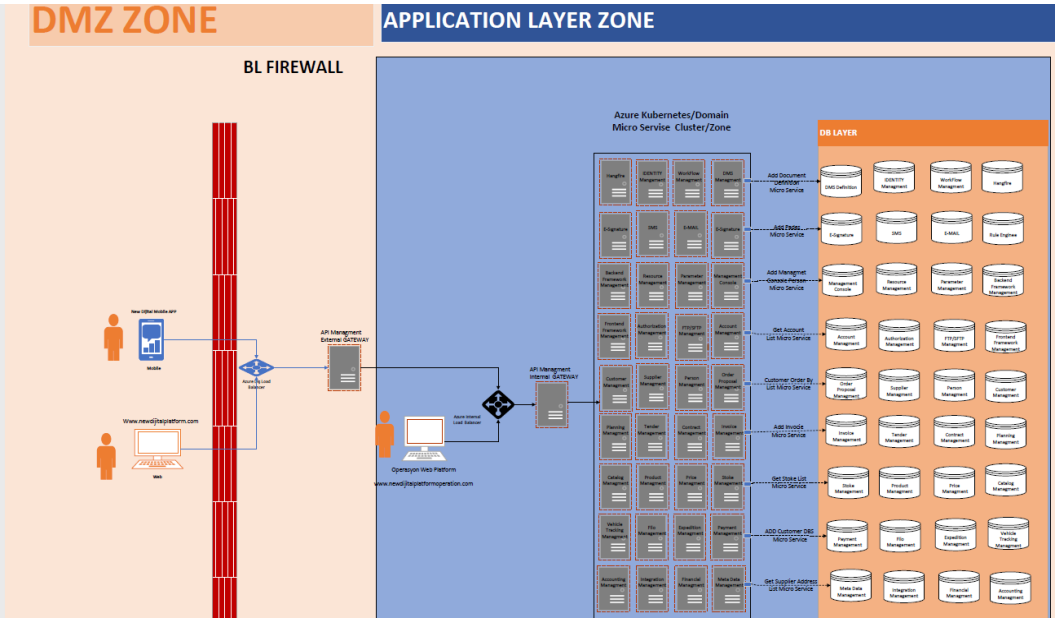

Table 5: DBAM (Domain-Based Architectural Model)

The TOGAF architectural model served as a guide for the institution's AS-IS investigations, which were focused on Product, Process, Application, Technology, Data, Service, and Framework. The size of the tables belonging to ten different applications, their relationships with one another, and their data models were all determined as a consequence of the asis investigations. Studies on table catalogs were conducted in conjunction with the Data Governance principles as a guide. On almost 3,000 MS SQL servers, tables were located, and their performance was examined. 6400 service architecture catalogs were created, and

the performances of the services were tested, by looking at the screens connected to the modules in the applications, the services belonging to the screens, and the methods of the services. The following decisions were reached as a result of the examinations performed in accordance with architectural standards.

- It has been concluded that due to the diversity of the database infrastructure among the 10 distinct applications, technical standards cannot be established and efficiently managed.
- There is no referenceable Framework infrastructure.
- Lack of a Service Architecture
- Absence of a suitable, advanced technology architecture
- Process standards are not sufficiently developed
- Data Architecture is still in its infancy.
- There is no Central Technology Steak
- Considering the variety of technologies available, specialization within the institution is not required.
- When various legacy applications have services that serve the same commercial purpose

Technology
The dependency on a single programming language is gone. The newly constructed build and deploy timings are separate, benefiting the developers because the Codebase deployment methods were inefficient. By establishing a technical institutional memory, dependence on developers was decreased and learning convenience was ensured. No codes Platform development activities using low code are kept to a minimum. Costs for development have decreased. It was possible to specialize by domain. A common language was established as a result of the platform and working methodology that were developed. Utilizing open source technologies helped to save operating costs. Performance and speed improvements were made.

Corporate Effectiveness
The first platform was singularized, which streamlined processes and increased operational effectiveness. By eliminating the institution's administrative tasks, manually advancing tasks were digital. A lean organization has been achieved and efficiency has grown as a result of the merger of the organizations.

Business Strategy
A new avenue for cross-selling has been established. Enhanced client satisfaction. Enhanced vendor loyalty.

References

- [1] Reference https://www.opengroup.org/togaf (accessed 15 August 2023)
- [2] Reference https://pubs.opengroup.org/architecture/togaf8-doc/arch/chap03.html (accessed 15 August 2023)
- [3] Reference https://dataninjago.com/2021/09/15/what-is-data-management-actually-dama-dmbok-framework/ (accessed 15 August 2023)
- [4] Reference https://herbertograca.com/2017/11/16/explicit-architecture-01-ddd-hexagonal-onion-clean-cqrs-how-i-put-it-all-together/ (accessed 15 August 2023)
- [5] Reference https://hbr.org/1992/01/the-balanced-scorecard-measures-that-drive-performance-2 (accessed 15 August 2023)
- [6] http://www.omg.org/spec/BPMN/2.0/ (accessed 15 August 2023)
- [7] https://www.pmi.org/ (accessed 15 August 2023)

PROCEDURAL EFFECT ON TANZANIA PORTS' ACCESSIBILITY AND SATISFACTION

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Abstract
Purpose: This study assessed the influence of complex cargo clearance procedures on the relationship between port accessibility and customer satisfaction as constructs based on the empirical evidence drawn from Tanzania's port operations.
Design/methodology/approach: The study used structured questionnaires administered with 228 port stakeholders from a sample of 298 respondents drawn from a population of 1,325 agents using simple random sampling, from five selected Tanzania ports to obtain data necessary for hypotheses testing using Structural Equation Modelling through Smart PLS 3.0. Using a positivist philosophy and deductive approach along with an explanatory design and quantitative method, and the Resource-Based Theory (RBT) and the Port Service Quality (PSQ) theories to operationalise the interactions of the three constructs. The study worked on the assumption that there has been no extensive research model that compounded the joint effects of constructs.
Findings: The study found that port accessibility has a positive significant impact on customer satisfaction whereas the moderated relationship has lower positive significant effects. Further, the findings of the Importance-Performance Matrix Analysis (IPMA) revealed that port accessibility has the highest levels of both importance and performance in predicting customer satisfaction. The study concludes with strong empirical confirmation that port accessibility positively influences customer satisfaction and expands the RBT and PSQ dimensions.
Practical implications: The results shed light on areas that the Tanzania Ports Authority and other Stakeholders from both the public and private sectors can improve to boost satisfaction. The study findings have implications for relevant policies, including the Ports Act 2004, National Transport and Trade Policies both of 2003, and the Agenda 2063 The Africa We Want.
Originality/value: This research pioneered in identifying dimensions of port resources and moderating effects of complex cargo clearance procedures and examined their impacts on customer satisfaction.

Keywords: Port accessibility, customer satisfaction, cargo clearance procedures, and port operations.

Introduction

Transport infrastructure can foster balanced economic and regional development in addition to influencing significantly the national integration into the world economic market (Dwarakish & Salim, 2015). Dwarakish and Salim (2015) and Pienaar (2013) found that the load carried, economies of fleet size, economies of distance, seaway transportation constitute the cheapest and most effective transportation mode relative to others in improving the living standard of locals (Dwarakish & Salim, 2015; Pienaar, 2013; Yin, 2020). Also, customers have increasingly become a rich source of information for firms through their views on services, particularly for service improvement while enhancing the user experience of the end products (Busagara, Mori, Mossberg, Jani, & Andersson, 2020). User experiences and interactions allow service providers to gather enormous information for improving services as well as designing and developing future services to optimise customer satisfaction (Kadir, Rahmani, & Masinaei, 2011).

The influence of port service quality on customer satisfaction particularly in the port sector is not a topic that has been well-researched upon empirically (Yeo, Thai, & Pak, 2016). Moreover, Phan, Thai and Vu (2020) in their study had observed that studies of service quality in the maritime sector generally, and in the port industry particularly, have not been carried out frequently in the literature; instead, most of these studies have focused on port efficiency, selection of port or carrier. Mkawuganga (2018) also found scant literature on customer satisfaction in the port industry and, specifically, on the effect of port service quality on customer satisfaction. This study aimed to determine the impact of port accessibility on customer

satisfaction in Tanzania's ports using the Resource Based Theory (RBT) and Port Service Quality (PSQ). Informed by the literature coupled with the studies' environment and variables, we adopted the moderation approach to portraying the co-variation effects rather than mediation that portrays the transitive effect (Umanath, 2003).

In Tanzania, the role trade plays in economic growth has not received as much attention and it is difficult to find studies that quantify the subject sufficiently (Magai, 2018). Yet, the ports in Tanzania serve many of the land-linked countries comprising Burundi, Rwanda, DR Congo, Uganda, Malawi, and Zambia (Issa & Masanja, 2022). The country also has lake ports. The market share analysis for respective Tanzania and Kenya ports for the 2013 – 2017 period shows that of the incoming cargo traffic to Tanzania from Burundi, Rwanda, DR Congo and Uganda, the average percentages of 97.92, 88, 77.2, 53.4 and 2.8 and 2.08, 12, 22.8, 46.6 and 97.2 went through Tanzania and Kenya ports, respectively. Such market share potentials amidst competition as well as future dynamic demand in the port industry suggest the need to investigate factors for enhancing customer satisfaction to retain the existing and attract new customers. This study strived to assess the aforementioned factors through the assessment of port accessibility on customer satisfaction with Tanzania ports and examine the moderating effects of the complexity of cargo clearance procedures on port accessibility and customer satisfaction.\

The findings on the relationships among study variables enhanced knowledge on and understanding at the local level. In setting port improvement priorities and strategies, port accessibility and customer satisfaction are competitive factors. The Important-Performance Map Analysis (IPMA) for Tanzania ports has been developed from the study findings through variables and the established relationships for management consideration. The study objectives have addressed, firstly, the Ports Act 2004 No 17 on page 12 about port promotion and, secondly, the National Transport Policy of 2003 (Tanzania, 2003) about its mission and the National Trade Policy for a Competitive Economy of 2003 (Viwanda, 2003) on its vision.

Literature Review

Theoretical Literature Review

To address its objectives, the study was informed by the Resource-Based Theory (RBT) and the Port Service Quality (PSQ):

Resource-Based Theory (RBT)

RBT tries to explain the origins of higher performance among firms in competitive environments (Akbari, Azbari, & Chaijani, 2019). According to RBT, resources that are valuable, rare, inimitable, and non-substitutable can enable firms to sustain above-average returns (Liang & You, 2009) and can enjoy a sustained competitive advantage if they successfully exploit these resources. Kim and Chiang's (2017) analysis of the effect of sustainability practice on the relationships between competitiveness and performance in port operations. Applying RBT, the study found that, the port needs step-by-step container handling procedures, and processes and simplified but satisfactory procedures for customs clearance to sustain practices in international port operations. Studies that have applied RBT also have a variable related to cargo clearance procedures, hence also supporting the independent variable because of the complex cargo clearance procedure is one of the study variables.

Port Service Quality (PSQ) Theory

Cho, Kim and Hyun (2010) demonstrated that Port Service Quality (PSQ) depends on three dimensions—endogenous quality, relational quality, and exogenous quality. Whereas endogenous quality has to do with internal capabilities of a port, including loading and unloading charges, berthing facilities, and terminal capacity, relational quality dwells on relationships the between port companies and shipping companies, such as the port logistic network, employee professionalism, the customer partnership. In contrast, exogenous quality correlates with external factors affecting the magnetism of a port, including the port location, the cargo volume, the distance. On their part, Applying the PSQ concept, Phan, Thai, and Vu (2021) found that enhanced PSQ positively influenced customer satisfaction, with the outcomes of port

service performance and its image accounting for the greatest impact. PSQ theory supported the operationalisation of the endogenous variable, Port Customer Satisfaction (PCS), and one exogenous variable Port accessibility (PA) as applied in this study.

Empirical Literature Review

Port accessibility and Customer Satisfaction Relationship

Raza, Jawaid and Hassan (2015) determined the effects of service quality dimensions including accessibility on customer satisfaction in Malaysia. The traits of responsiveness and empathy helped to meet the clients' demands whereas accessibility had a significant and positive influence on the satisfaction level of customers. Also, Nui Polatoglu and Ekin's (2001) study of how Turkish customers' embrace of Internet banking services considered reliability and accessibility and found clients to be more satisfied with online banking's accessibility and reliability factors because they countenanced no problems when using these services. In the studies reviewed, the influence of port accessibility on customer satisfaction remains an issue worth further exploration to enrich the literature of PSQ management especially in the context of developing countries. Thus, this study assessed the influence of port accessibility on port customer satisfaction with empirical evidence from Tanzania ports. As such, we hypothesise:

H_1: Port accessibility positively influences port customer satisfaction

Complexity of Cargo Clearance procedure and Customer Satisfaction Relationship

A study on the influence of cargo clearance procedures in the East African Community on trade facilitation in Rwanda by Rudahigwa and Tombola (2021) recommended for the simplification of trade documentation and procedures to facilitate trade in goods within the community. After all, well-performing logistics processes can contribute to a customer's commitment to the relationship by providing the best customer comparative net value, enhancing their satisfaction, eventually leading to a strong buyer-supplier relationship (Kanani, 2020; Tuan, 2017). Nyema's (2014) assessment of factors that influence container terminal efficiency based on Mombasa Entry Port in Kenya found inadequacy of the quay, equipment to facilitate the performance of the port, insufficient time for reducing bays, late coming of ships at the port, weak clearance of customers to be factors affecting the Mombasa port performance . Nevertheless, the studies reviewed indicate that few attempts made to assess the influence of port tangible and intangible resources on customer satisfaction. This study, therefore, assessed the moderation effect of the complex cargo clearance procedure and the relationship between port accessibility and port customer satisfaction with empirical evidence from Tanzania ports. Thus we hypothesise:

H_2: The complexity of the cargo clearance procedure moderates the relationship between port accessibility and port customer satisfaction

Methodology

This study adopted a positivist philosophical stance to relate the natural scientist stance with an observable social reality to produce law-like generalizations (Saunders, Lewis, & Thornbill, 2019), and deductive reasoning for the study's hypotheses and observable consequences that should have occurred with new empirical data if the hypotheses were to be found true (Antwi & Kasim, 2015). Moreover, it applied an explanatory design to explore a new universe based on the study variables, relationships, and associated objectives, which had not been studied earlier involving causes and reason factors about some phenomenon related to study variables (Megel & Heermann, 1993). Also, the study applied the quantitative method since it supported and identified what is embedded in the positivism paradigm that focuses on fresh data (Rahi, 2017). Also, it integrates purposes and procedures that are deductive, objective, and generalised (Morgan, 2014). The study applied Krejcie and Morgan's (1970) formula, which has already been applied by Januszyk *et al*. (2011) and Minani (2019), to a population of 1325 to obtain a representative sample of n = 298.

Sample Selection, Unit of Analysis and Inquiry

The sample size consisted of 298 port customers, Other Government Departments, and Tanzania Ports Authority from the five mentioned regions selected using simple random sampling that gave every one a

fair chance of being recruited in the sample (Creswell, 2014). Due to the participation of several stakeholder groups, the study presented a more comprehensive analysis of the research issue (Kovacs & Moshtari, 2019). A simple random sample from an existing sampling frame was adopted. The study's unit of analysis was the Clearing and Forwarding Agency Company (employer) and the units of inquiry were the staff members (employees) of the firm who had adequate information and knowledge about the Tanzania Ports Authority (TPA) services.

The study used a self-administered two-part questionnaire to collect data. The first part gathered the respondents' demographic information alongside the Company profile and the second part contained 7-point Likert-scale type statements with measures ranging from 'Strongly agree' to 'Strongly disagree'. The techniques used to address the common method bias include reverse coding of the variable values applied in the questionnaire during data entry and the application of the 7-point Likert scale for independent and dependent variables instead of the 5 or three 3-point scale; the reliability of the responses on the former scale is better than on the latter lower scales owing to items on the scale defined by the construct (Joshi, Kale, Chandel, & Pal, 2015).

Measurement and Operationalisation of variables
The study involved an endogenous variable, Port Customer Satisfaction (PCS) and an exogenous variable Port accessibility (PA), with the Complexity of Cargo Clearance Procedures (CCCP) serving as a moderating variable.

Port accessibility
Accessibility serves as a product of the land use and transport systems and describes the extent to which land use and transport systems enable individuals to reach activities or locations employing a combination of transport modes within the port (Karst Geurs, Tomaz Ponce Dentinho, & Patuelli, 2021).
Port Customer Satisfaction
Customer satisfaction is the response of consumers to the evaluation of the discrepancy between prior expectations and the perceived performance of the consumed product or rendered service (Yi, 1990).

Complexity of Cargo Clearance Procedure
Cargo clearance procedures constitute one of the major bottlenecks in product supply chains in Kenya because lengthy, complex procedures and excessive paperwork delay border crossings and port handling, hence creating a negative impact on trade coupled with soaring the costs of doing business in the country (Billy, Thomas, & Peter, 2019).

Data Analysis, Interpretation, And Discussion Of Findings

Respondent's Profile
The study generated data from 228 out of 298 questionnaires distributed in the five regional ports under review, a response rate of 76.5%. The gender split of the final sample was 83.8% male and 16.2% female. The mean age of the sample was 35.5 years. The sample comprised 63.6% respondents with College diplomas , 17.5%with secondary school certificates, 16.7% with university degree, and 2.2% with non-formal education. The majority (32%) had a mean working experience of 5 years.

Assessment of the Measurement Model
The assessment of the measurement model was conducted by composite reliability, Cronbach alpha, rho_A, AVE, and HTMT, and the following results were obtained:

Table 1: Measures of Construct Validity and Reliability

	Composite Reliability (>0.7)	**Cronbach Alpha** (>0.7)	**rho_A**	**Average Variance Extracted** (>0.5)	**HTMT** (HTMT < 1)		**Decision**
					CCCP	**PA**	
CCCP	0.955	0.937	0.946	0.842			Good
PA	0.931	0.901	0.905	0.771	$0.543CI_{0.95}$ [0.428;0.651]		Good
PCS	0.949	0.928	0.932	0.823	$0.465CI_{0.95}$ [0.353;0.572]	$0.799CI_{0.95}$ [0.742;0.852]	Good

Source: Field Data (2022)

The results obtained show that exogenous latent variables have good measures of validity and reliability across all the variables, including the endogenous variable, PCS.

Assessment of Common Method Bias

The CMV was subjected to a simple Collinearity Test using VIF, which show that all the constructs had variance inflated factor (VIF) values of less than the proposed threshold of 5. Hence CMV posed no threat.

Assessment of the Model's Predictive Power ($PLS_{Predict}$) (out-of-sample)

The assessment of the model's predictive power found the RMSE of LM (i.e. prediction) to be greater than that of PLS-SEM (i.e. actual) in SATIS4, SATIS2, SATIS5, and SATIS3, which implies lower prediction error. Also, the values of Q²_predict in the four indicators of the endogenous variable are above 0, meaning a lower prediction error. As such, the model has higher predictive power.

Evaluation Results of the Structural model

The measuring of the VIF values indicate that both independent variables have 1.335, which are acceptable levels of collinearity. Hence the structural model has no collinearity issues. Also, the path coefficient value of 0.687 indicates a strong positive relationship, which explains a 68.7% increase in PCS. Impliedly, if the PA construct increases by one standard deviation unit, the PCS construct will increase by 0.687 standard deviation unit, assuming all other independent constructs remain constant. The result of the coefficient of determination of R^2 stood at 0.546 for the direct model, which explains that a 54.6% change in PCS can be accounted for one (1) exogenous construct. Also, the effect size of f^2 yielded 0.779, which translates into a large effect size on R^2. The measuring of the predictive relevance of Q^2 produced a value of 0.418. Hence, the model has predictive relevance.

Model Assessment

The structural model results reveal a significant relationship that exists between PA and PCS. In this regard, The direct model was measured and the coefficient of determination of the R^2 value was 0.546, implying that, a 54.6% change in PCS can be accounted for two (2) exogenous constructs as follows:

Direct effect of port accessibility on port customer satisfaction

The first hypothesis, H_1 states that port accessibility positively influences port customer satisfaction. In testing the hypothesis, the results indicate that PA has a significant impact on PCS (β = 0.687, t = 16.471), i.e. one unit increase of PA increases PCS by path coefficient of 68.7%, *ceteris Paribas* (Hair, Sarstedt, & Ringle, 2017). Also, the confidence intervals [0.616; 0.754] do not include 0, indicating the existence of a direct effect (Hair *et al.*, 2017). Furthermore, the t-value of 16.471 is above the critical value for the z-test of 1.645. Therefore, H_1 was supported and hence not rejected.

Moderation Analysis Results

The moderated model was also measured and the coefficient of determination of R^2 value has improved from 0.546 to 0.554, hence a 55.4% change in PCS for two (2) exogenous constructs.

Complexity of cargo clearance procedure and port accessibility on Port Customer Satisfaction

The second hypothesis, H_2: states that the higher (lower) the complexity of the cargo clearance procedure, the weaker (stronger) the influence of port accessibility on port customer satisfaction. The results indicate that CCCP*PA has a significant impact on PCS (β = -0.094, t = 2.404). Implicitly, if one unit increases (decreases) of the complexity of the cargo clearance procedure, then the influence of port accessibility and port customer satisfaction decreases (increases) by the size of the path coefficient (9.4%), *ceteris Paribas* (Hair *et al.*, 2017). There is a weakening or reduction of t-value from 16.471 to 2.404, which is still above the critical value for the z-test of 1.645. Therefore, H_2 is supported and, hence, cannot be rejected.

Simple Slope Analysis

A typical moderator analysis results in representation using simple slope plots (Hair, Sarstedt, & Ringle, 2021). This study has one simple slope plot delineated as follows:

Moderation Effect of Simple Slope Analysis between PA, CCCP, and PCS

The relationship between PA and PCS is positive. Hence, lower levels of PA are associated with lower levels of PCS. The upper line (in green), which represents a higher level of the moderator, CCCP with standard deviation above the mean, has a flatter slope, hence representing a weaker positive effect. Also, the bottom line (in red) which represents a lower level of moderator, CCCP with a standard deviation below the mean, has a steeper slope, thus representing a stronger positive effect. The simple slope plot shows the positive interaction terms that lower CCCP levels entail a slightly weaker relationship between PA and PCS and vice versa which are accepted.

Importance-Performance Map Analysis (IPMA)

Ringle and Sarstedt (2016) contend that multiple moderators in a total effect or moderated effect complicates the interpretation of IMPA's importance dimension. As such, it is advisable to exclude moderators in an IPMA (Hair *et al.*, 2017; Ringle & Sarstedt, 2016). IPMA was conducted using Smart PLS. The results are based on the total effect of one exogenous variable (PA) on the endogenous variable (PCS). The findings confirm that PA, the exogenous variable, has high levels of importance and performance in Quadrant I with 'Concentrate Here' status.

Conclusion, Implications, and Recommendations

Effect of Port Accessibility on Port Customer Satisfaction

To begin with, the study findings substantiate hypothesis H_1, by showing the positive effect of port accessibility on port customer satisfaction. In fact, the higher the level of port accessibility the higher the level of port customer satisfaction. These findings are in line with the findings of (Kadir *et al.*, 2011; Nui Polatoglu & Ekin, 2001; Raza *et al.*, 2015). In this regard, the study findings provide strong empirical confirmation that port accessibility positively influences port customer satisfaction. Implicitly, port accessibility is a key determinant of port customer satisfaction whose four internal indicators are important in improving port accessibility.

Moderating Effect of Complexity of Cargo Clearance Procedures on Port Customer Satisfaction

Second, the study affirms hypothesis H_2 by accounting for the moderating effect of the complexity of the cargo clearance procedure and how it positively influences port accessibility and port customer satisfaction. Indeed, the higher (lower) the level of complexity of the cargo clearance procedure, the weaker (stronger) the influence of port accessibility on port customer satisfaction, which is consistent with the findings by Gittell (2011), Kanani (2020), Kim and Chiang (2017), Nyema, 2014); Rudahigwa and Tombola, (2021), and Tuan (2017). The findings are congruent with previous literature despite the theoretical, contextual, and methodological differences.

Also, cargo clearance procedure can complicate port accessibility and affect it either negatively or positively. Even though other variables could impair the attainment of port customer satisfaction, these two factors are critical areas port managers can ignore at their own peril amidst scarcity of resources, competition, and dynamism of the business environment, customer demand, and technology. In this study, the complexity of cargo clearance procedures was operationalised as the moderation variable on Port accessibility and Port Customer Satisfaction with five measurable indicators based on existing scales. Overall, the findings provide strong empirical confirmation regarding the moderating effect of the complexity of cargo clearance procedures that can positively influence the relationship between port accessibility and port customer satisfaction when enhanced. Implicitly, the moderation effect of the complexity of cargo clearance procedures makes it a key determinant of the relationship between port accessibility and port customer satisfaction.

Overall, the fact that both hypotheses (100%) have been supported has implications for routine port operations and theories. Port managers can enhance port accessibility alongside other resources to boost the effectiveness and efficiency of the port to improve customer satisfaction.

Implications

Firstly, since a limited number of studies had established the relationships between resources and port customer satisfaction, this study is complementary particularly by providing a theoretical framework that identifies a detailed relationship among the resources variables of port accessibility and complexity of cargo clearance procedure. Moreover, only anecdotal evidence existed for the intervening roles of and complexity of cargo clearance procedure in the relationships between resources and port customer satisfaction. In this regard, this study has confirmed that the two resources significantly and positively correlate with port customer satisfaction. Also, the study findings confirm that the complexity of the cargo clearance procedure is a potential moderating variable in the relationships between resources and port customer satisfaction.

Second, this study significantly contributes to the theory by showing that unique resources enable ports to enhance resources by considering port accessibility aspects in their cargo clearance processes and related operations. Previous studies had paid limited attention paid to its empirical contribution to port customer satisfaction along with moderating effects of the complexity of the cargo clearance procedure. This practice has left practitioners with the complex task of selecting alternative resources while making ports operate below customer satisfaction.

Thirdly, this study extends and strengthens the theoretical foundations of resources. Through extensive literature review and subsequent analyses, it has revealed that port accessibility is a reliable and valid dimension that both researchers and practitioners interested in measuring resources cannot overlook. Also, the study findings on this aspect could inform the revision of existing and can support further development of theory in the field of port customer satisfaction management.

Recommendations for future studies

Even though this study found port accessibility to be positively influenced by port customer satisfaction, future studies could apply these variables in other service settings such as banks and academic institutions to compare results. Moreover, future studies could use other resource attributes on port customer satisfaction to bring about more insight into the resource and port customer satisfaction interface. Other researchers could opt for a longitudinal approach as opposed to a cross-sectional approach applied during this study.

References

Akbari, M., Azbari, M. E., & Chaijani, M. H. (2019). Performance of the Firms in a Free-Trade Zone: The Role of Institutional Factors and Resources. *European Management Review, 16*(2), 363-378.

Antwi, S., & Kasim, H. (2015). Qualitative and Quantitative Research Paradigms in Business Research: A Philosophical Reflection. *European Journal of Business and Management, 7*(3), 2222-2839.

Billy, Thomas, & Peter. (2019). Effect of Single Window System procedures on Cargo Clearance Efficiency in Kenya - A Case for Mombasa port.

Busagara, T., Mori, N., Mossberg, L., Jani, D., & Andersson, T. (2020). Customer information sharing and new service development: is there a link? *The Bottom Line, 33*(2), 133-147.

Cho C.H., Kim B.I, and Hyun J.H. (2010) A comparative analysis of the ports of Incheon and Shanghai: The cognitive service quality of ports, customer satisfaction, and post-behaviour. *Total Quality Management*, 21 (9), 919–30.

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*: SAGE Publications.

Dwarakish, G., & Salim, A. M. (2015). Review on the Role of Ports in the Development of a Nation. *Aquatic Procedia, 4*, 295-301.

Gittell, J. H. (2011). Relational coordination: Guidelines for theory, measurement and analysis. *Waltham, MA: Brandeis University, 1*.

Hair, Sarstedt, & Ringle. (2017). Partial Least Squares Structural Equation Modeling, 10.1007/978-3-319-05542-8_15-1.

Hair, Sarstedt, & Ringle. (2021). Partial Least Squares Structural Equation Modeling. In *Handbook of Market Research* (pp. 1-47).

Issa, F. H., & Masanja, E. P. (2022). Change for performance improvement in the Tanzania Ports Authority, a public sector organization in Tanzania. *International Journal of Public Leadership, 18*(4), 337-354.

Joshi, Kale, Chandel, & Pal. (2015). Likert scale: Explored and explained. *British journal of applied science & technology, 7*(4), 396.

Kadir, H., Rahmani, N., & Masinaei, R. (2011). Impacts of service quality on customer satisfaction: Study of Online banking and ATM services in Malaysia. *International Journal of Trade, Economics and Finance, 2*, 1-9.

Kanani, R. (2020). The impact of Logistics Information Sharing and the Mediating Effect of Logistics Performance on Buyer Trust. *ORSEA JOURNAL, 9*(1).

Karst Geurs, Tomaz Ponce Dentinho, & Patuelli, R. (2021). Accessibility, Equity and Efficiency.

Kim, S., & Chiang, B. G. (2017). The role of sustainability practices in international port operations: An analysis of moderation effect. *Journal of Korea Trade*.

Kovacs, G., & Moshtari, M. (2019). A roadmap for higher research quality in humanitarian operations: A methodological perspective. *European Journal of Operational Research, 276*(2), 395-408.

Krejcie, R. V., & Morgan, D. W. (1970). Determining Sample Size for Research Activities.

Liang, T.-P., & You, J.-J. (2009). Resource-based view in information systems research: A meta-analysis.

Magai, P. S. (2018). An econometric analysis of trade and economic growth in Tanzania: Evidence from time series data. *Business Management Review, 21*(1), 74-84.

Megel, M. E., & Heermann, J. A. (1993). Research design. *Plast Surg Nurs, 13*(4), 209-210.

Mkawuganga, E. (2018). Customer relationship management (CRM), customer satisfaction, loyalty and port performance: a case study of Kenya Ports Authority (KPA).

Morgan, D. L. (2014). *Integrating Qualitative and Quantitative Methods: A Pragmatic Approach*. In. Retrieved from https://methods.sagepub.com/book/integrating-qualitative-and-quantitative-methods-a-pragmatic-approach

Nui Polatoglu, V., & Ekin, S. (2001). An empirical investigation of the Turkish consumers' acceptance of Internet banking services. *International Journal of Bank Marketing, 19*(4), 156-165.

Nyema, S. M. (2014). Factors influencing container terminals efficiency: A case study of Mombasa entry port. *European Journal of Logistics Purchasing and Supply Chain Management, 2*(3), 39-78.

Phan, T. M., Thai, V. V., & Vu, T. P. (2020). Port service quality (PSQ) and customer satisfaction: an exploratory study of container ports in Vietnam. *Maritime Business Review,* 6 (1), pp. 72-94. https://doi.org/10.1108/MABR-01-2020-0003.

Pienaar, W. W. (2013). Comparative economic efficiency, operating costs and fuel consumption rates of freight transport modes between the largest industrial cities and seaports in South Africa.

Rahi, S. (2017). Research design and methods: A systematic review of research paradigms, sampling issues and instruments development. *International Journal of Economics & Management Sciences, 6*(2), 1-5.

Raza, S. A., Jawaid, S. T., & Hassan, A. (2015). Internet banking and customer satisfaction in Pakistan. *Qualitative Research in Financial Markets*.

Ringle, C. M., & Sarstedt, M. (2016). Gain more insight from your PLS-SEM results. *Industrial management & data systems, 116*(9), 1865-1886. doi:10.1108/IMDS-10-2015-0449

Rudahigwa, O., & Tombola, G. M. (2021). The Influence of East African Community's Cargo Clearance Procedures on Trade Facilitation in Rwanda. *European Journal of Business and Management Research, 6*(3), 61-68.

Saunders, M.N.K, Lewis, P. and Thronbill, A. (2019). *Research Methods for Business Students.* 8th Edition, Pearson, New York.

Tanzania, U. R. o. (2003). National Transport Policy. In: Ministry of Communications and Transport.

Tuan, L. T. (2017). Under entrepreneurial orientation, how does logistics performance activate customer value co-creation behavior? *The International Journal of Logistics Management*.

Umanath, N. S. (2003). The concept of contingency beyond "It depends": illustrations from IS research stream. *Information & Management, 40*(6), 551-562.

Viwanda, W. y. (2003). *National Trade Policy Background Papers: Trade Policy for a Competitive Economy and Export-led Growth*: Dar es Salaam University Press.

Yeo, Thai, & Pak. (2016). Comparative analysis of port competency requirements in Vietnam and Korea. *Maritime Policy & Management, 43*(5), 614-629.

Yi, Y. (1990). A critical review of consumer satisfaction. *Review of marketing, 4*(1), 68-123.

Yin, W. (2020). The Role of Port Economic Benefits in the Coordinated Development of Society. *Journal of Coastal Research, 103*(SI), 686-690.

EXPLAINABLE AI APPROACH FOR IDENTIFYING CRITICAL FACTORS AFFECTING ON-TIME ARRIVAL OF TRUCKS IN LOGISTICS

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ABSTRACT

Purpose: Effective supply chain management depends on on-time delivery, and knowing what influences on-time arrival can help logistics organizations optimize their processes and improve customer satisfaction. This study explores the key factors that affect the on-time arrival of trucks in logistics operations using an explainable AI technique.
Design/methodology/approach: This study identifies the key factors that have a significant impact on the on-time arrival of trucks using explainable AI techniques and a large dataset made up of historical delivery records, current location, transportation distance, vehicle type, supplier, material shipped, vehicle state, destination state, and other relevant factors.
Findings: The research's conclusions provided clear understandings into the causes of delivery delays by shedding light on the relative significance and interplay of these factors.
Research limitations: The research may face limitations due to the availability and quality of data. Access to comprehensive and up-to-date datasets containing information on various factors that influence on-time arrival of trucks in logistics might be challenging. Insufficient or biased data can affect the accuracy and generalizability of the findings.
Practical implications The logistics sector will be significantly impacted by the results of the study. Logistics organizations may enhance their delivery schedules, manage resources more wisely, and put plans in place to reduce risks by developing a thorough grasp of the essential elements influencing on-time arrival. Cost reductions, increased operational effectiveness, and an overall improvement in logistics performance can result from this.
Originality/value: By particularly applying explainable AI techniques to the logistics context and concentrating on the on-time arrival of trucks, this research makes a contribution to the area. The proposed technique stands out for its transparency and interpretability, guaranteeing that stakeholders can understand the model's decision-making process and develop trust in AI-driven logistics solutions.

Keywords: Explainable AI, On-Time Arrival, Trucks, Logistics, Delivery Delays, Transparent Insights, Operational Efficiency.

1. Introduction

The timely delivery of products and services is fundamental to the operational efficiency and customer satisfaction of supply chain management. The complex network of processes and activities that comprise contemporary logistics operations depends on the capacity to ensure on-time shipment delivery. However, the complex nature of supply chains, which is characterized by diverse variables and dynamic conditions, makes it difficult to consistently meet delivery deadlines.

Understanding the key factors that influence the on-time arrival of a shipment is of crucial importance in this situation. By understanding the complex interaction between factors, logistics organizations can gain valuable insights that facilitate the optimization of operational procedures. Therefore, improved on-time delivery performance not only facilitates the entire supply chain, but also contributes significantly to enhancing customer satisfaction.

This study investigates the influence of these key factors on the on-time arrival of vehicles in logistics operations. To explain the complex relationships at play, the research employs an innovative method based on AI techniques that can be explained. Using the power of explainable AI, the study is to explain the factors that influence on-time arrivals, providing a clear and interpretable view of the decision-making processes.

In the following sections, we conduct a thorough investigation that puts light on the key factors that influence the timely arrival of trucks in the logistics landscape. Through the lens of explainable AI, this investigation aims to provide not only an enhanced understanding of these factors, but also a framework upon which logistics organizations can formulate strategies to optimize their operations and increase customer satisfaction to new heights.

2. Literature review

Predicting transit time and ensuring on-time delivery of shipments are critical challenges in logistics and supply chain management. In recent years, machine learning techniques have gained prominence as powerful tools to address these challenges. This section provides an overview of studies that have employed machine learning for predicting transit time and enhancing on-time delivery of shipments.

(Jonquais and Krempl, 2019) developed a project to determine if Machine Learning and predictive analytics can improve shipment arrival times. A model was developed using Machine Learning computing and historical shipment data, incorporating external factors like holiday seasons and port congestion levels. (Hathikal, Chung and Karczewski, 2020) develops a predictive model for ocean import freight shipment lead time using machine learning methods, considering stakeholder interests. Two terminal criteria are used: empty container return and delivery confirmation at the destination. Real data from an industry partner is used, and multinomial logistic regression is identified as the best classifier. Classifiers like multinomial logistic regression, decision tree, K-nearest neighbors, and support vector machine perform better than Naïve Bayes when categorical variables are binarized or converted into ordinal values. The model offers improved visibility and predictability for shipment lead times, benefiting various parties in the supply chain. (Lin, Chen and Chou, 2023) collected global positioning system travel data from a Taiwanese convenience store chain and proposed machine learning to predict travel times. The model was validated using historical data and a nonlinear regression equation for missing GPS data. The results exceeded 97%, demonstrating the model's potential for logistics fleets to estimate accurate travel times for future delivery tasks and route arrangements. The integrative literature review by (Mugurusi and Oluka, 2021) explores the status of XAI as a solution to AI's black-box problem in Supply Chain Management (SCM). It presents an integrative research typology for XAI in SCM, aiming to align literature conceptions and understand the gap between AI deployment in practice, maturity in SCM, and XAI's extent.

The research on Explainable AI (XAI) in identifying key factors affecting transit time and ensuring on-time delivery of shipments is scarce. Although machine learning techniques have been integrated for transit time prediction and on-time delivery enhancement, the focus on understanding the underlying drivers remains limited. XAI holds immense promise in providing actionable insights for informed decision-making and improved operational efficiency. However, the current research landscape highlights a significant gap in exploring key influencing factors, highlighting untapped potential and the need for further investigation. Researchers and practitioners must recognize this unexplored avenue and work to bridge the gap between XAI and identifying critical factors in transit time prediction and on-time delivery assurance. Addressing this research gap could yield valuable insights for academia and real-world logistics operations, ultimately leading to more reliable and efficient supply chain management.

3. Methodology

Figure 1 shows the whole operational method that this study proposes. At first, the data is pre-processed. The first step in making machine learning models is to divide the data into training, validation, and testing data sets. The training data set is used to build the classification model, the validation data set is used to fine-tune the models' hyperparameters, and the test data set is used to test how well the models work. Once the best model has been found, Explainable AI methods are used to set up additive attributes. These attributes are then used to figure out how important different variables are for injury severity and how different risk factors affect severity mode.

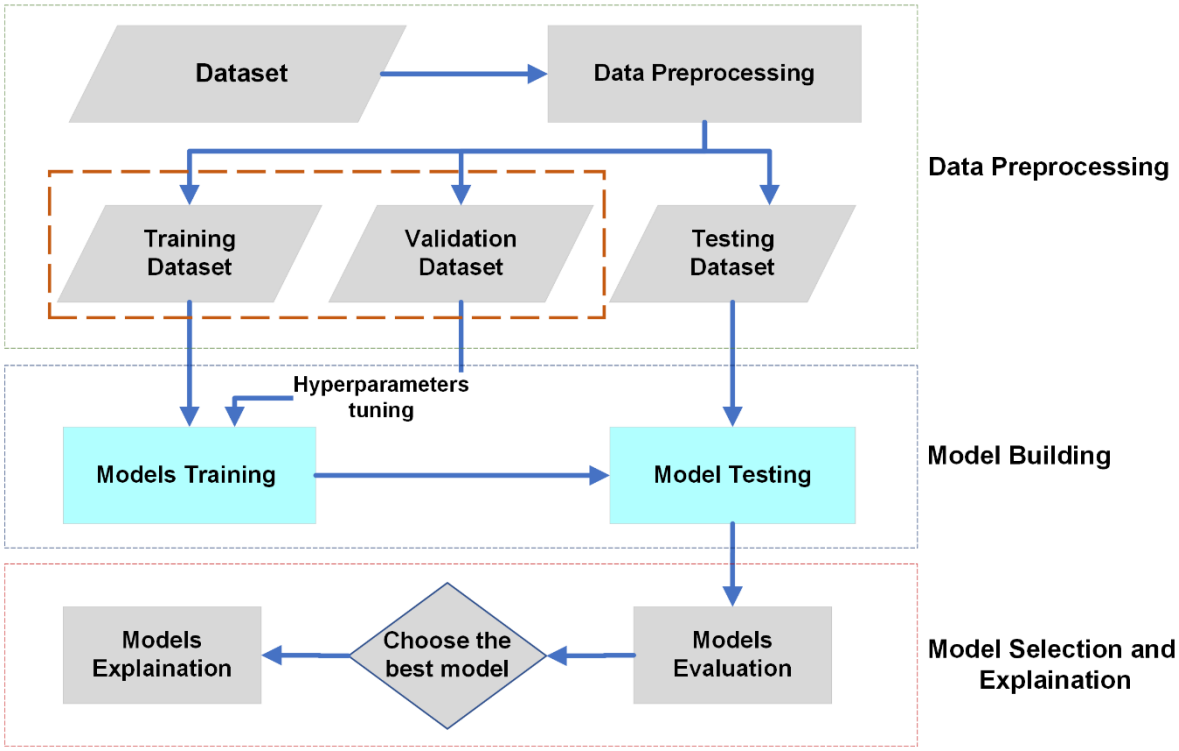


Figure 1: The research framework

3.1. Data Description

In this study, we used a historical delivery records dataset of a logistics company that is publicly available on Kaggle (www.kaggle.com). The dataset contains 6,849 historical delivery records. The description of variables is shown in Table 1.

Variable Name	Description
market_or_regular	Type of trip. Regular - contracted vendors Market - non-contracted vendors
origin_location_code	Origin location code
destination_location_code	Destination location code
transportation_distance_in_km	Transportation distance (in kilometre)
expected_travel_hours	Expected travel time (in hours)

vehicle_type	Vehicle Types
customer_id	Customer ID
supplier_id	Supplier ID
material_shipped	Type of material transported
ontime	On time or Delayed

Table 1: Data Description

3.2. Machine Learning Models

In this study, sixteen machine learning models are used to predicting on-time delivery of a shipment. These models represent a diverse range of machine learning algorithms, each with its own characteristics, strengths, and applications. To train the models, we used the Python packages PyCaret (Ali, 2020). Table 2 shows a short description of the machine learning algorithms used in this study.

No.	Algorithms	References	Short description
1	Logistic Regression	(Cox, 1958)	A classification algorithm used to model the probability of a binary outcome. It estimates the relationship between the independent variables and the probability of a specific outcome.
2	K Neighbors Classifier	(Cover and Hart, 1967)	A non-parametric classification algorithm that assigns a new data point's class based on the majority class among its k nearest neighbors in the feature space.
3	Naive Bayes	(Chan, Golub and LeVeque, 1982)	A probabilistic classification algorithm that applies Bayes' theorem with the "naive" assumption of feature independence to predict the class probabilities.
4	Decision Tree Classifier	(Breiman *et al.*, 1984)	A tree-based classification algorithm that recursively splits the data into subsets based on feature values, creating a decision tree structure to make predictions.
5	SVM - Linear Kernel	(Platt and others, 1999)	Support Vector Machine uses a linear kernel to find a hyperplane that best separates data points of different classes while maximizing the margin between them.
6	Ridge Classifier	(Hastie *et al.*, 2009)	A variant of linear regression that adds L2 regularization (ridge) to the loss function, helping prevent overfitting.
7	Random Forest Classifier	(Breiman, 2001)	An ensemble method that builds multiple decision trees and combines their predictions to improve accuracy and reduce overfitting.
8	Quadratic Discriminant Analysis	(McLachlan, 2005)	A classification technique assuming Gaussian distributions, allowing different covariance matrices for each class, in contrast to Linear Discriminant Analysis.
9	Ada Boost Classifier	(Freund and Schapire, 1997)	An ensemble method that combines multiple weak classifiers to create a strong classifier. It assigns higher weights to misclassified instances.
10	Gradient Boosting Classifier	(Friedman, 2001)	An ensemble technique that sequentially builds decision trees, focusing on the mistakes made by the previous trees to improve overall performance.
11	Linear Discriminant Analysis	(McLachlan, 2005)	A technique that seeks linear combinations of features that best separate classes by maximizing the ratio of between-class variance to within-class variance.
12	Extra Trees Classifier	(Geurts, Ernst and Wehenkel, 2006)	An ensemble method similar to Random Forests, but with additional randomization in selecting splitting points, aiming for improved generalization.
13	Extreme Gradient Boosting	(Chen and Guestrin, 2016)	Extreme Gradient Boosting (Chen and Guestrin, 2016)**: Also known as XGBoost, it's an advanced gradient boosting algorithm designed for improved performance, scalability, and handling missing values.
14	Light Gradient Boosting	(Ke *et al.*, 2017)	A gradient boosting framework that focuses on faster training and high efficiency using histogram-based learning.
15	CatBoost Classifier	(Prokhorenkova *et al.*, 2018)	A gradient boosting algorithm designed to handle categorical features efficiently by encoding them in a way that improves model performance.

No.	Algorithms	References	Short description
16	Dummy Classifier	((Lorena, De Carvalho and Gama, 2008)	A simple baseline classifier that makes predictions based on simple rules like random guessing or class distribution proportions. It's used to benchmark other classifiers.

Table 2: A short description of the machine learning algorithms used in this study.

3.3. Model Evaluation

In this study, the evaluation and selection of the best model are performed using the confusion matrix and its associated metrics, namely accuracy, precision, recall, and F1-score. Additionally, Area Under the ROC Curve (AUC), Cohen's Kappa and Matthews Correlation Coefficient (MCC) are utilized for this purpose. These metrics provide a comprehensive understanding of a classification model's performance, considering different aspects of correct and incorrect predictions.

A confusion matrix (also known as the contingency table) is a tabular representation of the predicted vs. actual class labels for a classification problem. It helps in understanding the performance of a classification model. Figure 2 depicts the confusion matrix, which can be used to compute numerous metrics.

	Predicted Positive	**Predicted Negative**
Actual Positive	True Positive (TP)	False Negative (FN)
Actual Negative	False Positive (FP)	True Negative (TN)

Figure 2: Confusion matrix

The true positives (TP) and true negatives (TN) have been correctly classified. A false positive (FP) occurs when an outcome is incorrectly classified as yes or positive when it is in fact no or negative. False negative (FN) refers to the incorrect classification of a positive result as negative. The true positive rate (TPR) quantifies the proportion of correctly identified positives, whereas the false positive rate (FPR) quantifies the proportion of incorrectly identified negatives as positives.

Accuracy is the ratio of correctly predicted instances to total instances, evaluating a model's overall performance. A 1 indicates accurate predictions, while a 0 indicates incorrect predictions and incorrect classification. Precision is the proportion of accurately predicted positive instances relative to all correctly predicted positive instances. The higher the value of Precision, the better. The best possible value is 1 (if a model made all correct predictions), and the worst possible value is 0 (if a model made no correct predictions). Recall is the proportion of accurately predicted positive instances in relation to all actual positive instances. It assesses the model's capacity to recognize all positive instances. A high recall score results in fewer false negatives. The best possible value for recall is 1 (model correctly identifies all positive instances and does not produce any false negatives). The worst possible value for recall is 0 (model fails to identify any of the positive instances and produces only false negatives). The F1 score represents the harmonic mean of precision and recall. It maintains a balance between precision and recall. F1 score is useful when classes are unbalanced because it provides false positives and false negatives equal weight. A higher F1 score is better, as it indicates that the model performs well in terms of precision and recall. The F1 score of a perfect classifier is 1. A score of 0 for the F1 measure indicates poor model performance.

Area Under the ROC Curve (AUC) is a binary classification evaluation metric that evaluates a model's ability to distinguish positive and negative instances (Fawcett, 2006). It represents the trade-off between True Positive Rate (Recall) and False Positive Rate (Specificity) for different threshold values. AUC ranges from 0 to 1, with a perfect classifier having a 1 and a random classifier having a 0.5. Higher AUC values indicate better discrimination.

Cohen's Kappa (Fleiss and Cohen, 1973) is a statistical measure that evaluates the level of agreement between observed and expected classifications, considering chance. It is commonly used to evaluate classification models and human raters' agreement in tasks like annotation or labeling. A 1 indicates perfect agreement, a 0 indicates equivalent agreement, and a less than 0 indicates worse agreement than random chance.

The Matthews Correlation Coefficient (MCC) is an evaluation metric that takes into account true positive, true negative, false positive, and false negative predictions to provide a balanced measure of a classification model's performance (Gorodkin, 2004). It ranges between -1 and 1, where 1 indicates perfect predictions, 0 indicates random predictions, and -1 indicates complete disagreement between predicted and actual classifications.

3.4. Model Interpretation

SHAP (SHapley Additive exPlanations) (Lundberg and Lee, 2017) is a powerful machine learning technique for interpreting complex model predictions. It reveals how individual features contribute to a model's prediction for a specific instance. SHAP values are derived from cooperative game theory concepts (Merrick and Taly, 2019) and seek to allocate each feature's "contribution" to the prediction outcome fairly. The SHAP framework has garnered enormous attention in the field of explainable AI due to its capacity to provide intuitive insights into the decision-making processes of black-box models. It provides a comprehensive and consistent method for understanding the impact of each feature on model predictions, thereby enhancing model transparency and allowing users to utilize machine learning models more effectively.

4. Results

4.1. Performance Assessment

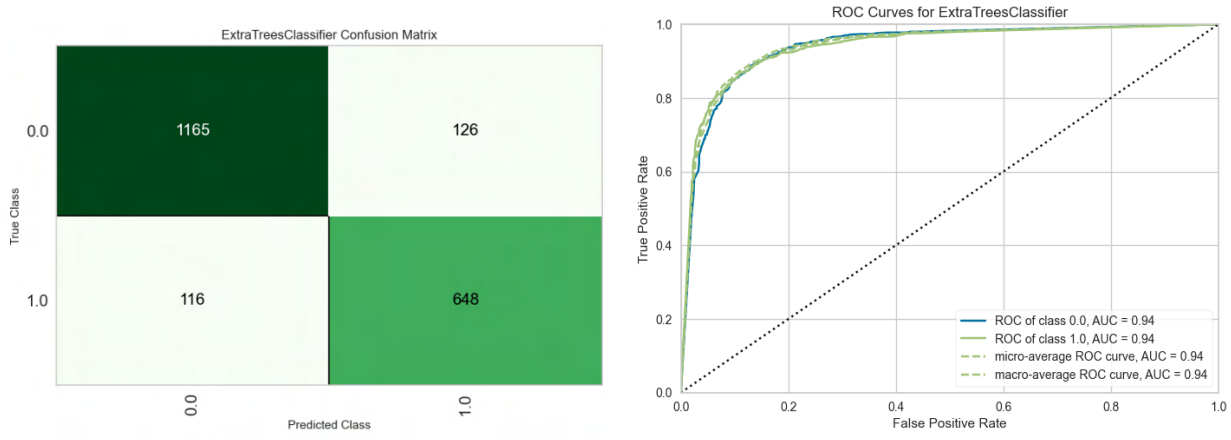
To train the models, we used the Python packages PyCaret (Ali, 2020). Initially, delivery data from the past were collected and pre-processed. For model development, we divided the data into the three subsets listed below: 80% of the data was divided into training and validation subsets, while 20% was used for testing and withheld for model performance evaluation. The training data set was used to develop the models, while the validation data set was used to estimate the performance of the model and tune its hyperparameters. Table 3 shows evaluation metrics for classification model and training time.

Model	Accuracy	AUC	Recall	Prec.	F1	Kappa	MCC	TT (Sec)
Extra Trees Classifier	0.8828	0.9374	0.8428	0.8434	0.8421	0.7489	0.7501	1.1000
Random Forest Classifier	0.8769	0.9446	0.8479	0.8274	0.8364	0.7378	0.7393	1.1370
Light Gradient Boosting Machine	0.8748	0.9438	0.8372	0.8298	0.8323	0.7326	0.7339	1.0500
CatBoost Classifier	0.8723	0.9464	0.8305	0.8289	0.8283	0.7268	0.7283	2.5110
Extreme Gradient Boosting	0.8694	0.9419	0.8378	0.8182	0.8267	0.7221	0.7236	1.0290
Gradient Boosting Classifier	0.8590	0.9343	0.8137	0.8101	0.8105	0.6983	0.6999	1.0780
K Neighbors Classifier	0.8581	0.9095	0.8187	0.8059	0.8108	0.6975	0.6992	0.9700
Ada Boost Classifier	0.8527	0.9278	0.8204	0.7920	0.8053	0.6870	0.6880	0.9960
Decision Tree Classifier	0.8450	0.8460	0.8058	0.7847	0.7939	0.6698	0.6713	0.9360

Model	Accuracy	AUC	Recall	Prec.	F1	Kappa	MCC	TT (Sec)
Logistic Regression	0.8440	0.9190	0.7851	0.7938	0.7887	0.6651	0.6659	1.6860
Quadratic Discriminant Analysis	0.8419	0.9084	0.6885	0.8606	0.7638	0.6472	0.6573	0.9340
Ridge Classifier	0.8408	0.0000	0.6925	0.8527	0.7631	0.6454	0.6542	0.9380
Linear Discriminant Analysis	0.8400	0.9138	0.6891	0.8531	0.7613	0.6432	0.6523	0.9920
SVM - Linear Kernel	0.8394	0.0000	0.7862	0.7848	0.7838	0.6562	0.6579	0.9400
Naive Bayes	0.8285	0.8970	0.6347	0.8693	0.7328	0.6112	0.6282	0.9010
Dummy Classifier	0.6283	0.5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9730

Table 3: Comparative evaluation metrics of various machine learning models.

As shown in Table 3, the Extra Trees Classifier model provided the best prediction performance. Accuracy, AUC, recall, precision, F1, Kappa and MCC for the model are 0.8828, 0.9374, 0.8428, 0.8434, 0.8421, 0.7489 and 0.7501 respectively. The model has a high overall accuracy and good precision and recall values. It appears to be performing well in both correctly identifying positive cases and avoiding false positives. Figure 3 shows confusion matrix and ROC curve output of Extra Trees Classifier model.



(a) (b)

Figure 3: Confusion matrix and ROC curve output of Extra Trees Classifier model.

The ROC provide insight into a model's ability to make accurate predictions across different thresholds, with AUC offering a summary measure of performance. From Figure 3 (b), A curve that is close to the top-left corner and has a higher AUC generally indicates better discrimination between classes.

4.2. Model Explanation

The implementation of the SHAP summary evaluation was undertaken in order to facilitate a more detailed analysis of the model. Based on the SHAP summary plot, we have derived a numerical

estimation that combines the Shapely values and represents the contributions of variables in the model (refer to Figure 4).

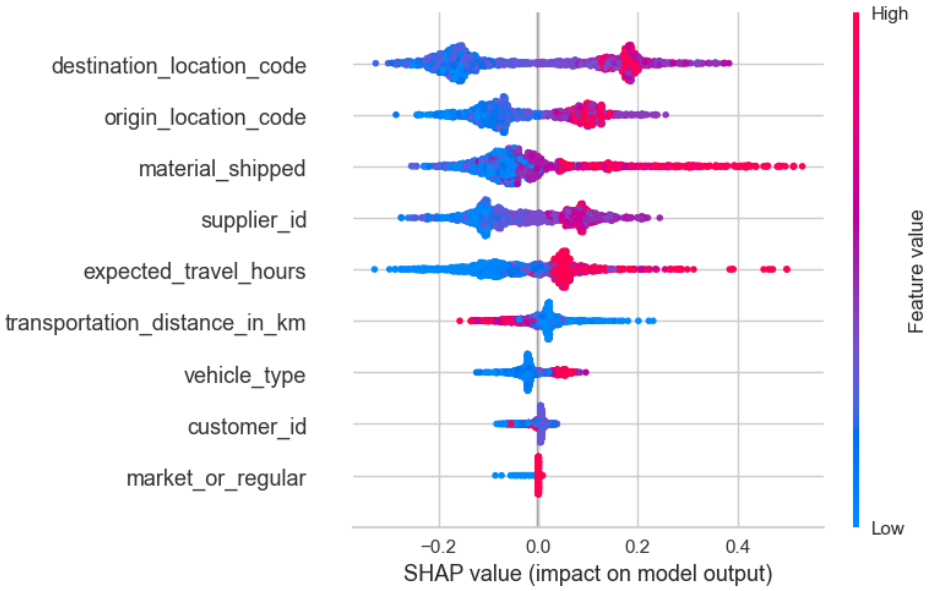


Figure 4: SHAP summary plot for variable importance.

Figure 4 summarizes the Shapely values and gives a graphical representation of the variables' contributions to the model based on the SHAP summary plot. Ascending from most influential to least, the input variables are arranged along the vertical axis. The SHAP value is shown by the horizontal axis, and the significance level of the variable, from low to high, is shown by the color scale. There is a higher degree of correlation between the input variable and the target variable if there are more data points within a particular range of SHAP values. From SHAP summary plot, the most important input variable in determining the on time delivery is destination_location_code, which is ranked first in the summary plots, followed by origin_location_code and material_shipped.

5. Conclusions

In this study, machine learning models and Explainable AI (XAI) were used to identify key factors that have a significant impact on the on-time arrival of vehicles. Typically, accurate models provide a comprehensive depiction of the fundamental relationship between on-time and factors. The Extra Trees Classifier model outperforms other machine learning models in terms of predictive accuracy, AUC, recall, precision, F1-score, Kappa, and MCC in this study. The model provides an additional viable option for modeling on-time vehicle arrival. XAI can be utilized as a tool to find and understand the key factors that affect the outcome of a machine learning model. In this study, SHAP (SHapley Additive exPlanations) was used to interpreting machine learning models and making their predictions more understandable. The analysis revealed that the top five factors that are more likely to affect have a significant impact on the on-time arrival of vehicles are destination location (destination_location_code), origin location (origin_location_code), type of material transported (material_shipped), supplier (supplier_id) and expected travel time (expected_travel_hours).

The destination location and origin location are the key factors that have a significant impact on the on-time arrival of vehicles. The factors concern with traffic congestion, road infrastructure and delivery windows. Urban areas or busy routes can experience heavy traffic congestion, leading to delays. Vehicles originating or destined for such areas might face challenges in maintaining on-time arrivals due to potential traffic jams. The quality of roads and infrastructure on the route can impact travel times. Poor road conditions,

construction zones, or detours can lead to unexpected delays. Certain delivery destinations might have specific delivery windows or time restrictions. Adhering to these time constraints is crucial for on-time delivery and customer satisfaction. For the material transported factor, the nature of the material being transported can impact the mode of transportation chosen, handling requirements, and potential delays (e.g., perishable goods might require faster transportation). For the expected travel time factor, as the travel time increases, the amount of uncertainty also increases. Accurate expected travel time estimates allow for more realistic predictions of when a vehicle will reach its destination. If these predictions are precise, it enables better planning and scheduling of vehicle routes.

References

Ali, M. (2020) *PyCaret: An open source, low-code machine learning library in Python*. Available at: https://www.pycaret.org.

Breiman, L. *et al.* (1984) 'Classification and regression trees (Wadsworth, Belmont, CA)', *ISBN-13*, pp. 978–0412048418.

Breiman, L. (2001) 'Random Forests', *Machine Learning*, 45(1), pp. 5–32. Available at: https://doi.org/10.1023/A:1010933404324.

Chan, T.F., Golub, G.H. and LeVeque, R.J. (1982) 'Updating formulae and a pairwise algorithm for computing sample variances', in *COMPSTAT 1982 5th Symposium held at Toulouse 1982: Part I: Proceedings in Computational Statistics*. Springer, pp. 30–41.

Chen, T. and Guestrin, C. (2016) 'Xgboost: A scalable tree boosting system', in *Proceedings of the 22nd acm sigkdd international conference on knowledge discovery and data mining*, pp. 785–794.

Cover, T. and Hart, P. (1967) 'Nearest neighbor pattern classification', *IEEE transactions on information theory*, 13(1), pp. 21–27.

Cox, D.R. (1958) 'The regression analysis of binary sequences', *Journal of the Royal Statistical Society: Series B (Methodological)*, 20(2), pp. 215–232.

Fawcett, T. (2006) 'An introduction to ROC analysis', *Pattern recognition letters*, 27(8), pp. 861–874.

Fleiss, J.L. and Cohen, J. (1973) 'The equivalence of weighted kappa and the intraclass correlation coefficient as measures of reliability', *Educational and psychological measurement*, 33(3), pp. 613–619.

Freund, Y. and Schapire, R.E. (1997) 'A decision-theoretic generalization of on-line learning and an application to boosting', *Journal of computer and system sciences*, 55(1), pp. 119–139.

Friedman, J.H. (2001) 'Greedy function approximation: a gradient boosting machine', *Annals of statistics*, pp. 1189–1232.

Geurts, P., Ernst, D. and Wehenkel, L. (2006) 'Extremely randomized trees', *Machine learning*, 63, pp. 3–42.

Gorodkin, J. (2004) 'Comparing two K-category assignments by a K-category correlation coefficient', *Computational biology and chemistry*, 28(5–6), pp. 367–374.

Hastie, T. *et al.* (2009) *The elements of statistical learning: data mining, inference, and prediction*. Springer.

Hathikal, S., Chung, S.H. and Karczewski, M. (2020) 'Prediction of ocean import shipment lead time using machine learning methods', *SN Applied Sciences*, 2(7), p. 1272. Available at: https://doi.org/10.1007/s42452-020-2951-5.

Jonquais, A. and Krempl, F. (2019) 'Predicting shipping time with machine learning'.

Ke, G. *et al.* (2017) 'Lightgbm: A highly efficient gradient boosting decision tree', *Advances in neural information processing systems*, 30.

Lin, Y.-K., Chen, C.-F. and Chou, T.-Y. (2023) 'Developing Prediction Model of Travel Times of the Logistics Fleets of Large Convenience Store Chains Using Machine Learning', *Algorithms*, 16(6), p. 286.

Lorena, A.C., De Carvalho, A.C. and Gama, J.M. (2008) 'A review on the combination of binary classifiers in multiclass problems', *Artificial Intelligence Review*, 30, pp. 19–37.

Lundberg, S.M. and Lee, S.-I. (2017) ‘A Unified Approach to Interpreting Model Predictions’, in I. Guyon et al. (eds) *Advances in Neural Information Processing Systems*. Curran Associates, Inc. Available at:https://proceedings.neurips.cc/paper_files/paper/2017/file/8a20a8621978632d76c43dfd28b67767-Paper.pdf.

McLachlan, G.J. (2005) *Discriminant analysis and statistical pattern recognition*. John Wiley & Sons.

Merrick, L. and Taly, A. (2019) ‘The explanation game: Explaining machine learning models with cooperative game theory’, *arXiv preprint arXiv:1909.08128* [Preprint].

Mugurusi, G. and Oluka, P.N. (2021) ‘Towards Explainable Artificial Intelligence (XAI) in Supply Chain Management: A Typology and Research Agenda’, in A. Dolgui et al. (eds) *Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems*. Cham: Springer International Publishing (IFIP Advances in Information and Communication Technology), pp. 32–38. Available at: https://doi.org/10.1007/978-3-030-85910-7_4.

Platt, J. and others (1999) ‘Probabilistic outputs for support vector machines and comparisons to regularized likelihood methods’, *Advances in large margin classifiers*, 10(3), pp. 61–74.

Prokhorenkova, L. *et al.* (2018) ‘CatBoost: unbiased boosting with categorical features’, *Advances in neural information processing systems*, 31.

EXPLORING SUSTAINABILITY-RELATED ISSUES IN HOTEL BUSINESS: A CASE OF THAI PUBLIC COMPANIES

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ABSTRACT

Purpose – This paper aims to analyze and compare the inclusion of sustainable development issues in the hotel business through the companies' annual and sustainability reports. Two groups of hotel operators, the group listed in the Thailand Sustainability Index (THSI) and the Non-THSI listed, were used for comparison.
Design/Methodology/Approach – The analysis of sustainable development issues in the hotel business was conducted by utilization of the text analysis technique. The analysis divides into two parts. First, the sustainability-related keywords were extracted from existing research. The keywords are to be used as search keywords in the text analysis. In text analysis, the data used in this study comes from published annual reports and sustainability reports of the public companies in a service sector listed in the Stock Exchange of Thailand (SET). The search keywords are then used to match the keywords found in the reports in terms of a cooccurrence between a pair of keywords. The frequency of keywords' cooccurrence should reflect the focused areas of sustainable development in the hotel business.
Findings - The analysis reveals sustainable-related issues in the hotel business. The frequency of associated keywords also indicates the difference in the degree of the inclusion of sustainability issues among hotel operators.
Research limitations/implication - The approach presented in this research can be applied to different areas of study using a different set of data. Nonetheless, the availability and consistency of the input data are to be concerned.
Practical implications – In the context of the hotel business, understanding the status and progress of sustainable development can lead to a proper direction of sustainable development. A redundant investment can be avoided. Moreover, a benchmark among the same industry is also possible and can be beneficial to the formulation of business strategy.
Original/value – This paper proposes a combination of techniques, bibliometric analysis, and text analysis, and utilizes both academic and business knowledge to comprehend the current situation of sustainability-related issues in Thailand's hotel business.

Keywords Hotel industry, Sustainability, Bibliometric analysis, Text analysis, Occurrence analysis

INTRODUCTION

The hospitality industry is one of the most important sectors which has an extensive impact on local economies and the global market. Indirectly, it influences consumer behaviors and business practices (Scott et al., 2019). However, its influence also brings about significant environmental, social, and governance challenges (Bae, 2022). Recently, attention to the concept of sustainability within the hotel industry has become increasingly important (Chung, 2020; Jones & Comfort, 2020). Like other industries, sustainable development in the context of the hotel business considers the balance between economic growth, environmental preservation, and social responsibility (Ruggerio, 2021).

The degree of sustainability integration in hotel operations varies significantly among business sectors, locations, and even within the same geographical area (Jones et al., 2014). Thailand's hotel industry is a case in which the importance of sustainability integration is emphasized due to the sector's significant impact on the nation's economy and environment (Tong-On et al., 2021).

The Stock Exchange of Thailand (SET) introduced the Thailand Sustainability Investment (THSI) index in 2015, which serves as a standard for sustainability performance among publicly listed companies (Sanoran, 2023). Companies listed in the THSI are expected to demonstrate best practices and serve as models for other businesses and attempt to integrate sustainable operations. This research reveals the sustainability efforts of hotel operators, both listed in the THSI and those not listed.

This study applies an innovative combination of bibliometric and text analysis techniques to identify and analyze sustainability-related issues through keywords in companies' annual and sustainability reports. This approach provides a comprehensive understanding of the focus areas of sustainability practices and the extent of their integration into hotel operators' strategies.

While this research is academically valuable, it also brings practical implications for businesses in the hospitality sector. Understanding the status and progress of sustainable development allows hotel operators to streamline their sustainability efforts, avoid redundant investments, and benchmark their practices against industry standards.

METHOD

This research employs a three-stage methodology aimed at assessing the progress of sustainable development in the hotel industry, necessitating a thorough analysis of pertinent data. The first stage revolves around defining the boundaries of this analysis, which, in this context, are marked by keywords relating to sustainability and the hotel industry. Utilizing VOS viewer software, this stage involves determining the frequency of these associated keywords within the bibliometric data sourced from the SCOPUS database. Keywords that surface at least 50 times are earmarked for further examination. The search parameters used to extract bibliometric data from the SCOPUS database are outlined in

Table ***2***.

Table 2 Search criteria of bibliometric data

Database:	**Scopus**
Search scope:	Title, Abstract, Authors' keywords, Indexed keywords
Keywords:	(TITLE-ABS-KEY (hotel) AND TITLE-ABS-KEY (sustainable) OR TITLE-ABS-KEY (green) AND TITLE-ABS-KEY (development)) AND PUBYEAR > 1999 AND PUBYEAR < 2024 AND (LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "ENER") OR LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "ECON") OR LIMIT-TO (SUBJAREA , "EART") OR LIMIT-TO (SUBJAREA , "AGRI") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "MATE") OR LIMIT-TO (SUBJAREA , "MATH"))
Years of publication:	2000 - 2023
Number of documents:	1,397

The identification of these keyword weights will play a crucial role in delineating the scope of the ensuing text analysis. Importantly, during the text analysis in the third stage, combined keywords (such as 'sustainable development', 'environmental management', and 'sustainable tourism') that were identified in this phase will be disaggregated into individual words. The ensuing algorithm will then autonomously calculate the frequency of cooccurrences between each keyword pair identified within the primary data sources, namely, the annual and sustainability reports. Thus, the initial definitions of the keywords will be retained throughout this process.

In the second stage, the focus is on identifying target companies that will serve as the sources of sustainability data. Publicly listed companies are generally required to publish an annual report, known as the 56-1 report, with an option to publish a sustainability report as well. While the annual reports are publicly accessible, not all hotel operators provide sustainability reports, which are essential data sources for this study. Hence, careful selection of target companies is crucial.

The Stock Exchange of Thailand (SET) advocates for the issuance of sustainability reports. As such, all publicly listed companies can create these reports to inform investor decisions. However, only companies meeting specific criteria, including participating in the SET's annual sustainability assessment, and achieving an ESG score of at least 50% in all dimensions, can be included in the Thailand Sustainability Index (THSI). Consequently, this research includes both THSI-listed and non-THSI-listed companies, with additional selection criteria like market capitalization and industry ranking being taken into consideration.

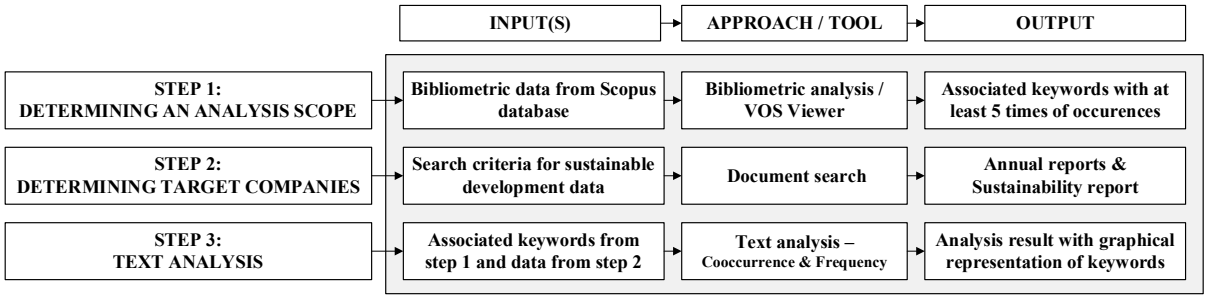

Figure 2 Research Methodology

Following the definition of the research scope and the selection of target companies, the third and final stage of this study gets underway. This stage is centered on scrutinizing sustainability-related keywords that correspond with the scope delineated during the initial stage. The material for this analysis is sourced from the annual and sustainability reports of the companies that fulfilled the criteria set out in the second stage. In this phase, a method of text analysis is implemented to determine the frequency of all related keywords within the annual and sustainability reports of the selected companies. This investigation covers the period from 2019 to 2022, during which these reports are publicly available.

To visually represent the data, graphical illustrations are utilized. These graphics display the frequency of the identified keywords in the reports and facilitate a comparative analysis of sustainable development facets between THSI-listed and non-THSI-listed companies. It should be noted that the frequency of a particular keyword can signal the degree of emphasis a company places on that aspect of sustainability. The overview of the research methodology is presented in Figure 2.

RESULT AND DISCUSSION

This section encompasses three components of the findings, each aligning with the research procedures delineated in the preceding section. The initial segment divulges the research scope, predicated on the keywords with a minimum occurrence frequency of 15 times in extant literature. The subsequent segment exhibits the roster of the handpicked companies. Finally, the third component uncovers and deliberates upon the outcomes of the text analysis.

- **Determining an analysis scope using keywords**

Drawing from the research procedure detailed previously, this part of the study shares the findings yielded by a bibliometric analysis, executed using the VOS Viewer software. This software is highly recognized for its excellence in carrying out bibliometric analysis (Effendi et al., 2021). The analysis furnished two

categories of data: bibliographic information that measures the regularity of keyword appearances and their interconnections, along with data that reveals the importance and the number of occurrences for all recognized keywords.

Figure *3* offers a visual representation of the bibliographic information gathered using VOS Viewer, highlighting the keywords that will direct the analytical parameters in the third stage of this study. It further signals potent connections between major clusters like sustainable development, hotels, and sustainability, and smaller ones such as energy efficiency, energy conservation, sustainable tourism, and tourism development. These correlations potentially shed light on the focus areas and sustainable development within the realm of the hotel business and the broader tourism sector. Leveraging the data sourced from VOS Viewer,

Table ***3*** contains a selection of the top 10 keywords (out of a pool of 95) along with their corresponding weights, indicating their overall link strength and frequency of occurrences.

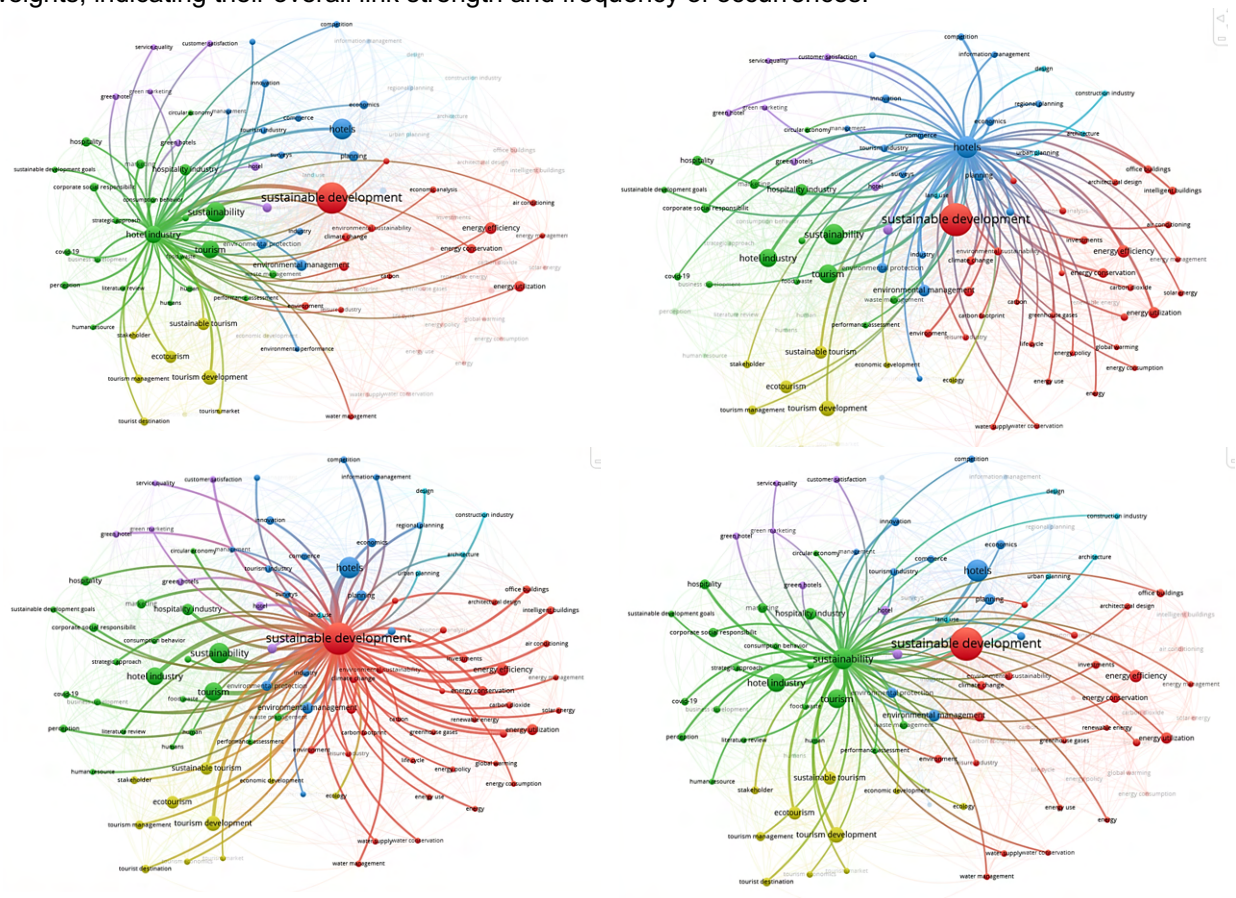

Figure 3 Bibliographic of sustainability-associated keywords in the hotel business.

However, rather than relying exclusively on the top 10 keywords based on their frequency or weight, this research turned the attention to keywords that, while perhaps less frequent, bore a higher degree of relevance to the sustainable development practices within the hotel industry.

Subsequently, the keywords chosen to define the text-analysis framework in the third phase were meticulously selected from the results of the bibliometric analysis due to their pertinence to sustainable

development. The chosen keywords include: *'sustainable', 'development', 'water', 'sustainability', 'wastes', 'intelligent', 'eco', 'energy', 'innovation', 'green', 'carbon', 'food', 'circular', 'efficiency', 'utilization', 'environmental', 'management', 'planning', 'conservation', 'protection', 'social', 'responsibility', 'governance', 'emission', 'solar', and 'information'*. Despite their lower frequency or weight, these words are more representative of sustainable initiatives in the hotel sector.

As part of the text analysis process, compound keywords such as 'sustainable development', 'environmental management', and 'sustainable tourism' were dissected into their components. Subsequently, an algorithm was employed to autonomously compute the cooccurrence frequency of each keyword pairing in the primary data sources, namely, the annual and sustainability reports. This approach ensured the preservation of the original keyword definitions throughout the entire analysis.

Table 3 Examples of top 10 keywords with the relatively highest frequency of occurrences.

id	label	cluster	weight<Links>	weight<Total link strength>	weight<Occurrences>
6513	sustainable development	1	94	577	629
3325	hotels	3	92	264	274
6443	sustainability	2	92	213	238
3286	hotel industry	2	85	178	189
6827	tourism	2	87	173	196
6838	tourism development	4	76	128	133
1888	ecotourism	4	71	85	89
2078	energy efficiency	1	69	82	82
6586	sustainable tourism	4	73	82	90
2254	environmental management	3	84	71	73
3227	hospitality industry	2	72	67	72

- **Identifying target companies**

The next stage of this research entails the identification of our target corporations for examination. Six public companies have been earmarked for this purpose. These comprise three entities listed on the Thailand Sustainability Investment Index (THSI) - namely, CENTEL, MINOR, and SHR - and three entities not listed on the THSI - DUSIT, ERW, and OHTL. The selection of these companies was guided by a dual criterion: their market capitalization and their assets. The leading three companies in both the THSI-listed and non-THSI-listed categories, as assessed on these parameters, were selected. The details of this process are encapsulated in

Table ***4***.

Table 4 List of selected companies

Company Name	Symbol	Market Cap (USD 000'000) *	Total Asset (USD 000'000) *	THSI Indexed
Central Plaza Hotel PLC	CENTEL	$1,793.57	$1,520.50	***Yes***
Dusit Thani PLC	DUSIT	$605.93	$613.78	*No*
The Erawan Group PLC	ERW	$284.14	$746.29	*No*
Minor International PLC	MINT	$5,157.11	$10,344.27	***Yes***
Ohtl PLC	OHTL	$204.47	$171.39	*No*
S Hotels and Resorts PLC	SHR	$287.49	$1,032.57	***Yes***

**Conversion rate of currency from Thai Baht to USD is approximately 35 Baht / 1 USD.*

The data extracted about these companies extends beyond mere measurement of their size. It also provides insights into their capability to service their clientele, which largely includes top-tier multinational corporations with stringent sustainability mandates for their operations. In this light, the profiles of these chosen companies are reflective not only of their scale but also of their capacity to fulfill sustainability-oriented obligations.

- **Text analysis for identifying sustainability-related issues**

Once the scope and source data have been established, the final stage involves implementing a text analysis methodology to scrutinize the content of the annual and sustainability reports of the selected companies. This phase employs a Python-based algorithm, specifically designed to identify and tally the occurrences of the main keywords within these corporate reports. The outcomes of this process are then visually illustrated via a graphic representation, in addition to a tabulated account of the frequency of keyword appearances.

  - **The co-occurrence analysis result**

The co-occurrence analysis of keywords presents significant insights into the prevalent themes of sustainability within the hotel industry.

Table 5 represents the top 30 co-occurrence keywords found across the annual and sustainability reports of all six companies.

Table 5 Top 30 co-occurrence keywords

Keyword 1	Keyword 2	Co-occurrence Frequency	Keyword 1	Keyword 2	Co-occurrence Frequency
hotel	management	309	sustainability	environmental	29
sustainable	development	229	sustainable	environmental	28
hotel	sustainability	98	hotel	environmental	27
tourism	industry	77	hotel	energy	24
sustainability	management	74	energy	environmental	23
hotel	development	54	hotel	sustainable	23
environmental	management	51	management	hospitality	20
development	management	48	hotel	tourism	14

sustainable	management	48	sustainable	industry	14
energy	management	44	tourism	hospitality	14
sustainable	tourism	36	development	environmental	13
development	sustainability	34	hotel	efficiency	11
energy	efficiency	33	tourism	management	11
sustainable	sustainability	33	development	efficiency	10
hotel	industry	30	industry	management	10

Primarily, the frequent cooccurrence of 'hotel' and 'management' underscores the incorporation of sustainability into strategic operations. Secondly, the high pairing frequency of 'sustainable' and 'development' emphasizes the industry's commitment to sustainable practices. Thirdly, the pairing of 'energy', 'efficiency', and 'environmental' with 'management', 'hotel', and 'development' respectively, points towards a strong focus on resource conservation and environmental stewardship. Finally, the regular pairing of 'tourism' and 'industry' suggests that sustainable discourse extends beyond hotels to the broader tourism sector. These results highlight the multidimensional nature of sustainability in the hotel sector, offering valuable insights for academics, practitioners, and policymakers alike.

- **The sustainability-related issues**

Text analysis was conducted on the annual and sustainability reports of six Thai hotel companies (CENTEL, DUSIT, ERW, MINT, OHTL, and SHR) to reveal key sustainability-related themes. The prominence of these themes across the firms was determined based on the frequency of sustainability-related keywords in the annual and sustainability reports. The top 10 keywords are shown in Figure 4.

'Management' was found to be a common theme across all companies, indicating that a strong focus on sustainable management practices was prevalent. 'Development' and 'governance' were also recurring keywords, suggesting that a commitment to developing sustainable strategies and ensuring governance for sustainability was shared among the companies.

However, distinctive emphases were also noted. For CENTEL and MINT, 'food' emerged as one of the top keywords, suggesting a potential focus on sustainable food practices. This could encompass areas such as sustainable food sourcing, waste reduction, or other food-related sustainability initiatives.

ERW was unique in the prominence of the keyword 'social', indicating a distinct emphasis on social aspects of sustainability. This could include areas like community engagement, employee welfare, and equitable business practices. OHTL and SHR stood out due to their frequent use of the keywords, 'sustainability' and 'sustainable', indicating a broad-based and comprehensive approach to sustainability.

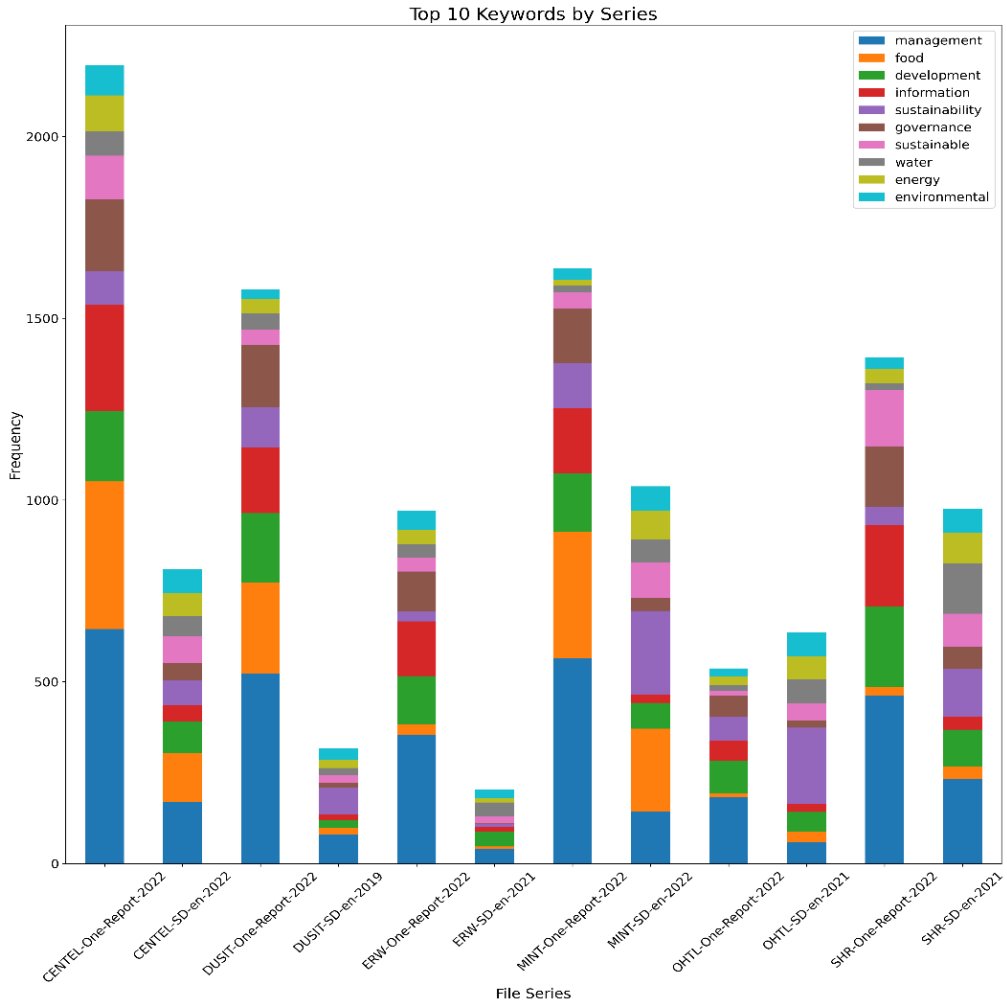

Figure 4 Top 10 keywords found across annual and sustainability reports of six companies.

In conclusion, the text analysis suggested a shared emphasis on sustainable management, development, and governance across Thai hotel companies. However, unique focus areas were also observed in individual firms, such as sustainable food practices (CENTEL and MINT), social sustainability (ERW), and a comprehensive focus on sustainability (OHTL and SHR). These insights provide a valuable understanding of the sustainability practices in the Thai hotel industry and highlight focus areas for further research. In addition, this analysis was based on keyword frequency, providing a high-level view of the companies' sustainability focuses. More nuanced insights could be obtained from a detailed content analysis of the companies' reports, which would provide the context in which these keywords were used.

CONCLUSION AND FURTHER RESEARCH

The conducted text analysis of annual and sustainability reports of six Thai hotel companies (CENTEL, DUSIT, ERW, MINT, OHTL, and SHR) has unveiled key sustainability-related themes. These themes, represented by keywords such as 'management', 'development', and 'governance', suggest a shared commitment across the companies towards sustainable management and development practices. Unique sustainability focuses, such as a focus on 'food' for CENTEL and MINT, 'social' aspects for ERW, and a broad-based approach to 'sustainability' and 'sustainable' for OHTL and SHR, was also observed.

Despite providing valuable insights, our keyword frequency analysis offers a high-level view of sustainability practices. To gain a more nuanced understanding, future research should perform a detailed content analysis of the companies' reports. This would clarify the context and specific implications of the identified keywords.

Incorporating temporal analyses in future research could reveal how companies' sustainability focus has evolved over time. This can provide additional insights into changing sustainability trends and priorities in the industry.

Further, examining potential correlations between sustainability focus and various company performance metrics, such as financial performance and customer satisfaction, could help understand the impact of sustainability practices on business performance. Expanding the scope of research to other sectors or geographical regions could provide comparative insights, contributing to a broader understanding of global corporate sustainability trends. The findings highlight the importance of sustainability in the hotel industry and pave the way for more nuanced, temporal, and comparative analyses, thereby enriching the sustainability discourse within the hospitality sector.

REFERENCES

Bae, J.-H. (2022). Developing ESG Evaluation Guidelines for the Tourism Sector: With a Focus on the Hotel Industry. *Sustainability*, 14(24), 16474.

Chung, K. C. (2020). Green marketing orientation: Achieving sustainable development in green hotel management. *Journal of Hospitality Marketing & Management*, 29(6), 722-738.

Effendi, D. N., Anggraini, W., Jatmiko, A., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. Journal of Physics: Conference Series,

Jones, P., & Comfort, D. (2020). The COVID-19 crisis and sustainability in the hospitality industry. *International journal of contemporary hospitality management*, 32(10), 3037-3050.

Jones, P., Hillier, D., & Comfort, D. (2014). Sustainability in the global hotel industry. *International journal of contemporary hospitality management*, 26(1), 5-17.

Ruggerio, C. A. (2021). Sustainability and sustainable development: A review of principles and definitions. *Science of the Total Environment*, 786, 147481.

Sanoran, K. L. (2023). Corporate sustainability and sustainable growth: The role of industry sensitivity. *Finance Research Letters*, 53, 103596.

Scott, D., Hall, C. M., & Gössling, S. (2019). Global tourism vulnerability to climate change. *Annals of Tourism Research*, 77, 49-61.

Tong-On, P., Siripipatthanakul, S., & Phayaphrom, B. (2021). The implementation of business intelligence using data analytics and its effects towards on performance in the hotel industry in Thailand. *International Journal of Behavioral Analytics*, 1(2).

GEN-Z CUSTOMERS' SERVICE PREFERENCE FOR EXPRESS DELIVERY ENTERPRISES: A CASE STUDY OF CHINA

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ABSTRACT

Purpose: The study aims to identify the decision-making factors of Gen-Z customers towards a service of five different express delivery enterprises, which includes SF, ZTO, YUNDA, YTO and STO, based on TOPSIS method.
Design/methodology/approach: As a pilot study, this research was conducted by interview 24 Gen-Z customers who are the students at Yunnan University during the year 2023 by adopting the TOPSIS technique to analysis the customer service preferable factor towards the express delivery enterprise's service.
Findings: The results show that Timeliness is the most important factor that influences on customer satisfaction for the express company's service, following by security, convenience, price, customer service and courier. Moreover, the private express enterprises evaluation result based on TOPSIS method show as follows: SF (0.810), ZTO (0.404), YUNDA (0.269), YTO (0.187) and STO (0.183).
Research limitations/implications: As a pilot study and a limitation of time, there is a small sample size of the interview group. Also, the data was collected with the students from Yunnan University only. Therefore, the further study should concern to improve its validity by expanding the sample size for the study in future.
Practical implications: The express delivery enterprise may apply the suggestions to improve its services for satisfying this customer group's preferable and requirements.
Originality/value: There is limited study focusing on Gen-Z satisfaction towards the service of express delivery company. This customer group will become the largest and most important market in the future. The results show the suggestion factors that help the shopping company to improve their service and competitive advantages.

Keywords: Express company, Customer preference, Gen Z, China, TOPSIS

Introduction

Express delivery industry, one of the most dynamic links in the consumption economy, has constantly satisfied the diversified consumption patterns. It accelerates consumer demand along with rapid digital and internet economy development (Yang and Zhang, 2015). With the rapid development of China's economy and the continuous expansion of private economy, enterprises or individual consumers have a higher demand for the timeliness, convenience, and security of the express delivery of documents, samples, and catalogues etc. There are four different types of express courier services in the market which are air courier services, ground courier services, sea courier services, and rail courier services (Dfrieght, 2022). In china market, the express delivery companies are operated as private express enterprises, state-owned express enterprises, or foreign express enterprises. According to Maigoo.com, a knowledge and research-based portal site, there is a TOP10 list of the most popular express delivery enterprises in 2023, which consists of 9 private express enterprises and 1 state-owned express enterprise. The private express enterprises contain S.F. express, KY express, DEPPON express, ZTO express, JD express, YUNDA express, YTO express, J&T express, and STO express. The only one state-owned express enterprise is EMS express. The score for each express brand is based on a combination of 6 parts, credit index, attention, votes, comments, likes and share rates. Moreover, maigoo.com announces the top 10 China's courier service company in 2023, which is shown in Figure 1.

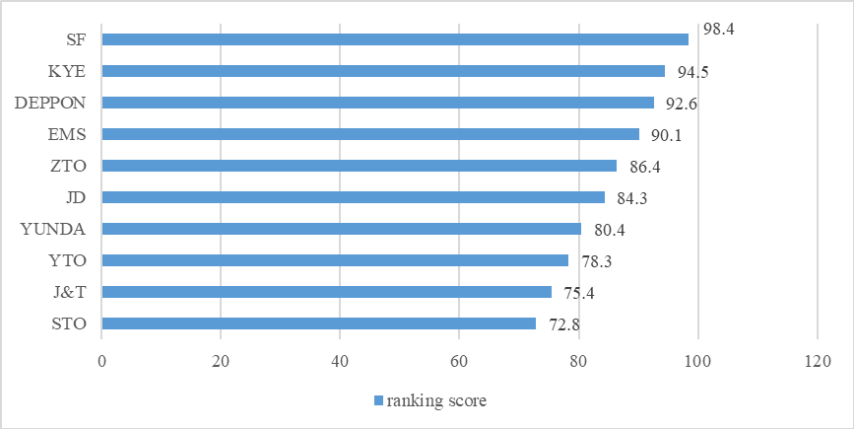

FIGURE 1. Top 10 express popularity list in China market in 2022

There is a highly competitive environment among the express delivering enterprises and some express delivery enterprises are not precisely orient relevant direction to improve service quality and lack of experience in systematically improving service quality (Mei et al., 2011). Furthermore, in these era, Generation Z is now concerned the largest generation, comprising 32% of the world population (Miller and Wei, 2018). However, there is limited research that focuses on the behaviour and preference of this young generation cohort, especially towards the courier service preferable. Therefore, this research aims to study the Gen Z customer's preference and identify key influencing factors which affect their decision making for express delivery enterprises service by using TOPSIS method. The study contains private express enterprises and service quality factors. The factors affecting decision making come from the students as consumers.

Literature Review

Generation Z

Generation Z or Gen Z is referred to young adults who born between 1995-2010 (Kuncoro and Kusumawati, 2021). They are the first generation who born into a digital world; therefore, they are technology savvy, innovative and creative (Priporas et al., 2017). This generation live online and engages with virtually products and services. It also shows than the behave differently to other earlier generations such as Millennials (Gen Y) and Gen X, which lead to consumer behaviour changing. According to Wood (2013), there are four trends that explain Gen Z's consumer characteristic: 1) Interesting in all innovative technologies, 2) Insistence on ease of use, 3) Desiring to feel safe, and 4) desiring to temporarily escape the realities. Moreover, this group of consumers have less brand loyalty, care more about customer experiences and higher expectations (Priporas et al., 2017). Generation Z also has special reasons for purchasing products or services that their desire, as they concern mainly about the convenience, reasonable prices, variety of products/ services selections and time efficiency (Simangunsong, 2018; Kuncoro and Kusumawati, 2021).

The customer service preference towards express delivery enterprise

The express delivery industry first appeared in the United States in the 1960s, while the express delivery industry in China gradually developed after the reform and opening (Huang and Liu, 2005). Most scholars' research on express delivery enterprises have mainly focused on service competitiveness, green development competitiveness, customer loyalty and other aspects. To increase and maintain the customer satisfaction and loyalty, the enterprises should concern to satisfy their customer preferences that mostly refer to a service quality, pricing, convenience, courier function and security (Zhou et al., 2016).

Many previous studies focusing on customer perceived service quality are adopted the concept of quality service quality (SERVQUA) which is proposed by Parasuraman (1985) and it is explained into 5 dimensions: Tangibles, reliability, responsiveness, access and empathy (Zhong, 2022). For research on customer perception express service quality, many studies are applied Attribute Hierarchical Model (AHP) and Fuzzy comprehensive to evaluate (Zhou et al., 2016). Furthermore, there are various scholars researched on China's express delivery service quality and SERVQUA model has been adopted to analysis the customers preferable. According to Li and Xie (2016), the three dimensions of the express service value chain model are the aspects of goods packaging, corporate image and after sales service.

Regarding the concept of logistics service quality (LSQ) model by Mentzer Flint and Kent (1999), it primarily developed by considering on the time management and courier utilities and then took more customer-based approach into its concept (Zhang and Smutkupt, 2021). Also, Dang and Wagn (2016) combined SERVQUA model and the logistic service quality (LSQ) model to form an evaluation index for China's express delivery service and tested with the e-commerce environment. Zhou et al. (2016) proposed the dimensions of express delivery's service quality based on customer perception by combining the concept of SERVQUA and LSQ model. They suggested that the express delivery service quality evaluation system should be concerned about the reliability, price, safety, customer service (includes responsiveness and staff's manners), and assurance (attitude of the staffs and company policies). Furthermore, Zhou et al. (2016) noted that courier utilities refer to a diversity of service functions and all platforms that the company has to connect with their customer, is also influence to customer satisfaction. Therefore, this research developed the dimensions for evaluating express delivery service towards customer preference by adopting the previous related studies. There are six dimensions involved in this study: 1) Customer service, 2) timeliness, 3) courier utilities, 4) Price, 5) security and 6) convenience.

TOPSIS Method

Technique for Order Preference by Similarity to An Ideal Solution (TOPSIS) is a method to sort a limited number of evaluation objects according to their proximity to an idealized target, which is proposed by Hwang and Yoon (1981). It is a multi-criteria decision-making (MCDM) technique which is widely applied for decision-making problems (Behzadian et al., 2012). This method is also concerned the optimal perspective performance, or a point that represents it, should have a minimum distance from the positive-ideal and the negative solutions, which easy to compute and implement procedure (Zhang et al., 2021). TOPSIS method is simple in principle, objective, efficient, flexible, and convenient. The method has no strict restrictions on the sample size and the number of indicators. It is applicable to the large system with multiple indicators and has great applicability to the evaluation.

This approach has been used as a tool for evaluating service quality, decision-making and Zhang et al. (2018) also studied an evaluation of Wuhan's urban public transport priority performance based on the applied TOPSIS model. Additionally, Tiwari et al. (2019) integrated TOPSIS method and Shannon entropy for product design evaluation and to explore customers' preferences. Furthermore, the study by Singh et al. (2017) adopted TOPSIS approach to analysis rank the factors the influence new customers' preferable for online retailing business sector.

Research Methodology

Research sampling

The sample group of this study is the students at Yunnan University, China, who are from 18-25 years old and have had an experience with the courier station center at the University during the year 2022. There are two courier station centers located in Yunnan University, which are Qinyuan courier station center and Nanyuan courier station center. Five express delivery companies have been operating their businesses at these two centers, including S.F. express, YTO express, ZTO express, Yunda express and STO express. Hence, this study focused on comparing the customer preferences regarding these five selected courier

companies. A total of 24 students participated in this research. The interview process was conducted during February and March 2023.

Data Analysis based on TOPSIS method.

The research topic concerns five private express enterprises and related six factors affecting students' selection. There are three parts to the interview questions: firstly, it is the participant bibliography information to confirm that they met the sampling requirements. The second part aims to measure all six factors of express delivery service from the participants' perspective. The last part, the questions are about rating measurement of the six factors for each private express enterprise. The five-level Likert scale was applied to measure the content based on the interviewees' attitude. According to the recognition degree of interviewees, there are five levels: "strongly disagree", "disagree", "Neither agree nor disagree", "agree", "strongly agree", and assigned 1-5 points respectively. After that, the data were analysis based on the TOPSIS method. According to Hwang and Yoon (1981), the TOPSIS approach has 6 steps as follows.

Step 1: Calculating the normalized decision matrix by using vector normalizations, as (1).

$$r_{kj} = \frac{x_{kj}}{\sqrt{\sum_{k=1}^{n} x_{kj}^2}} \quad (1)$$

Step 2: Calculating the weighted normalized decision matrix, as (2)

$$v_{kj}(x) = w_j \widetilde{r}_{kj}(x) \quad (2)$$

r_{kj} is the normalized value of alternative k and attribute j.

w_j is the weight of the attribute j

The assignment of weights plays a key role in the decision making process and may vary from decision makes to decision makers who is going to determine require weight information during decision making process with decision making methods. In the multi-attributes group decision making process, how to determine the reasonable weight of decision maker is very important to obtain the reasonable decision result (Pathania et al., 2023). The simplest way of assessing weights is to arrange the attributes in a simple rank order, listing the most important attribute first and the last attribute last. The researcher assigns 1 to the most important attribute, and n that is the number of attributes at hand to the least important. The cardinal weights can be obtained from the following formulas.

$$w_j = \frac{\frac{1}{r_j}}{\sum_k^n \frac{1}{r_k}} \quad (3)$$

Step 3: Determining the ideal and negative-ideal solution, as (4) and (5)

$$\text{PIS} = A^+ = \{v_1^+(x), v_2^+(x), \dots, v_j^+(x), \dots, v_n^+(x)\} = \left\{\left(\max_k v_{kj}(x) \,\middle|\, j \in J_1\right), \left(\min_k v_{kj}(x) \,\middle|\, j \in J_2\right) | k = 1,2,\dots,n\right\} \quad (4)$$

$$\text{NIS} = A^- = \{v_1^-(x), v_2^-(x), \dots, v_j^-(x), \dots, v_n^-(x)\} = \left\{\left(\min_k v_{kj}(x) \,\middle|\, j \in J_1\right), \left(\max_k v_{kj}(x) \,\middle|\, j \in J_2\right) | k = 1,2,\dots,n\right\} \quad (5)$$

PIS is a positive ideal point.

NIS is a negative ideal point.

Step 4: Calculating the separation measures using the n-dimensional Euclidean distance.

$D_k^+ = \sqrt{\sum_{j=1}^{m}\left[v_{kj}(x) - v_j^+\right]^2}$ The separation of each alternative from the ideal solution is given as (6) and (7);

, k = 1, 2, ... , n (6)

$$D_k^- = \sqrt{\sum_{j=1}^{m}\left[v_{kj}(x) - v_j^-\right]^2}$$

, k = 1, 2, ... , n (7)

Step 5: Calculating the relative closeness to the ideal solution, as (8).

$C_k^+ = \frac{D_k^-}{\left(D_k^+ + D_k^-\right)}$

, k = 1, 2,..., n (8)

The calculation needs separation measures in Step 5 both D^*_k and D^-_k. The calculation process of each alternative is shown in Table 1.

Alternatives	D_k^+	D_k^-	$C_k^+ = D_k^- / \left(D_k^+ + D_k^-\right)$
A_1	D_1^+	D_1^-	$C_1^+ = D_1^- / \left(D_1^+ + D_1^-\right)$
A_2	D_2^+	D_2^-	$C_2^+ = D_2^- / \left(D_2^+ + D_2^-\right)$
A_3	D_3^+	D_3^-	$C_3^+ = D_3^- / \left(D_3^+ + D_3^-\right)$
.....	.....	.....	
A_n	D_n^+	D_n^-	$C_n^+ = D_n^- / \left(D_n^+ + D_n^-\right)$

Table 1: the relative closeness calculation of each alternative.

Step 6: Use arithmetic comparison to compare the value of A_1, A_2, A_3, A_4, ..., A_n based on C_1^+, C_2^+, C_3^+, ...,C_n^+. Then the best alternative correspond is the best value.

Research Results

The results of 24 participants are explained in Table 2. There are 16 female and 8 male students participated in this study and all of them are Generation Z, who were born during 1995-2010. Most of the sampling have had experienced with express delivering 3-5 times during the year 2022.

		Amount	%
Gender	Male	9	37.5
	Female	15	62.5
	Total	**24**	**100**
Age	28 >	-	0
	23-27	6	25
	18-22	18	75
	13-17	-	0
	< 17	-	0
	Total	**24**	**100**
Service experience	1 – 2 times	3	12.5
	3 – 5 times	15	62.5
	>5 times	6	25
	Total	**24**	**100**

Table 2: Participants' bibliography

The findings show that Timeliness factor has the highest average point as the most considered factor among all six dimensions of customer service preferable for express delivery company, following by Security, Convenience, Price, Customer service and Courier Utilities, as illustrated in Table 3. Six factors are A) Timeliness, B) Security, C) Convenience, D) Price, E) Customer Service and F) Courier Utilities. Then, equation (3) was adopted to calculate the weight of six factors. The weights from ranks of six factors are as the following: Timeliness 0.408, Security 0.204, Convenience 0.136, Price 0.102, Customer service 0.082, Courier utilities 0.068.

Factors	**A**	**B**	**C**	**D**	**E**	**F**
Average point	4.25	4.21	3.42	3.21	3.17	3.13
Ranking	1	2	3	4	5	6
Weight	0.408	0.204	0.136	0.102	0.082	0.068

Table 3: The average points of six factors

Moreover, the average points of each factor for five selected express delivery enterprises are shown in Table 4. the results of each factor of each private express enterprise are applied into comparative analysis among five enterprises. The data shows that the average point of all factors for each private express enterprise is greater than 2. The highest point is SF Express's timeliness (4.63). The lowest point is SF Express's price (2.38).

Factor / Company	**A**	**B**	**C**	**D**	**E**	**F**
STO	3.13	3.38	2.75	3.67	3.00	2.92
S.F.	4.63	3.92	3.67	2.38	3.08	3.21
YUNDA	3.38	3.04	3.13	3.5	3.08	3.25
YTO	3.17	3.54	2.79	3.67	3.21	3.00
ZTO	3.67	3.25	3.29	3.75	3.13	3.00

Table 4: The average points for six factors of five private express enterprises

Equation (1) and (2) were adopted to calculate the normalized decision matrix of Five express delivery companies and their weighted normalised value, as shown in Table 5 and 6.

Factor / Company	A	B	C	D	E	F
STO	0.385	0.407	0.445	0.408	0.451	0.424
S.F.	0.569	0.510	0.522	0.310	0.444	0.466
YUNDA	0.415	0.440	0.481	0.440	0.487	0.472
YTO	0.390	0.412	0.451	0.413	0.457	0.436
ZTO	0.451	0.423	0.468	0.489	0.451	0.436

Table 5: The normalized decision matrix.

Factor / Company	A	B	C	D	E	F
STO	0.157	0.090	0.053	0.049	0.035	0.029
S.F.	0.232	0.104	0.071	0.032	0.036	0.032
YUNDA	0.170	0.081	0.061	0.047	0.036	0.032
YTO	0.159	0.094	0.054	0.049	0.038	0.030
ZTO	0.184	0.086	0.064	0.050	0.037	0.030

Table 6: The weighted normalized value of five enterprises and six factors.

Next, equation (4) and (5) were applied to simply identify the best value (positive ideal point) or worst value (negative ideal point) in each factor from Table 6. The best value or worst value for the weighted normalized value, as presented in Table 7. After that, the distance of alternative from the positive and negative one is calculated separately by equation (6) and (7), as shown in Table 8.

Factor	A	B	C	D	E	F
PIS	0.232	0.104	0.071	0.050	0.038	0.032
NIS	0.157	0.094	0.053	0.032	0.035	0.029

Table 7: The best value or worst value for the weighted normalized value

Company	D^*_k	D^-_k	C^*_k
STO	0.079	0.018	0.183
S.F.	0.018	0.078	0.810
YUNDA	0.068	0.025	0.269
YTO	0.076	0.017	0.187
ZTO	0.052	0.035	0.404

Table 8: The relative closeness results.

The last step of TOPSIS, equation (8) was adopted to calculate the relative closeness value of each alternative express delivery company. The results in Table 8 show the comparative of the relative closeness of five private express enterprises: SF (0.810) > ZTO (0.404)> YUNDA (0.269) > YTO (0.187) > STO (0.183). So that, it can be explained that SF Express is the most valuable private express enterprise for Gen Z customers.

Discussion and Conclusion

This research aims to explore the Gen Z's preferable towards a service of five different express delivery company which are S.F., ZTO, YUNDA, YTO, and STO. The six factors of customer preference are included A) Timeliness, B) Security, C) Convenience, D) Price, E) Customer Service and F) Courier Utilities. After analysis the Gen Z's service preference of express delivery enterprise by adopting TOPSIS, it was found that Timeliness is the most important factor that Gen Z concerned, following by security, convenience, price, customer service and courier utilities. Timeliness factor is the core factor affecting the quality of express service. It not only depends on the fast arrival time, but also the information feedback and time control of

express arrival time (Zhang and Smutkupt, 2021). Moreover, young customers require the express service to ensure about the safety of goods and personal information while meeting the speed requirement. Also, they will select the service of express company that is in a convenience and easy to access location (Zhou et al., 2016). From the results, it also reveals that service / package fees and the service of all staffs are impacted to the young customer preferable when they select the express company. However, the courier utility is the last factor the gen Z customer concerns due to it is a basic service function that every express company has. Therefore, it is not an outstanding factor for young customer consider when they select the express delivery service comparing to others.

From the research results, it can be concluded that S.F. express is the 1st express deliver company that Gen Z prefer based on their services, following by ZTO express, YUNDA express, YTO express and STO express. However, there is some suggestions for each express delivery company which might increase their business advantages, market share and customer satisfaction level. Combining the factors that most affect students' choice of express delivery service, timeliness, security, and convenience of S.F. express is well received by participants. Even though the price of S.F. express is the most expensive with the lowest price evaluation, the participates tend to choose S.F. express for good timeliness, security, and convenience. S.F. express gain the highest points in timeliness (4.63), security (3.92) and convenience (3.67) based on the result. At the same time, the three factors are the top 3 important from the average points. However, SF express's price point is weak (2.38) which consider to be lower than other private express enterprises. Therefore, SF express can prioritize price strategies in the process of improving or maintaining the customer loyalty of young customer group.

For ZTO express, the company gains a highest points in price (3.75) based on the result. Also, it is the top 2 relative closeness to the optimal selection. The top 3 important factors of ZTO express are timeliness (3.67), security (3.25), and convenience (3.29). However, the timeliness is much lower than S.F. express. Compared with S.F. express, only two factors' evaluation of ZTO express are higher than S.F. express are price and customer service factors. Hence, ZTO express can have an improving strategy focusing on timeliness factor based on continuously maintaining the advantaged factors for Gen Z customer group. The 3rd preferable express company is YUNDA express, it has relatively balanced evaluation points with certain positive effect in the top 3 important factors: timeliness (3.38), security (3.04) and convenience (3.13). To gain more high evaluation in Yunnan University, the express can focus on and invest more into these three aspects, as well as attentions to improve their customer service factors and mange on price factor in order to satisfy more customer satisfaction.

On other hands, the 4th express delivery enterprise of the study is YTO company, gains the highest value in the factor customer service (3.21). Also, its price (3.67) is also relatively high enough. But one of the top 3 factor convenience of YTO express gains only 2.79, lower than 3. This leads to lower relative closeness to the optimal express selection than the previous three private express enterprises, because convenience factor (3.42) is one of the top 3 important factor of Gen Z's preference factors. So that, it is necessary for YTO to focus on convenience factor to improve the evaluation of young customer group as same as YUNDA express. These two express companies can pay more attention to the convenience factor while attracting students with good prices, such as improving in the door - to - door services or temporary storage services. For STO express, the company is the last relative closeness to the optimal selection. One of the top 3 important factor which is convenience factor (2.75) is lower than 3 point and its courier utilities factor also lower than other companies. Therefore, to improve the preference of young customer group, STO express absolutely needs to make efforts to the top three important factors that influence Gen Z service preference, especially the convenience factor.

However, there are some limitations of this research. Firstly, due to the limitation of time, the sample size selected in this study is not large enough. Therefore, the research conclusions can be further verified by

expanding the sample size in future studies. Secondly, this study adopted only the TOPSIS to analysis, hence, other MCDM techniques should be applied to increase the results' trustworthiness.

References

Dfrieght, 2021. "Different type of courier services: A comprehensive overview." Available at: https://dfreight.org/blog/different-types-of-courier-services/

Huang, Z. and Liu, D., 2005. China's logistics system for agricultural products: Their development and institutional aspects. Issues in Agricultural Economy (China), 26(4), pp.49-53.

Kuncoro, H.A.D.P. and Kusumawati, N., 2021. a Study of Customer Preference, Customer Perceived Value, Sales Promotion, and Social Media Marketing Towards Purchase Decision of Sleeping Product in Generation Z. Adv. Int. J. Business, Entrep. SMEs, 3(9), pp.265-276.

Meng, Q., Jiang, X. and Bian, L., 2015. A decision-making method for improving logistics services quality by integrating fuzzy Kano model with importance-performance analysis. Journal of Service Science and Management, 8(03), p.322.

Mentzer, J.T., Flint, D.J. and Kent, J.L., 1999. Developing a logistics service quality scale. Journal of Business logistics, 20(1.1999).

Miller,L.J. and Wei, L., 2018,"Gen Z is set to outnumber millennials within a year", Bloomberg.com, available at: https://www.bloomberg.com/news/articles/2018-08-20/gen-z-to-outnumber-millennials-within-a-year-demographic-trends#xj4y7vzkg

Priporas, C.V., Stylos, N. and Fotiadis, A.K., 2017. Generation Z consumers' expectations of interactions in smart retailing: A future agenda. Computers in human behavior, 77, pp.374-381.

Simangunsong, E., 2018. Generation-z buying behaviour in Indonesia: Opportunities for retail businesses. MIX: Jurnal Ilmiah Manajemen, 8(2), pp.243-253.

Wood, S., 2013. Generation Z as consumers: trends and innovation. Institute for Emerging Issues: NC State University, 119(9), pp.7767-7779.

Zhang, Y. and Smutkupt, S., 2021. Online logistics service quality: a case study of Chinese home appliance retailing delivery. Journal of Supply Chain Management: Research and Practice, 15(1).

Zhong, D., 2022. Simulation and Prediction of the Service Quality of China's Private Express Delivery and Its Influencing Factors Based on the System Dynamics Model. Journal of Global Information Management (JGIM), 30(9), pp.1-20.

Zhou, L., Zhu, L. and Ma, Y., 2016, July. The research on express delivery service quality evaluation system based on customer perception. In 2016 5th International Conference on Social Science, Education and Humanities Research (SSEHR 2016) (pp. 740-743). Atlantis Press.

HORIZONTAL LOGISTICS COLLABORATION IN AGRI-FOOD SUPPLY CHAINS: AN ANALYSIS OF MOTIVES AND ENABLERS

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ABSTRACT

Purpose: This research aims to gain insight into the motives and enablers influencing the feasibility of Horizontal Logistics Collaboration (HLC) in the agri-food industry.
Design/methodology/approach: The main methodology in this study is developing a survey –based on the theoretical framework derived from the existing literature. The survey is distributed among food logistics/SC experts (including shippers and third-party logistics companies). Additionally, statistical analysis is performed to get insight into the relevance of movies/enables for horizontal collaboration in food chains and the factors that influence that.
Findings and originality: The survey analysis shows that the "cost-oriented motives" received the strongest support, potentially caused by low-profit margins and fierce price competition in the food and logistics sectors. In contrast, the "market-oriented motives" – like access to new market areas via collaboration- had a lower evaluation. For enablers of collaboration, "Incentive alignment" has received the strongest support, which implies the necessity of designing fair incentive mechanisms for horizontal collaboration. Besides, the strong support for "compatibility" – including "product compatibility" and "logistics compatibility" - reveals the importance of partner selection for a feasible collaboration in food chains. Regarding company size, larger companies valued "decision synchronization" and "compatibility" more as enabling factors. Due to the common power asymmetry in the food industry, SMEs are forced to be flexible and adaptive in a collaborative relationship. So, they are willing to look into more possibilities for selecting partners. Also, SMEs underpinned the "size similarity" as an enabler, revealing their concerns about not being heard in a power-imbalanced relationship. Finally, larger companies prefer to make a formal setting (like a contract) as the governing mechanism, while SMEs prefer to collaborate in a more informal trust-based manner.
Research/Practical implications: The findings provide the theoretical insight and practical guideline for practitioners to understand the critical factors and achieve feasible/successful operations of HLC in the food industry.

Keywords: Horizontal Logistics Collaboration, Food Supply Chains, Enablers.

Introduction

In the past two decades, logistics has undergone significant changes due to globalization, increased competition, high customer expectations, increasing operational costs, and stricter environmental regulations (Haralambides, 2019). Particularly in the context of the food sector, the additional key logistical aims of preserving food quality and minimizing food waste put extra burdens on the food supply chains (Behdani et al., 2019). At the same time, the design and management of the food supply chain is complicated by its unique characteristics. Especially the perishability and short shelf life of food products lead to an ordering strategy of high frequency of ordering under small quantities, which may result in logistics inefficiency in Food Supply Chains (Fan et al., 2020). Examples of these inefficiencies are a high percentage of empty running and the low truck utilization factor in Europe (Cruijssen, 2012).

One possible solution to this emerging challenge is collaborating with other companies within or beyond the supply chain (Schmoltzi & Marcus Wallenburg, 2011). Collaboration is a negotiated process between independent organizations to share information, risks, and resources to improve mutual probability and reach common goals (Prakash & Deshmukh, 2010). According to the characteristics of the supply chain

structure, possible collaboration arrangements can be categorised into two primary types: vertical and horizontal collaboration (Figure 1). Vertical collaboration is defined as collaboration between the provider and user of a specific service or product. This is mostly formalized in a buyer-seller relationship (e.g., the collaboration between a manufacturing company and its suppliers or customers). Horizontal collaboration, on the other hand, includes collaboration with competitors and other supply chain actors to provide a product or service. For instance, competing companies may share manufacturing capacity – in case of disruption or to reduce the risk in developing new technologies- and logistics service providers may share the transportation capacity – to gain broader market access (Behdani et al., 2015). The collaboration among two or more companies at the same level of a supply chain who share similar or complementary logistics requirements/capabilities is called Horizontal Logistics Collaboration (HLC) (Sanchez Rodrigues et al., 2015). This collaboration can be in different logistics activities, e.g., in transportation or warehousing, aiming to optimize all involved companies' logistics efficiency. In a broader sector context, this type of collaboration can also help overcome the logistics sector's challenges like high empty truck running and low asset utilization.

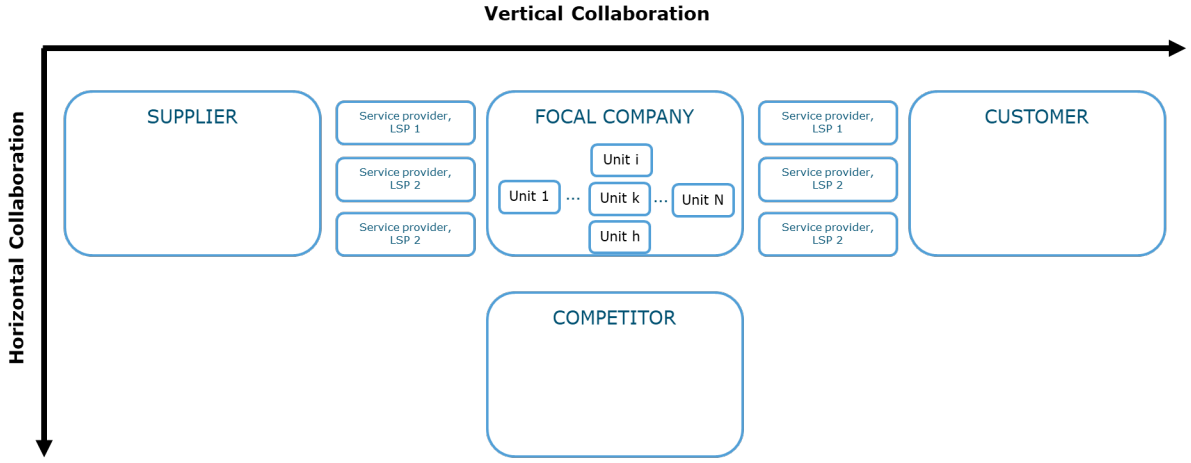

Figure 1: Vertical vs. Horizontal collaboration

In the food sector, HLC has also become a topic of growing interest (Stellingwerf et al., 2021). However, due to the unique characteristics of food products and supply chains, HLC may encounter more difficulties and specific challenges in practice. For example, there are natural (and safety) limitations on how agri-food products can be transported or stored together (to avoid undesired quality effects).

Although some practical initiatives in the food sector have been undertaken, theoretical studies on HLC in the food sector are scarce. In particular, there is limited focus on how the food industry can successfully initiate and operate HLC initiatives. This paper aims to study the enablers and motivations for Horizontal Logistics Collaboration in the food sector, formalized in a conceptual model.

Theoretical background

Agri-food supply chains

A food supply chain includes all stages of delivering food from a farm to the final consumer's tables. A typical chain consists of farmers, food manufacturing, wholesalers, retailers, and consumer, while transport and storage link the activities between each stakeholder (Behdani et al., 2019). A food supply chain has some specific characteristics and, accordingly, requires specific logistics management solutions (see Figure 2).

Figure 2: Characteristic of agri-food supply chains

A primary characteristic of the food sector is the diversity of products and logistics channels. The agri-food sector produces a wide range of products, including non-perishable (processed) food items and perishable temperature-sensitive products. Additionally, based on the temperature requirement for the cargo, we can differentiate between ambient fresh, frozen, and deep-frozen cargo (Behdani et al., 2019). As a result, one other key feature of a food chain is the perishability of agri-food products and the importance of managing product quality along the chain. To limit food quality decay, a food chain usually avoids long-term storage, employs special processing actions (drying, salting, and UV treatment), and storage and transportation conditions (such as refrigeration, freezing, or modified atmosphere). Furthermore, perishability and short shelf life of food products lead to ordering strategies involving a high frequency of ordering in small quantities to ensure food quality. Therefore, the average transportation load is relatively small and seldom fulfils a full truckload (Govindan, 2018).

Another characteristic of the agri-food chain is demand and supply variability. The production of agri-food is restricted by season and is often long and inflexible (Zhong et al., 2017). This seasonality may cause substantial fluctuations in the availability, price, and quality of agri-food products. Influenced by demographic and socio-economic characteristics, the demand for agri-food products is also highly variable (Behdani et al., 2019). Consumers are also constantly asking for year-round availability of high-quality agri-food products, which places significantly more pressure on the food logistics sector (Guiné et al., 2020).

Collaboration in the supply chain

Supply chain collaboration is defined as the mechanism by which firms within or beyond the supply chain work actively together towards common goals through exchanging information, knowledge, risks and rewards (Prakash & Deshmukh, 2010). A similar notion is discussed by Simatupang & Sridharan (2002) describing the collaboration as “more than two independent enterprises work jointly to plan and manage supply chain operation with greater achievements than act individually”.

Based on the nature of collaborating parties, we can distinguish between vertical vs. horizontal and internal vs. external collaboration (Figure 3). While external collaboration is about collaboration between multiple divisions inside one company, external collaboration is defined by the interaction of different companies. As mentioned, vertical collaboration aims to achieve beneficial partnerships and coherent linkages among entities operating at different steps of the same supply chain. The horizontal collaboration includes two

potential partners (unrelated companies or even potential competitors) being active at the same level in the market, collaborating, e.g., in managing a joint distribution or transportation process.

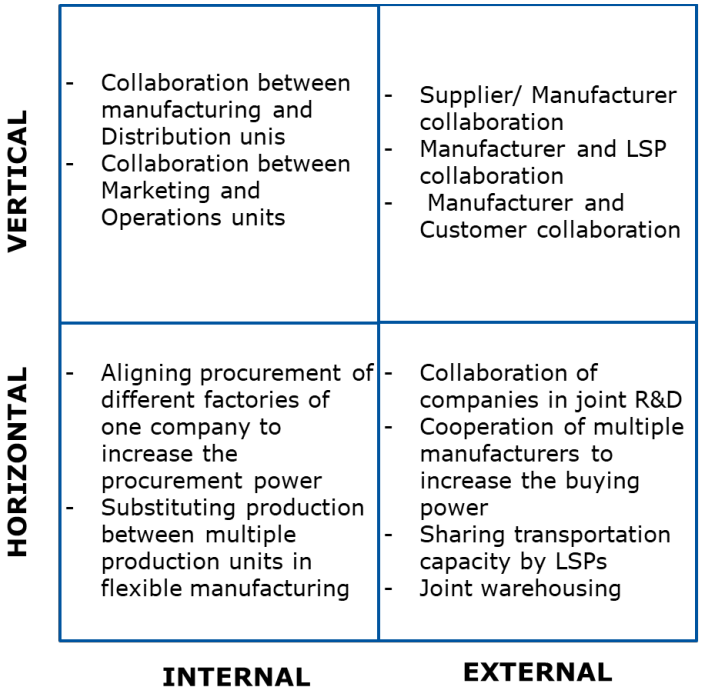

Figure 3: Different types of supply chain collaboration

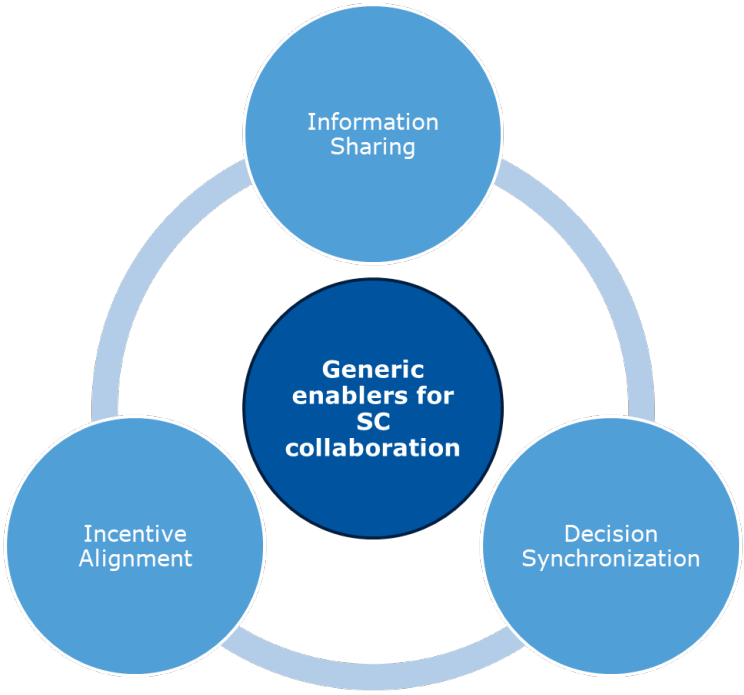

Figure 4: Key enablers for supply chain collaboration (based on Simatupang & Sridharan (2004))

Initiating supply chain collaboration (vertical or horizontal) calls for investing in a set of key capabilities or specific enablers. A well-known model in the supply chain literature, presented by Simatupang & Sridharan (2004), categorizes the enablers of supply chain collaboration into three interrelated dimensions: (1) information sharing; (2) decision synchronization; (3) and incentive alignment (Figure 4). Information sharing refers to capturing, processing, and delivering timely and relevant information for decision-makers to (jointly) plan and control supply chain operations. Decision synchronization is the second dimension and can be defined as "joint decision-making" at different managerial levels and time horizons for pursuing common goals. It includes aligning strategic objectives, tactical improvements, and synchronizing the supply chain planning and execution. The third essential enabler of collaboration is incentive alignment which refers to sharing costs, risks, and benefits of collaboration and formulating incentive schemes (Simatupang & Sridharan, 2002). According to Simatupang & Sridharan (2002), there are three strategies for developing incentive schemes: (1) Rewarding productive behaviour (rewarding observable actions which contribute to attaining the common goal); (2) Pay-for-performance (evaluating the achievements of individual participants on core objectives of the collaboration through applying performance metrics); (3) and equitable compensation (gains are allocated to the partners based on ex-ante agreed gain-sharing mechanism).

A conceptual model for Horizontal Logistics Collaboration in the agri-food supply chains

Based on the literature presented in section 2, we present a conceptual framework that is the basis for the empirical analysis in the rest of this research.

Enablers

The starting point for developing a model for enablers of HLC in the food sector is the three primary dimensions of Simatupang & Sridharan (2004) model, as discussed in section 2. Additionally, the success of horizontal logistics collaboration depends on finding the right partners and collaboration opportunities. We define this dimension as “compatibility”, referring to the possibility of planning and working together in a productive and solution-oriented manner. The first sub-dimension here is “logistics compatibility”; the potential for horizontal logistics collaboration increases if collaborating partners (1) have geographical proximity, (2) use standard/similar packaging (like pallet size); (3) have flow complementary. Flow complementary refers to the potential to combine collaborating partners' shipments to make a full truckload or combine the forward and backhaul flows. This attribute can be measured by examining the partners’ shipment quantity and intensity. Especially, Xu (2013) pointed out that companies show no interest in collaborating when there is a significant disparity in this indicator.

The second aspect of compatibility is “Product compatibility’”. For general cargo, the enablers regarding the compatibility dimension only focus on logistics aspects. However, in the context of FSC, product compatibility is also key to ensuring that the food products can be transported and stored together. Product compatibility can be summarized into the following attributes: 1) Similar environmental conditions during transportation and 2) avoiding product interferences.

Agri-food products are living organs from cultivation till final consumption. Therefore, they may keep interacting with each other and the surrounding environment. It is necessary to avoid product interferences to reduce undesired quality changes during collaborative transportation and storage (Behdani et al., 2019). For instance, bananas can produce ethylene, facilitating the ripening of other fruits like apples. Additionally, for agri-food supply chains, the processing technology (and, accordingly, the logistics requirements) can be very different. The production and processing lead time also varies between companies (Rijpkema, 2014). Take milk products as an example; the production lead times of drinking milk and cheese are significantly different. We formalize this sub-dimension as “Process compatibility” in the model.

The other essential enabling factor for collaboration in agri-food supply chains is “product suitability." It is expected that the potential for collaboration is higher for products with longer shelf life (Stellingwerf et al., 2021) and a more stable demand profile (Wang et al., 2020).

The five dimensions of enablers for Horizontal Logistics Collaboration in the food supply chains are summarized in Table 1. Each dimension has also been subdivided o some more detailed sub-factors.

Enabler	Dimension	Sub-dimension
Information sharing	Availability of key information	Availability of logistics-related information like transportation orders (Stellingwerf et al., 2021) or delivery schedule (Yuan et al., 2019)
		Availability of product-related information (Stellingwerf et al., 2021)
	Availability of ICT infrastructure	Availability of ICT infrastructure for collaborative planning like CPFR (Shi et al., 2014)
		Availability of data transfer and automated communication (Xu, 2013)
	Information consistency	Similarity of data type and information format (Chi et al., 2020)
		Similarity of ICT infrastructure (Chi et al., 2020)
	Information quality	Information accuracy (Viet et al., 2021)
		Information timeliness (Yuan et al., 2019)
Decision synchronization	Strategic fit	Common interest/ shared goal (Jepsen, 2014)
	Organizational similarity	Ccompany size/ scale similarity (Xu, 2013)
		Similarity of operational routine and managerial practices (Raue and Wallenburg, 2013)
		Top management involvement (Xu, 2013)
	Enterprise culture	Existence of cooperative culture (Kumar et al., 2016)
Incentive alignment	Relationship management	Mutual trust (Pomponi et al., 2015)
		Contract formality (Chi et al., 2020)
		Positive history of interactions (Pomponi et al., 2015)
	Sharing rules	Fair gain sharing mechanism (Stellingwerf et al., 2019)
Compatibility	Logistics compatibility	Geographical proximity (Herczeg et al., 2018)
		Logistics asset standardization (Basso et al., 2019)
		Flow complementary (Xu, 2013; Basso et al., 2019)
	Product compatibility	Similar environmental conditions (Rijpkema, 2014)
		Avoiding product interferences (Stellingwerf et al., 2021)
	Process compatibility	Similar production lead time (Rijpkema, 2014)
Suitability of product nature	Shelf life	Longer shelf life (Stellingwerf et al., 2021)
	Demand pattern	Stable demand profile (Wang et al., 2020).

Table 1: Enablers for Horizontal Logistics Collaboration in Agri-food supply chains

Motives

We further look into companies' motives for adopting HLC to complete the conceptual framework. A most often mentioned objective for HLC is ***cost reduction*** (Hernández-Espallardo *et al.,* 2010; Pomponi et al., 2015). For example, transportation costs can be reduced by sharing transportation resources (Asawasakulsorn, 2015). However, the findings of Schmoltzi & Wallenburg (2011) argued that compared to cost-oriented drivers, ***service quality improvement*** *and* ***market share enhancement*** (market-oriented drivers) are more crucial motives in HLC decision-making processes. In terms of ***service quality improvement***, Xu (2013) provides empirical evidence that collaborating with partners would result in logistics planning flexibility, thus increasing customer satisfaction. On the other hand, referring to the ***market share enhancement***, HLC can be instrumental in expanding the service options and geographic coverage (Yuan et al., 2019).

Schmoltzi & Marcus (2011) complement with one additional common-mentioned motive in the literature: i.e., ***access to additional knowledge and skills***. Similarly, Xu (2013) also emphasized this motive, elaborating that intensive communication through HLC provides access to partners' business processes, operations, and know-how. Therefore, participants can improve their competence and performance based on additional knowledge and skills gained through collaborative relationships.

Finally, ***environmental sustainability*** is another motive commonly cited in the literature (Stellingwerf et al., 2018).

All elements of the conceptual model are summarized in the conceptual model as shown in Figure 5.

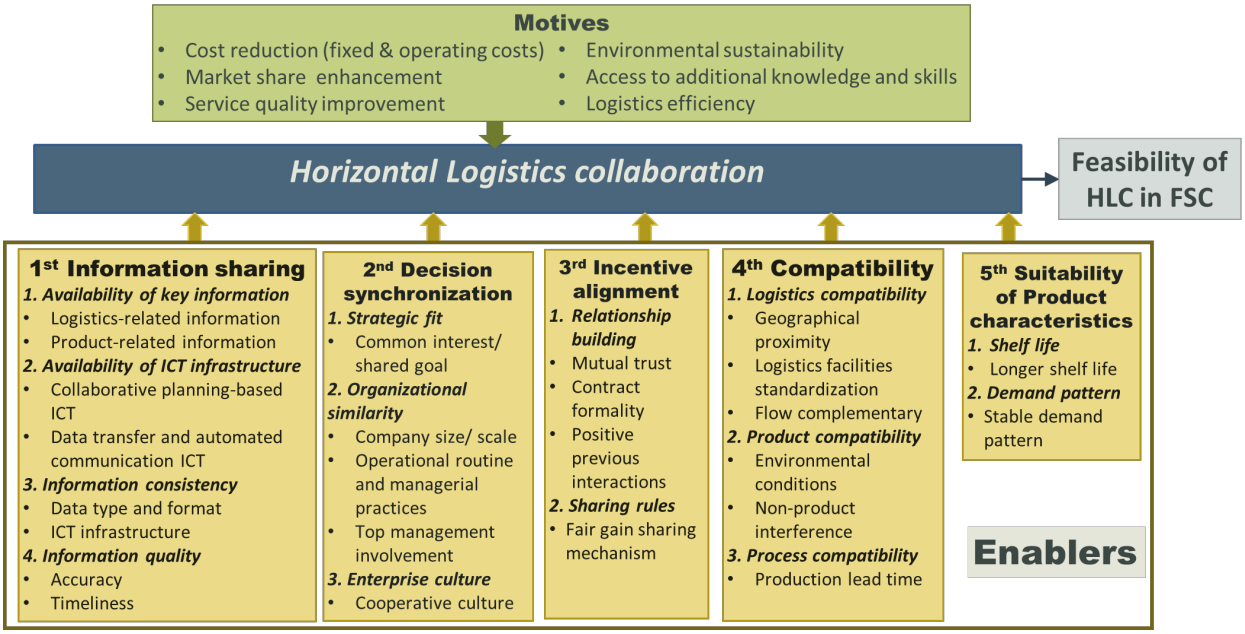

Figure 5: Conceptual model for Horizontal Logistics Collaboration in the agri-food supply chains

Concluding remarks

This paper aims to provide insight into the motives and enablers influencing the feasibility of Horizontal Logistics Collaboration (HLC) in the agri-food industry.

The food logistics sector faces distinct challenges due to the unique characteristics of the agri-food chains and the growing demand for year-round availability of agri-food products. Therefore, it is essential to

develop custom-tailored models that reflect these unique characteristics and specific food sector challenges.

This article presents a conceptual model describing the key enablers, the dimensions of each enabler, and the sub-factors influencing the horizontal logistics collaboration in the food sector. The key enablers include *information sharing*, *decision synchronization*, *incentive alignment*, *compatibility*, and *suitability of product nature*. For each leading enabler, the dimensions and sub-factors are derived from the literature and adapted with some modifications with expert views.

Using a quantitative research method, in our follow-up study, we investigate the relevance of movies/enablers for horizontal collaboration in food chains and the contextual mediating factors (like company size, type of product, and the history of collaboration).

The conceptual framework developed in this study can support top and middle management in companies to get insight and make better-informed decisions in implementing logistics collaboration initiatives in the food sectors. The model can also be used to develop a benchmarking tool to analyze the organization's readiness for horizontal logistics collaboration.

References

Basso, F., D'Amours, S., Rönnqvist, M. and Weintraub, A., 2019. A survey on obstacles and difficulties of practical implementation of horizontal collaboration in logistics. *International Transactions in Operational Research*, *26*(3), pp.775-793.

Behdani, B., Fan, Y., Wiegmans, B. and Zuidwijk, R., 2014. Multimodal schedule design for synchromodal freight transport systems. *Behdani, B., Fan, Y., Wiegmans, B., & Zuidwijk*, pp.424-444.

Behdani, B., Fan, Y. and Bloemhof, J.M., 2019. Cool chain and temperature-controlled transport: An overview of concepts, challenges, and technologies. *Sustainable Food Supply Chains*, pp.167-183

Chi, M., Huang, R. and George, J.F., 2020. Collaboration in demand-driven supply chain: Based on a perspective of governance and IT-business strategic alignment. *International Journal of Information Management*, *52*, p.102062.

Cruijssen, F., 2012. Framework for Collaboration: A CO3 Position paper. Collaboration Concepts for Co-modality.

Fan, Y., Behdani, B. and Bloemhof-Ruwaard, J.M., 2020. Refer logistics and cold chain transport: A systematic review and multi-actor system analysis of an un-explored domain. *European Journal of Transport and Infrastructure Research*, *20*(2), pp.1-35

Govindan, K., 2018. Sustainable consumption and production in the food supply chain: A conceptual framework. *International Journal of Production Economics*, *195*, pp.419-431.

Guiné, R.P., Florença, S.G., Barroca, M.J. and Anjos, O., 2020. The link between the consumer and the innovations in food product development. *Foods*, *9*(9), p.1317

Haralambides, H.E., 2019. Gigantism in container shipping, ports and global logistics: a time-lapse into the future. *Maritime Economics & Logistics*, *21*(1), pp.1-60.

Herczeg, G., Akkerman, R. and Hauschild, M.Z., 2018. Supply chain collaboration in industrial symbiosis networks. *Journal of cleaner production*, *171*, pp.1058-1067.

Hernández-Espallardo, M., Rodríguez-Orejuela, A. and Sánchez-Pérez, M., 2010. Inter-organizational governance, learning and performance in supply chains. *Supply Chain Management: An International Journal*, *15*(2), pp.101-114

Jepsen, L.B., 2014. Critical Success Factors for Horizontal Logistics Collaboration. In *Innovative Methods in Logistics and Supply Chain Management: Current Issues and Emerging Practices. Proceedings of the Hamburg International Conference of Logistics (HICL), Vol. 18* (pp. 459-477).

Pomponi, F., Fratocchi, L. and Rossi Tafuri, S., 2015. Trust development and horizontal collaboration in logistics: a theory based evolutionary framework. *Supply Chain Management: An International Journal*, *20*(1), pp.83-97

Prakash, A. and Deshmukh, S.G., 2010. Horizontal collaboration in flexible supply chains: a simulation study. *Journal of Studies on Manufacturing*, *1*(1), pp.54-58.
Raue, J.S. and Wallenburg, C.M., 2013. Alike or not? Partner similarity and its outcome in horizontal cooperations between logistics service providers. *Logistics Research*, *6*, pp.217-230.
Rijpkema, W.A., 2014. *Effective use of product quality information in food supply chain logistics*. Wageningen University and Research.
Sanchez Rodrigues, V., Harris, I. and Mason, R., 2015. Horizontal logistics collaboration for enhanced supply chain performance: an international retail perspective. *Supply Chain Management: An International Journal*, *20*(6), pp.631-647
Schmoltzi, C. and Marcus Wallenburg, C., 2011. Horizontal cooperations between logistics service providers: motives, structure, performance. *International Journal of Physical Distribution & Logistics Management*, *41*(6), pp.552-575.
Shi, N., Zhou, S., Wang, F., Xu, S. and Xiong, S., 2014. Horizontal cooperation and information sharing between suppliers in the manufacturer–supplier triad. *International Journal of Production Research*, *52*(15), pp.4526-4547.
Simatupang, T.M. and Sridharan, R., 2002. The collaborative supply chain. *The international journal of logistics management*, *13*(1), pp.15-30.
Simatupang, T.M. and Sridharan, R., 2004. A benchmarking scheme for supply chain collaboration. *Benchmarking: An International Journal*, *11*(1), pp.9-30 .
Stellingwerf, H.M., Laporte, G., Cruijssen, F.C., Kanellopoulos, A. and Bloemhof, J.M., 2018. Quantifying the environmental and economic benefits of cooperation: A case study in temperature-controlled food logistics. Transportation Research Part D: Transport and Environment, 65, pp.178-193
Stellingwerf, H.M., Kanellopoulos, A., Cruijssen, F.C.A.M. and Bloemhof, J.M., 2019. Fair gain allocation in eco-efficient vendor-managed inventory cooperation. *Journal of cleaner production*, *231*, pp.746-755
Stellingwerf, H.M., Groeneveld, L.H., Laporte, G., Kanellopoulos, A., Bloemhof, J.M. and Behdani, B., 2021. The quality-driven vehicle routing problem: Model and application to a case of cooperative logistics. International Journal of Production Economics, 231, p.107849.
Viet, N.Q., Behdani, B., Bloemhof, J. and Hoberg, K., 2021. Value of data in multi-level supply chain decisions: a case study in the Dutch floriculture sector. *International Journal of Production Research*, *59*(5), pp.1368-1385.
Wang, Y., Zhang, S., Guan, X., Peng, S., Wang, H., Liu, Y. and Xu, M., 2020. Collaborative multi-depot logistics network design with time window assignment. *Expert Systems with Applications*, *140*, p.112910.
Xu, X., 2013. *Collaboration mechanism in the horizontal logistics collaboration* (Doctoral dissertation, Ecole Nationale Supérieure des Mines de Paris).
Yuan, Y., Viet, N. and Behdani, B., 2019. The impact of information sharing on the performance of horizontal logistics collaboration: A simulation study in an agri-food supply chain. IFAC-PapersOnLine, 52(13), pp.2722-2727.
Zhong, R., Xu, X. and Wang, L., 2017. Food supply chain management: systems, implementations, and future research. *Industrial management & data systems*, *117*(9), pp.2085-2114.

IDENTIFICATION OF FACTORS INFLUENCING COST AND BENEFIT ASPECTS OF CROSS-COMPANY DATA EXCHANGE USING THE EXAMPLE OF THE STEEL INDUSTRY

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ABSTRACT

Purpose: In the last decade, enterprises realized the high value of data and learned to successfully utilize it for internal processes and business models, and they are trying to find more ways to acquire relevant data. Since enterprises are part of complex networks, the data from their partners and customers can also be beneficial: from adjusting the demand and supply to planning production and aligning capacities. One such example is adaptive process control: detailed material data from a supplier can be used to adjust process parameters in their production. This approach may be especially beneficial for the steel industry, as there is a possibility to adjust the material properties by changing the speed, force, or temperature in their own production processes. However, such an approach requires tight collaboration, e.g., regarding improving IT infrastructure, ensuring data acquisition and transfer and most importantly, the utilization of such data.
Approach: First, through literature research potential cost and benefit aspects regarding data exchange were identified. Second, conditions for the influence factors were defined. This determines which (qualitative) characteristics they must fulfil in order to be considered as such. On the one hand, there should be minimal overlaps of influence between the factors, and, on the other hand, the influencing factors should have a direct impact on the cost and benefit aspects. Finally, a qualitative analysis was conducted to determine the characteristics of the cost and benefit aspects under the influence of the factors.
Findings: 18 cost aspects in 6 categories as well as 14 benefit aspects in 3 categories were identified. 7 influence factors in 3 dimensions (strategy, technology, product) were determined. Additionally, an analysis, how each factor influences the cost and benefit aspects (only major influences will be described due to the page limit)
Originality/value: Cost-benefit-analysis is only useful on a specific use case. Trying to create a general analysis for a whole industry leads to high ranges for the cost and benefit aspects. The results of this paper help companies to understand, on which influence factors should they focus in order to either decrease costs or increase benefits of cross-company data exchange.

Keywords: Cross-company data exchange, intercompany data exchange, supply chain data management, cost-benefit-analysis, steel industry

Introduction

Data is becoming an increasingly important asset for manufacturing companies. Product and manufacturing-related data can be utilized to optimize decision-making, internal processes, reduce throughput times, and enhance product quality (Falck and Koenen, 2020; Brynjolfsson *et al.*, 2011). Moreover, data integration can contribute to the development of new products and services by acquiring knowledge about product usage and customizing products to meet individual customer requirements (Fritsch and Krotova, 2020).

Furthermore, data can be shared among different companies within a supply chain. Numerous research articles and studies have already explored successful cooperation in data sharing within supply chains, offering promising results. For instance, a study demonstrated that companies could reduce bullwhip effects by sharing demand signals or capacity (Erdebilli *et al.*, 2022). Successful implementation of functioning

supply chain tracking can lead to inventory capacity reductions up to 50 %, resulting in increased profits across the supply chain (Winterhoff *et al.*, 2016). Other studies suggest that data exchange with supply chain partners, along with the consideration of data from external sources, can enhance the resilience of a supply chain during disruptive events (Janßen *et al.*, 2022; Stich *et al.*, 2021).

A special case can be observed in the steel industry. It is possible to produce different types of final products from one semi-finished product thanks to the high adjustability of steel as a material. This adjustability is not only limited to the primal material creation (melting and solidification) but also extends throughout further production steps (e.g., rolling or heat treatment). Key parameters here mainly include the chemical composition, microstructure, and crystal lattice (Verein Deutscher Eisenhüttenleute, 1984). As a result, metal products go through a multi-step production chain from ore to semi-finished products, ultimately leading to the final product. Due to the complexity and cost of production, it is profitable to carry out the manufacturing process efficiently by specializing and producing large quantities. Therefore, the supply chain in the steel industry represents more of a process chain, involving several companies in the manufacturing of a final product. At each processing step, data is generated within individual companies, but during the transition between different companies, only a portion of this collected data is shared. For example, shared data on specific and detailed material properties can be used for adaptive process control – to set more suitable machine parameters to achieve better quality and reduce scrap.

When establishing cross-company data exchange mechanisms, a relevant and crucial challenge is that economic incentives are not immediately apparent. The measurement of the net benefits (benefits minus costs) of the utilization of internal data is easier in comparison to the implementation of cross company data exchange. The net benefit of data exchange depends on multiple parties and initially means higher effort for the data producer. For example, sharing data only provides a benefit if it is used by the data recipient, but the costs or effort on collecting the data lies on the data producer. Furthermore, the protection of a company's own data against misuse, unauthorized viewing or use, modification, or falsification is also a risk for the data producer (Rückert *et al.*, 2021).

This paper aims to present the influence factors that have an impact on costs and benefits of cross-company data exchange and to describe their characteristics. This creates transparency of dependencies and approach the possibility of integrating cross-company data exchange into investment calculations and thus create a higher incentive for its introduction.

Approach

To achieve the aim of the paper, three main research steps were made. In the first step, relevant cost and benefit aspects were identified. For the identification of the aspects a systematic literature research according to Levy and Ellis, 2006, was conducted. Following search string was used: (“inter-company” OR “cross-company” OR “supply chain”) AND (“(data OR information) exchange” OR “(data OR information) transfer” OR “(data OR information) management” OR “(data OR information) collaboration”) AND (“benefits” OR “costs” OR “cost benefit analysis” OR “motivation” OR “implementation”); in following academic data bases: Elsevier (ScienceDirect), ProQuest (ABI/INFORM), JSTOR, Scopus, GoogleScholar, Researchgate. After the reviewing the identified papers, in this paper five especially relevant papers with detailed overview of possible cost and benefit aspects regarding data exchange are presented. To complete the list of relevant cost and benefit aspects separate research for possible aspects as well as a workshop with representatives from steel industry according to Niederberger und Wassermann, 2015, were conducted.

To evaluate how the identified cost and benefit aspects can be affected (decrease of increase), it is important to understand which situational and company-specific factors can influence the aspects. For this purpose, in the second step possible influence factors were identified, defined, and clustered. Based on systems (Ulrich and Hill, 1976) and model (Stachowiak, 1973) theory the requirements for the influence factors were defined. A valid influence factor must have a logical and direct influence on the expression of

at least one of the cost or benefit aspect as well as the influence of the factor must be undependable from other factors (they may, however, influence the same aspects).
In the final and concluding step, the influences of the factors on the cost and benefit aspects are qualitatively determined. For this purpose, all characteristics (if any) of the individual cost and benefit aspects are defined for each influence factor. However, this is limited to purely correlative and qualitative relationships. In the case of a positive correlation, the aspect increases as the influence factor increases; in the case of a negative correlation, the aspect decreases. If the cost or benefit aspect does not correlate with the influence factor, the value remains constant as the influence factor increases or decreases.

State of the art

During the research five especially relevant papers regarding cost-benefit-analysis of data exchange in supply chains were identified. All these papers focus on the evaluation of added value through increased data availability. Rückert *et al.*, 2021, and Gelhaar *et al.*, 2023, examine cross-company data exchange using the example of milling and within the framework of Catena-X respectively. Cheng and Westman, 2020, and King and Shrems, 1987, explore general benefits of digitalization or implementation of IT systems. Zipfel *et al.* 2021 have identified, that information is not being shared between supply chain partners, so they developed a method for quantifying the value of information to create incentives for companies to exchange information for short-term production control.

These papers have two crucial common aspects. First, they prove that data or information sharing in a supply chain is beneficial and that the benefits outweigh the invested costs. Second, the precise determination of the final benefits is only achievable based on specific examples. Across various industries or companies within an industry, these benefits can only be described at an abstract level. This idea is also supported by Flyvbjerg und Bester, 2021, as the authors assert that cost-benefit analyses without a specific case reference lack precision and validity because of many simplifications and assumptions.

Through this research a comprehensive list of possible cost and benefit aspects was developed. However, it was noticed that the used cost and benefit aspects in every paper were not consistent. In order to create a comprehensive list of all relevant aspects further research for possible cost and benefit aspects as well as a workshop with representatives from the steel industry was conducted. The results are be presented in the chapter Findings.

Findings

In this chapter, the core findings of the research are presented. First, a short overview of possible cost and benefit factors regarding cross company data exchange in the steel industry is presented. The overview of these factors gives an insight into the expected costs and benefits when companies intend to exchange data in a supply chain. However, the focus of this paper lies on the description of influence factors and their influence regarding these aspects. This description helps companies to define, which of the aspects can they influence based on their maturity or abilities in the presented dimensions.

Overview of cost aspects

As shown in Figure 5, a total of 15 cost aspects were identified from six different categories that must be considered when implementing cross-company data exchange. These categories allow a simple allocation of costs to the respective tasks and topics.

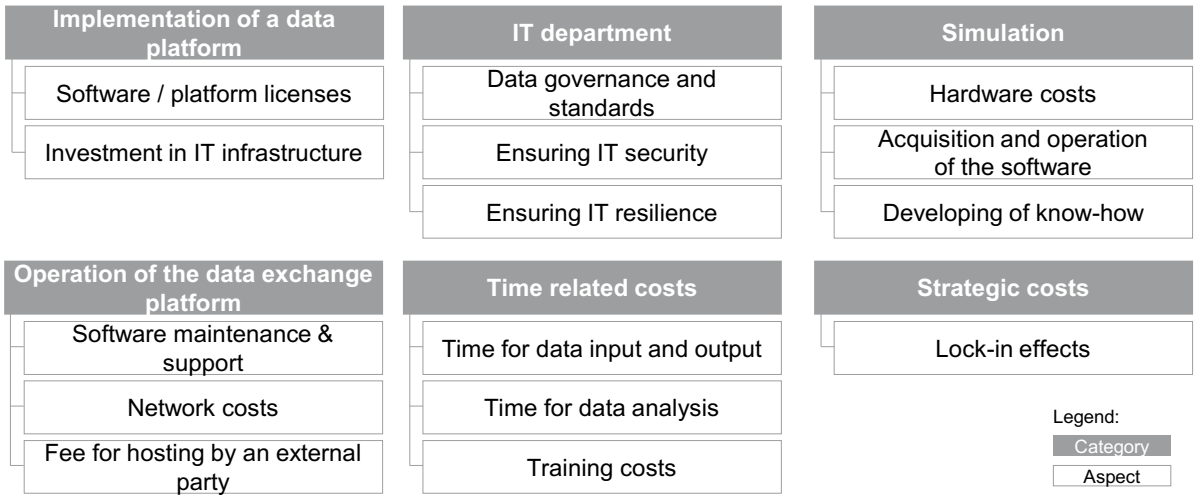

Figure 5: Overview of relevant cost aspects for cross-company data exchange

Overview of benefit factors

A total of 14 benefit aspects were identified from three different categories that have an impact on the added value of cross-company data exchange (see Figure 6).

Figure 6: Overview of relevant cost aspects for cross-company data exchange

Overview of dimensions and influence factors

This section introduces and defines the dimensions and associated factors. The influence on the factors on the previously introduced aspects is then presented. The dimension **Strategic Capabilities** of a company are the characteristics that determine the company's ability to develop and maintain a long-term orientation and competitive advantage. This dimension contains the influence factors **Market Power**, **Resource Availability** and **Transaction Quantity**.

Market Power refers to the ability of a company to influence price and other economic conditions in a given market. This can be caused by its size, market share, product differentiation or competitive advantages. The underlying scenarions for different market positions are defined through different market forms according to the number of suppliers and demanders, e.g. monopol/monopson or oligopol/oligopson (Stackelberg, 1934). Table 6 presents the infulence of high market power.

	Category	Aspect	Influence
Benefits	Quantitative	Time savings	Increasing
	Quantitative	Efficiency increase	Increasing
	Quantitative / Qualitative	Quality increase	Increasing
	Qualitative	Customer satisfaction	Decreasing
Costs	IT department	Data governance and standards	Decreasing
	Time related costs	Time for data entry/ output	Decreasing
	Time related costs	Time for data analysis	Decreasing
	Strategic costs	Lock-in effects	Decreasing

Table 6: Influence of the increasing factor Market Power (dimension Strategic Capabilities) on costs and benefits of a cross-company data exchange

Resource Availability reflects the company's ability to provide internally available resources (especially on a short notice). Internal resources can be divided into material, non-material and personnel resources. Material resources are for example physical resources like machinery. The term of non-material resources encompasses for example the characteristics technology, know-how as well as reputation. Examples of personnel resources include staff, work experience and deployment flexibility. Table 7 presents the influence of an increasing resorce avaiability concerning costs and benefits.

	Category	Aspect	Influence
Benefits	Quantitative/ Qualitative	Synergies	Increasing
	Qualitative	Innovation	Increasing
Costs	Implementation	Software maintenance & support	Decreasing
	IT department	Ensuring IT security	Decreasing
	IT department	Ensuring IT resilience	Decreasing
	Simulation	Acquisition and operation of the software	Decreasing
	Simulation	Developing of know-how	Decreasing
	Time related costs	Training costs	Decreasing

Table 7: Influence of the increasing factor Resource Availability (dimension Strategic Capabilities) on costs and benefits of a cross-company data exchange

The influence factor **Transaction Quantity** refers to the number of transactions which take place in a business relationship. This factor can be used to analyse the relationship between business partners as it offers insights in intensity and duration of the data exchange. Two possible scenarios could be a short- and a long-term oriented partnership. For example, the higher the transaction quantity, the more synergies can be achieved, and the fixed costs can be distributed on more transactions. The impact of this factor on the costs and benefits is shown in Table 8.

	Category	Aspect	Influence
Benefits	Quantitative	Time savings	Increasing
	Quantitative	Efficiency increase	Increasing
	Quantitative	Quality increase	Increasing
	Quantitative / Qualitative	Synergies	Increasing
	Qualitative	Customer Satisfaction	Increasing
Costs	Operation of the data exchange platform	Variable costs	Increasing
	Strategic costs	Lock-in effects	Increasing

Table 8: Influence of the increasing factor Transaction Quality (dimension Strategic Capabilities) on costs and benefits of a cross-company data exchange

The dimension **Technical Capabilities** of a company refer to the technical characteristics which relate to the company´s technical infrastructure and (informational technology and communications) systems. Influence factors of this dimension are the **Digitalization Maturity Level** and **Simulation Expertise**.

The **Digitalization Maturity Level** can be assessed based on various factors such as resources, information systems, organization, and company culture. It describes the progress of a company´s digitalization. The “Industry 4.0 Maturity Index” is used to separate the digitalization maturity level into six steps (Schuh *et al.*, 2020). There exists a relationship between the level of digitalization maturity and cost and benefit aspects. Table 9 shows that an increasing level of digitalization maturity has a positive impact on costs and benefits. Higher digital maturity level of a company means that some investments in digitalization were already made, and some relevant data may be already acquired; then sharing this data through already existing infrastructure will mean little cost simultaneously providing high benefits in return.

	Category	**Aspect**	**Influence**
Benefits	Quantitative	Time savings	Increasing
	Quantitative	Quality increase	Increasing
	Quantitative / Qualitative	Synergies	Increasing
	Qualitative	Innovation	Increasing
Costs	Implementation	Investment in IT infrastructure costs	Decreasing
	IT department	Data governance and standards	Decreasing
	Simulation	All expenses	Decreasing
	Time related costs	Time for data analysis	Decreasing

Table 9: Influence of the increasing factor Digitalization Maturity Level (dimension Technical Capabilities) on costs and benefits of a cross-company data exchange

Simulation Expertise refers to the knowledge within the company that is necessary to conduct and interpret simulations. Simulations are computer models or virtual prototypes utilized to analyse the performance, behaviour or characteristics of processes or products. This allows for cost savings in real processes. The ability to utilize comprehensive material data (e.g., digital twin) in simulation models is crucial for adaptive process control in the scope of this paper.

	Category	**Aspect**	**Influence**
Benefits	Quantitative	All factors	Increasing
Costs	Simulation	Acquisition and operation of the software	Decreasing
	Simulation	Acquisition and operation of the software	Decreasing
	Simulation	Developing of know-how	Decreasing

Table 10: Influence of the increasing factor Simulation Expertise (dimension Technical Capabilities) on costs and benefits of a cross-company data exchange

The dimension **Product Features** describe the qualitative or quantitative attributes of a product. This dimension includes the influence factors **Costs and Complexity of a Product** and **Criticality of a Product**. The **Costs of a Product** include all expenses incurred for its manufacturing, marketing, and distribution (Kirchner, 2020). **Product complexity** refers to the number and interaction of different components and processes required to manufacture or operate the product. On one hand, a higher complexity of a product implies higher production costs. On the other hand, investment in the digitisation of expensive products is more lucrative than for inexpensive products. For example, the usage of finite element method (FEM) simulations is standard for automotive industry for decades, whereas for packaging steels it is still a developing field (Köhl *et al.*, 2022). Table 11 shows how different costs change due to increasing product complexity.

	Category	Aspect	Influence
Benefits	Quantitative	Time savings	Increasing
	Quantitative	Quality increase	Increasing
	Quantitative	Energy savings	Increasing
Costs	IT department	Data governance and standards	Increasing
	IT department	Ensuring IT resilience	Increasing
	Simulation	Acquisition and operation of the software	Increasing
	Time related costs	All costs	Increasing

Table 11: Influence of the increasing factor Costs and Complexity of a Product (dimension Product Features) on costs and benefits of a cross-company data exchange

The second influence factor of this dimension is the **Criticality of the Product**. The criticality of a product or component refers to the significance or influence that a product has on the functioning of the final overall product at the end of the value chain. Components can be classified based on their criticality. For a non-essential component, like steel panels and covers, the criticality is typically low, whereas for a component, like a brake disc, quality and safety regarding requirements are high, resulting in an increase in importance of the product for the overall system or final product. The higher the criticality of a product, the higher are expectation towards its quality, stricter possible legal regulation, and higher possible fines or losses, if the quality is not ensured properly. In the case of a critical product, investments in systems that increase productivity and quality e.g., a manufacturing execution system or a coordinate measurement machine are high, however, also reasonable. Such investments can ensure that company collects and store vast amount of data in the production that can be also exchanged with supply chain partners thus creating synergy. The influence of this factor is presented in Table 12.

	Category	Aspect	Influence
Benefits	Quantitative	Time savings	Increasing
	Quantitative / Qualitative	Efficiency increase	Increasing
	Quantitative / Qualitative	Reduction of defective products	Decreasing
	Quantitative / Qualitative	Customer satisfaction	Increasing
Costs	IT department	Ensuring IT resilience	Increasing
	Simulation	Acquisition and operation of the software	Increasing
	Time related costs	All costs	Increasing

Table 12: Influence of the increasing factor Criticality of a Product (dimension Product Features) on costs and benefits of a cross-company data exchange

Summary
Due to the increasing value of data as an asset and the high potential benefits of its utilization ever more companies decide to implement various data-driven use cases, from improvement of internal processes and products to collaboration in supply chains and intercompany data sharing in order to increase possible benefits of the supply chain.

However, all digitalization projects and data-driven use cases have certain costs of implementation: direct monetary investments, personnel costs, and time as well as shifting the focus from daily business to digitalization projects. Therefore, enterprises must carefully approach such projects, picking the path of the best cost-benefit ratio. And for this, it is important to know what the potential benefits and upcoming costs are. Especially it is crucial for cross-company collaborations. This paper identifies the relevant cost and benefit aspects and corresponding influence factors for successful and effective data exchange in a supply chain using the example of the steel industry.

The overview of the cost and benefit aspects gives companies a comprehensive understanding of anticipated investments and possible benefits when planning cross company data exchange. It can be used of risk management of better investment planning. The overview of the influence factors and their specific influence on costs and benefits may help companies to assess their ability to leverage the potential of data exchange. By assessing own strategic and technical capabilities as well as product features companies can derive a suitable strategy to reduce costs and increase possible benefits, e.g., sharing the same investment costs between several digitalization projects or use cases.

For more precise research, companies engaged in intercompany data exchange projects (e.g., Gaia-X Funding Competition by BMWK) should be invited to participate in a long-term case study to quantify real costs and benefits over time. This would not only quantify the real costs and benefits, but also identify further implicit cost and benefit aspects.

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References
Brynjolfsson, E., Hitt, L. M. and Kim, H. H. (2011) ‘Strength in Numbers: How Does Data-Driven Decisionmaking Affect Firm Performance?’, SSRN Electronic Journal.

Cheng, J. and Westman, J. (2020) Effects of Digitalization in Steel Industry: Economic Impacts & Investment Model, Master-Thesis, Schweden, KTH Industrial Engineering and Management.

Erdebilli, B., Nacar, E. N., Gundogan, M. and Piya, S. (2022) ‘Comparing SMEs According to Industry 4.0 Adaptations for Mitigating the Bullwhip Effect’, in Multiple Criteria Decision Making with Fuzzy Sets, Springer, Cham, pp. 151–166.

Falck, O. and Koenen, J. (2020) Rohstoff "Daten": Volkswirtschaftlicher Nutzen von Datenbereitstellung - eine Bestandsaufnahme: Studie mit finanzieller Unterstützung der IHK für München und Oberbayern im Rahmen des Vertrags zur Erstellung volkswirtschaftlicher Studien, München, ifo Institut.

Flyvbjerg, B. and Bester, D. W. (2021) ‘The Cost-Benefit Fallacy: Why Cost-Benefit Analysis Is Broken and How to Fix It’, Journal of Benefit-Cost Analysis, vol. 12, no. 3, pp. 395–419.

Fritsch, M. and Krotova, A. (2020) ‘Wie datengetrieben sind Geschäftsmodelle in Deutschland?’, Institut der deutschen Wirtschaft, no. 9.

Gelhaar, J., Müller, P., Bergmann, N. and Dogan, R. (2023) ‘Motives and Incentives for Data Sharing in Industrial Data Ecosystems: An Explorative Single Case Study’, Proceedings of the 56th Hawaii International Conference on System Sciences.

Janßen, J., Schuh, G. and Stich, V. (2022) ‘Typification of Incorrect Event Data in Supply Chain Event Management’, in: Herberger, D.; Hübner, M. (Eds.): Proceedings of the Conference on Production Systems and Logistics: CPSL 2022. Hannover.

King, J. L. and Schrems, E. L. (1978) ‘Cost-Benefit Analysis in Information Systems Development and Operation’. in: Computing Surveys, Vol. 10, No. 1, March 1978.

Kirchner, E. (2020) ‘Werkzeuge und Methoden der Produktentwicklung‘, Springer Vieweg Berlin, Heidelberg.

Köhl, M., Knieps, F., Weinand, I. and Liebscher, B. (2022) ‘Effiziente Produktentwicklung in der Verpackungsstahlindustrie durch Nutzen von FE-Methoden’, *Aachener Stahlkolloquium*, pp. 313–322.

Levy, Y. and Ellis, T. (2006) ‘A Systems Approach to Conduct an Effective Literature Review in Support of Information Systems Research’, *Informing Science: The International Journal of an Emerging Transdiscipline*, vol. 9, pp. 181–212.

Niederberger, M. and Wassermann, S. (2015) Methoden der Experten- und Stakeholdereinbindung in der sozialwissenschaftlichen Forschung, Wiesbaden, Springer Fachmedien Wiesbaden.

Rückert, A., Frank, A., Gimpel, H., Starke, J., Heinzer, J., Trautmann, L., Stöter, M. and Nüske, N. (2021) ‘Ökonomische sowie ökologische Potenziale des unternehmensübergreifenden Datenaustauschs: Wie eine Umsetzung für Unternehmen sicher und erfolgreich gestaltet werden kann’, Mai ILQ 2020 Trut 2 Value.

Schuh, G, Anderl, R, Dumitrescu, R and Krüger, A (eds) (2020) Industrie 4.0 Maturity Index: Die digitale Transformation von Unternehmen gestalten [Online], acatech – Deutsche Akademie der Technikwissenschaften. Available at https://www.acatech.de/publikation/industrie-4-0-maturity-index-update-2020/ (Accessed 24 March 2023).

Stachowiak, H. (1973) Allgemeine Modelltheorie, Wien, New York, Springer.

Stackelberg, H. von (1934) Marktform und Gleichgewicht, Berlin, Springer.

Stich, V., Schröer, T., Linnarzt, M., Marek, S., Herkenrath, C., Hocken, C. and Kaufmann, J. (2021) Wertschöpfungsnetzwerke in Zeiten von Infektionskrisen: Expertise des Forschungsbeirats der Plattform Industrie 4.0.

Ulrich, P. and Hill, W. (1976) Wissenschaftstheoretische Grundlagen der Betriebswirtschaftslehre, 7th edn.

Verein Deutscher Eisenhüttenleute (ed) (1984) Werkstoffkunde Stahl: Band 1: Grundlagen, 4th edn, Berlin, Heidelberg, Springer Berlin Heidelberg; Imprint: Springer.

Winterhoff, M., Keese, S., Boehler, C. and Hoyes, C. (2016) Digital factories: The renaissance of the U.S. automotive industry, Roland Berger.

Zipfel, A., Herdeg, D. and Theumer, P. (2021) ‘Method for quantifying the value of information for production control in cross-company value-adding networks’, Procedia Manufacturing, vol. 54, pp. 1–6.

INVENTORY MANAGEMENT AND PRODUCT DEMAND PLANNING: CASE STUDY BAKERY PRODUCT FACTORY

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ABSTRACT

Purpose: AMZAP Group Company Limited is engaged in the agricultural product processing business, focusing on food preservation and bakery products. Among its product portfolio, the Memorize brownie has gained widespread recognition. The company recognizes the need to enhance and optimize its factory and store inventory efficiency to serve the market's demands effectively. The lack of accurate knowledge regarding the appropriate quantities and timings for deliveries has resulted in instances of raw material shortages or excessive ordering, leading to lost customers and unnecessary costs. To address these challenges, the company has embarked on a research project to improve its inventory system, including the raw material and ready-made goods inventory. The project aims to facilitate efficient inventory checks, integrating forecasting theory to anticipate demand quantities for each branch accurately.
Design/methodology/approach: This study adopts a comprehensive analytical approach, integrating the principles of Design and Plant Layout, Inventory Management, Production Planning, and Scheduling Theory. To optimize and determine the factory inventory layout, Economic Order Quantity (EOQ), and Reorder Point (ROP) for raw materials and ready-made goods within the inventory, a range of tools are employed, including ABC Classification analysis, Rectilinear, FIFO, and FEFO principles. Additionally, Microsoft Excel analyzes sales history and forecasts future plans.
Findings: The outcomes of this study comprise comprehensive delivery plans for each branch based on sales forecast data analysis. Furthermore, the study provides two inventory layout diagrams, offering practical guidance to the company's operational endeavors.
Research limitations/implications: In order to gather relevant data for analysis, this study collects information from five branches, namely AQUA, Ladprao, Ayutthaya, Central Festival Chiang Mai, and Nimmanhaemin, focusing on three key products: Brownie Shot, Original Brownie, and Chocolate Nama dark and mild.
Originality/value: In conclusion, by adopting the analytical methodologies and tools, this study presents valuable insights and actionable recommendations to enhance inventory efficiency and effectively meet market demands.

Keywords: Keywords: Inventory Management, Demand Forecasting and Planning, Bakery Product

Introduction

The case study company operates in the agricultural product processing sector, specializing in food preservation and bakery products. The company's objective is to effectively meet the increasing market demands by optimizing inventory efficiency across factory and store operations. However, challenges such as raw material shortages and excessive ordering have arisen due to a need for more accurate knowledge regarding appropriate quantities and delivery schedules. These challenges have resulted in customer attrition and unnecessary costs and wastes.

This study aims to enhance the inventory system by addressing two primary issues. Firstly, it employs the theory of Plant Layout Design, which focuses on designing the best arrangement of physical facilities for efficient operations, to optimize the arrangement of raw materials and finished goods. Secondly, the study emphasizes the importance of demand information and the challenges of demand unpredictability. To mitigate forecasting errors, the study proposes integrating forecasting theory into efficient inventory checks

for accurate demand anticipation. Additionally, Microsoft Excel is recommended as a simple and quick tool for TS-forecasting.

Literature Reviews

According to Thanapotivirat and Jitpakdeepornrat (2022), in the recent years, the confectionery market in Thailand have witnessed a significant influence of socio-psychological factors on consumer behaviour, leading to the notable popularity of bakery industries despite their relatively higher prices. However, the increasing demand has introduced challenges in inventory management and sales forecasting. Jurado-Muñoz, et.al. (2021) highlighted that inaccurate inventory management can result in defective products, and they advocate adopting lean method to improve inventory management, reduce defects, and enhance economic flow. Various tools, such as motion and time study, process flow analysis, and plant layout design, were suggested to effectively decrease production time by optimizing movement distances Tippayawong and Prapasirisulee (2011). Additionally, the ABC class-based storage concept can significantly reduce travel distance and picking time and improve space utilization and inventory service level (Tippayawong et.al., 2013). Efficiency-focused organizations, as discussed by Liu and Ma (2019) strive to reduce emissions from inventory and warehousing without compromising profitability, thus aligning with sustainability goals through waste and emission reduction efforts. Mehdizadeh (2020) underscored the utility of the ABC analysis in forecasting future retailer demands and suggests implementing a periodic review approach when placing orders. Combining the ABC concept with plant layout design offers two main advantages. Firstly, it simplifies product search and retrieval processes, making it easier and more efficient for employees to locate and access items within the inventory (Srisuk and Tippayawong, 2020). Secondly, it increases space utilization, allowing the facility to better accommodate potential future demand growth and optimize the use of available storage space.

Abolghasemi, et al. (2020) emphasized the impact of demand unpredictability on store inventory management. Inaccurate demand forecasting can lead to substantial errors, resulting in unnecessary costs and wastage. In contrast, accurate demand forecasting enables better inventory, supply, and transportation decision-making. Rahardja (2021) discussed the usefulness of Excel's (2019) built-in function "FORECAST.ETS" for implementing the Exponential Smoothing Methods (ESM) family of Time Series (TS) methods. This function considers the presence of level, trend, and seasonality components in the data. It requires minimal computing resources, making it a practical option for forecasting in scenarios with limited computational power. It can be effectively applied to various data series, including sales data, to generate forecasts that account for underlying trends, seasonality, and level components. Furthermore, Pamungkas et.al. (2021) concluded that the Holt Winter Exponential Smoothing method is particularly suitable for production forecasting. They emphasize the importance of accurate data for successful forecasting and advocate for effective data management practices to maintain accurate records.

Methodology

The methodology of this study consists of six steps as follows;

Studying the Current Situation of Inventory before Implementing Improvements

Data collection had been conducted several times in order to gather data in the warehouse which included all inventory information, order patterns, locations, current demand, existing management model.

Analyzing Products to Classify and Allocate Inventory Space

The inventory is evaluated and grouped based on annual demand, picking frequency and value using the ABC Classification technique. The result will be later utilized to assign storage area in for optimizing retrieval time.

Analyze Historical Sales Data to Generate Forecasts for Product Demand

Sales data for three products (A, B, C) are collected from five branches (1, 2, 3, 4, 5) over a 24-month period (January 2021 to December 2022) for the first four branches. For branch 5, the data spans 14 months

(April 2021 to December 2022). Multiple forcasting techniques such as Moving Average, Exponential Smoothing, and Linear Regression are utilized to forecast sales using historical data.The forecasting performance is evaluated using the mean absolute percentage error (MAPE), where a lower MAPE indicates better results.

Developing Individualized Delivery Plans for Each Branch

Examine the freight schedule of the central depot. Next, analyze the delivery plan based on historical daily sales data from 2022, and establish a comprehensive and efficient delivery schedule.

Results

This study integrates a range of theories and tools to enhance and optimize inventory management to maximize space utilization in raw material and finished goods. Additionally, it aims to determine the optimal delivery quantities for each branch, thereby, improving overall operational efficiencies.

Current Situation

The inventory occupies an area of 96 square meters (8 x 12 meters) with a single entry and exit point. The data reveals that the factory follows a Fixed Location System without proper records, resulting in inefficient storage and accessibility issues. Figure 1 shows the initial warehouse layout.

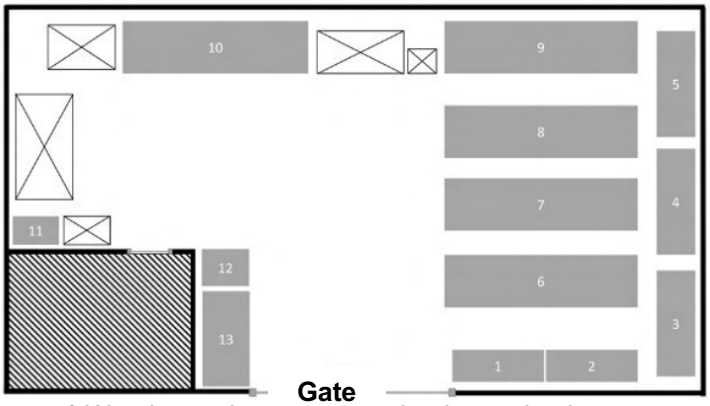

Figure 1 Warehouse Layout before Implementing Improvements

ABC Classification Analysis

The inventory is subjected to an ABC Classification Analysis based on historical data from 2022. It consists of 160 items, including 61 raw materials, 47 packaging materials, and 52 miscellaneous items. Equation 1 provides the method for calculating the product value, and Table 1 demonstrates a sample classification of five materials derived from raw materials. The classification criteria are as follows: Group A represents highly significant products, accounting for about 80% of the product value. Group B includes moderately important items, comprising approximately 15% of the product value. Group C consists of less critical products, contributing to around 5% of the product value.

The product value = the frequency of use x the price per unit. **(1)**

Material	Frequency of use	Product value	Percentage	Cumulative Percentage	Group
Material A	5,504	1,265,920	29.1	29.1.	A
Material B	860	828,180	19.0	48.1	A
Material C	7	128,844.80	3.00	80.00	B
Material D	79,543	91,474.45	2.10	84.70	B
Material E	83	24,900	0.6	95.1	C

Table 1 Sample of Raw Material Grouping Example

Based on the classification, the materials can be grouped as follows:

- Raw materials: Group A consists of 5 items, Group B consists of 12 items, and Group C consists of 44 items.
- Packaging materials: Group A comprises 9 items, Group B comprises 10 items, and Group C comprises 28 items.
- Miscellaneous items: Group A includes 5 items, Group B includes 9 items, and Group C includes 38 items.

The Layout of the Inventory Storage

Utilize the Rectilinear Distances, as shown in Equation 2, and strategically position products based on their value from ABC classification analysis. In this method, it is necessary to measure the distances along the x and y axes from the centroid of the door to the centroid of each shelves. The shelves closest to the door can be designated as Zone A, as illustrated in the Figure 2. Group A products, being of high importance, will be placed near the entrance for easy accessibility.

$$d_{ij} = |\Delta x| + |\Delta y| \quad \textbf{(2)}$$

d_{ij} = The distance between the door and shelves j (let j be the shelves number {j = 1,2,3,4,5,6,7,8,9,10,11,12,13}).
Δx = The difference in distance on the x-axis.
Δy = The difference in distance on the y-axis.

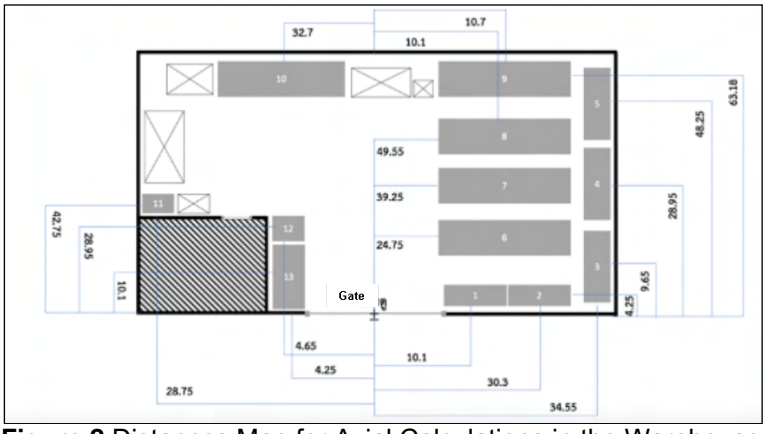

Figure 2 Distances Map for Axial Calculations in the Warehouse

By designating the centre of the door as the origin point (0,0), an illustrative calculation example is demonstrated as illustrated in the Table 2.

$d_{door,j}$	$\|\Delta x\| + \|\Delta y\|$	Total distance (meters)	$d_{door,j}$	$\|\Delta x\| + \|\Delta y\|$	Total distance (meters)
$d_{door,1}$	|10.1| + |4.25|	14.35	$d_{door,8}$	|10.1| + |49.55|	59.65
$d_{door,2}$	|30.3| + |4.25|	34.55	$d_{door,9}$	|10.7| + |63.18|	73.88
$d_{door,3}$	|34.55| + |9.65|	44.2	$d_{door,10}$	|-32.7| + |63.18|	95.88
$d_{door,4}$	|34.55| + |28.95|	63.5	$d_{door,11}$	|-28.75| + |42.75|	71.5
$d_{door,5}$	|34.55| + |48.25|	82.8	$d_{door,12}$	|-4.65| + |28.95|	33.6
$d_{door,6}$	|10.1| + |24.7|	34.8	$d_{door,13}$	|-4.25| + |10.1|	14.35

$d_{door,7}$	|10.1| + |39.25|	49.35			

Table 2 The distance between the door and shelves j

Shelves 1, 12, and 13, which are closest to the door, are assigned as Group A for raw materials, miscellaneous materials, and packaging materials, respectively. Shelves 2, 6, and 3 are designated for Group B materials. Group C materials will be arranged on adjacent shelves, as shown in Figure 3.

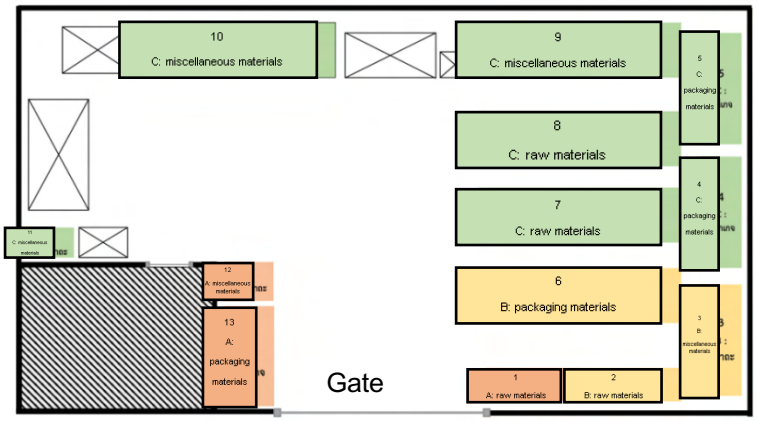

Figure 3 Inventory Layout after Implementing Improvements (1)

Furthermore, considerations are made for weather and environmental factors, ensuring that certain raw materials are protected from sunlight or heat. Implementing the FIFO and FEFO principles, products within this group are organized on the middle shelves, as depicted in Figure 4.

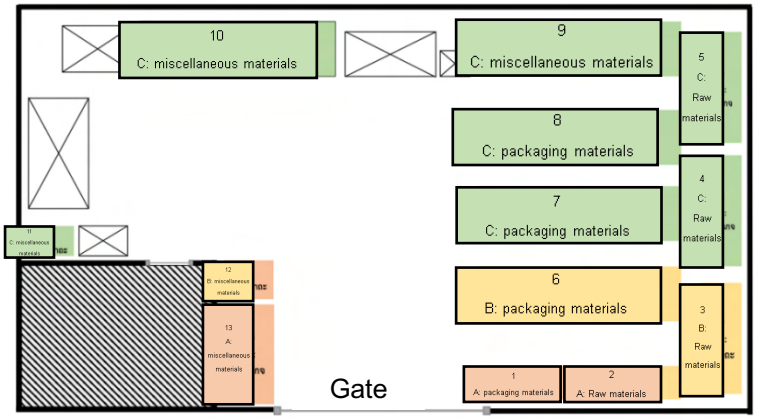

Figure 4 Inventory Layout after Implementing Improvements (2)

Forecasting Sales from Historical Data with Microsoft Excel Program

Analysing 24 months of historical sales data for four products across five branches, Excel program was used. By comparing forecasting methods with MAPE as an indicator, Exponential Smoothing showed the lowest error. A forecast graph will be generated, along with a pop-up window displaying the format for Forecast and Seasonal numbers. Adjustments can be made for desired forecasts, including quantity increases if necessary. Pressing the create button generates forecast results, as depicted in Figure 5.

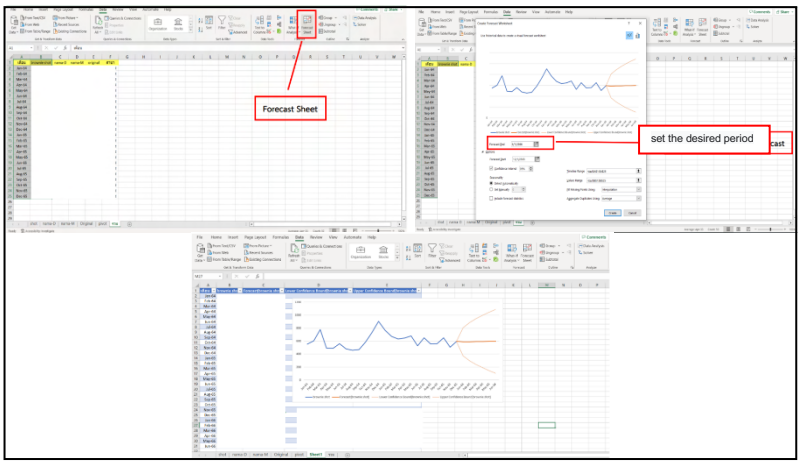

Figure 5 Sales forecasting using Forecast Sheet mode in Excel program

Once the forecast values have been obtained for all five branches, a further three-month forecast is conducted in order to develop a delivery plan for each branch. The sample of forecasted values for Brownie Shot across the branches are illustrated in Table 7.

Month	Product A	Branch	Month	Product A	Branch	Month	Product A	Branch
Jan-23	589	1	Jan-23	542	3	Jan-23	229	5
Feb-23	590	1	Feb-23	456	3	Feb-23	160	5
Mar-23	592	1	Mar-23	370	3	Mar-23	91	5
Jan-23	1,497	2	Jan-23	2,244	4			
Feb-23	1,477	2	Feb-23	2,104	4			
Mar-23	1,458	2	Mar-23	1,964	4			

Table 7 The Forecasted Values for Product A Across the Branches

After reviewing the forecast values, it was noted that some items showed a consistent decline, resulting in negative or non-positive values. These items may need to be revised for long-term delivery planning. Instead, generating forecasts at shorter intervals within a 24-month is advisable to ensure more accurate forecasts for these specific items. It is recommended to focus on sales data from the past 12 months.

Individualized Delivery Plans for Each Branch

The primary warehouse's freight schedule was examined, revealing that the Chiang Mai branches consist of Branch 1 and 2, with deliveries scheduled for Mondays, Thursdays, and Saturdays. The Bangkok branches include Branch 3, 4, and 5, with transport rounds scheduled for Wednesdays and Fridays. The delivery plan will be further analysed using historical daily sales data from 2022, considering the percentage of weekly sales and delivery cycles. Table 8 presents a sample of quantities and percentages of weekly sales for Product A in January 2022 at Branch 1.

Week	Day	Product A	Percentage	Week	Day	Product A	Percentage
Week 1	Fri-Sat	62	8.1	Week 3	Sun-Mon	50	6.5
Week 1	Sun-Mon	99	12.9	Week 3	Tue-Wed-Thu	52	6.8
Week 1	Tue-Wed-Thu	77	10.0	Week 3	Fri-Sat	51	6.6
Week 1	Fri-Sat	41	5.3	Week 4	Sun-Mon	30	3.9
Week 2	Sun-Mon	67	8.7	Week 4	Tue-Wed-Thu	37	4.8

Week 2	Tue-Wed-Thu	60	7.8	Week 4	Fri-Sat	46	6.0
Week 2	Fri-Sat	58	7.6	Week 5	Sun-Mon	37	48
					Total	**767**	**100**

Table 8 The percentage of weekly sales for Product A at Branch 1 in January 2022

This analysis will enable the formulation of a comprehensive delivery plan for each store's cycle, as shown in Table 9.

				The forecasted values for Product A – Jan 2023 – Branch 1
				589
Week	**Day**	**Product A**	**Percentage**	**The delivery quantity**
Week-1	Fri-Sat	62	8.1	48
Week-1	Sun-Mon	99	12.9	31
Week-1	Tue-Wed-Thu	77	10.0	59
Week-1	Fri-Sat	41	5.3	31
Week-2	Sun-Mon	67	8.7	51
Week-2	Tue-Wed-Thu	60	7.8	46
Week-2	Fri-Sat	58	7.6	45
Week-3	Sun-Mon	50	6.5	38
Week-3	Tue-Wed-Thu	52	6.8	40
Week-3	Fri-Sat	51	6.6	39
Week-4	Sun-Mon	30	3.9	23
Week-4	Tue-Wed-Thu	37	4.8	28
Week-4	Fri-Sat	46	6.0	35
Week-5	Sun-Mon	37	48	28
Week-5	Tue			47
				589

Table 9 Delivery plans for Product A at Branch 1 in January 2023

Subsequently, a delivery plan is devised for each product at every branch.

Discussion and Conclusion

The study combined inventory improvement techniques such as ABC analysis, FIFO, FEFO principle, and plant layout design within a company case study. Additionally, delivery plans for each branch were formulated based on the analysis of sales forecast data using Microsoft Excel functions and historical sales data. The results demonstrate that the inventory layout diagrams, as depicted in Figure 4, serve as practical guidance for the company's operations, ensuring greater safety from environmental factors and facilitating ease in locating and picking items. Furthermore, the developed delivery plans for each branch are optimized and practical, aimed at reducing losses arising from shortages and excessive ordering.

References

Abolghasemi, M., Beh, E., Tarr, G., and Gerlach, R. (2020), " Demand forecasting in supply chain: The impact of demand volatility in the presence of promotion", *Computers & Industrial Engineering*, Vol. 14 No. 2, pp.346-352.

Jurado-Muñoz, J., Fernandez-Paredes, I., Quiroz-Flores, J. (2021). Lean Inventory Management Model to Reduce Defective Products in Peruvian Baking SMEs, *10th International Conference on Industrial Technology and Management (ICITM)*, pp. 46-40.

Liu, F. and Ma, N. (2019). “Multicriteria ABC Inventory Classification Using the Social Choice Theory, *Sustainability*, Vol. 12 No.1, pp. 182-190.

Mehdizadeh, M. (2020), “Integrating ABC analysis and rough set theory to control the inventories of distributor in the supply chain of auto spare parts”. *Computers & Engineering*, Vol. 139 No.1, pp. 292-301.

Pamungkas, A., Puspasari, R., Nurfiarini, A., Zulkarnain, R., and Waryanto, W. (2021), Comparison of Exponential Smoothing Methods for Forecasting Marine Fish Production in Pekalongan Waters, Central Java, *IOP Conf. Series: Earth and Environmental Science*, Vol. 934, 2021.

Rahardja, D. (2021). “Statistical Time-Series Forecast via Microsoft Excel (FORECAST.ETS) Built-In Function”*Journal of Research in Applied Mathematics*, Vol. 7 No. 11, pp. 69-73.

Srisuk, K., Tippayawong, K.Y. (2020). “Improvement of raw materials picking process in sewing machine factory using lean techniques”. *Management and Production Engineering Review* Vol.11 No.1, pp 79-85.

Thanapotivirat, P., Jitpakdeepornrat, T. (2022), “Marketing and Socio-Psychological Factors Influencing Consumption Bakery Product in Thailand”, *Studies in Business and Economics*, Vol. 17 No.1, pp. 256-271.

Tippayawong, K.Y., Prapasirisulee, T. (2011). “Productivity Enhancement in a Wood Furniture Manufacturing Factory by Improving Work Procedures and Plant Layout”, *4th International Conference on Manufacturing Engineering, Quality and Production Systems 2011*, pp. 30-34.

Tippayawong, K.Y., Sopadang, A., and Patitad, P. (2013). “Improving Warehouse Layout Design of a Chicken Slaughterhouse using Combined ABC Class Based and Optimized Allocation Techniques”. *Proceedings of The World Congress on Engineering*, 2013, pp. 479-483.

MITIGATING SUPPLIER VULNERABILITIES TO IMPROVE SUPPLY CHAIN RESILIENCE

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ABSTRACT

Purpose: After the shocks from the coronavirus pandemic were over, supply chain resilience has been proposed by experts to help businesses and their supply chains to better prepare, better respond, and better recover from the next disruptions within short timeframe. All stakeholders along the chain are equally vital to build a resilient supply chain. To the best of the authors' knowledge, however, almost all studies have built the supply chain resilience through the lens of buyers, where numerous vulnerabilities around the buyers including suppliers as sources of supply have been pinpointed. Resilient initiatives have then been strategised for buyers to eliminate vulnerabilities in their networks (e.g. multi-sourcing and diversifying supplier base). Despite the significant improvement on resilience, these initiatives do not create business-friendly environment with suppliers. The aims of the paper are to look into increasing the resilience capability from the perspective of suppliers. Vulnerabilities of suppliers are analysed, identified, and alleviated through the proposed framework. This is to mitigate supply chain risks created by suppliers. This is to ensure building the resilient supply chain while also maintaining the supplier businesses.
Design/methodology/approach: A case of cross-border supply chain from Thailand to Laos is chosen for this action research study. International trade from Thailand are crucial to drive Laos economic growth and uplift the living standards of population. The research team works with key practitioners in developing the framework for analysing and identifying vulnerabilities of Thai suppliers. Then, the developed framework is validated with actual cross-border supply chains. Mitigation action plans are recommended to increase supplier resilience capacity.
Findings: The developed framework is able to identify vulnerabilities of Thai suppliers. Mitigating supplier vulnerabilities improve reliability and resilience capacity of Thai suppliers. Cross-border supply chain risks can eventually be mitigated.
Originality/value: This paper is among the first to put efforts in improving the supply chain resilience from the perspective of suppliers. Mitigating supplier vulnerabilities can reduce cross-border supply chain risks. Supply chain can be more resilient on one hand. Supplier can maintain their businesses on the other hand.

Keywords: Supplier vulnerability, Supply chain resilience, Risk mitigation, Risk identification, Cross-border supply chain

Introduction

A cross-border supply chain comprises a series of value-added processes and activities (Yan *et al*., 2020) conducted by different actors (or stakeholders) along the chain including manufacturers, shippers, suppliers (i.e. tier-1, tier-2, and so on), distributors, exporters, traders, and service providers of an exporting country as well as buyers (i.e. including importers, firms, retailers, markets, and final consumers) of an importing country. Figure 1 maps the cross-border supply chain.

The supply chain is as strong as its weakest link (Jazdzewska-Gutta and Borkowski, 2022). It has been observed that one of the most vulnerabilities (or the weakest links) in the cross-border supply chain is the cross-border supplier (i.e. supplier tier-1 in figure 1) who deals with distributing commodities across the border. Over the past few years, the cross-border supply chains and their suppliers have been impacted by numerous uncertainties, risks, and catastrophes such as the coronavirus pandemic, disasters, political tensions, and global economic recessions. Consequently, more complexities of mobilisation, especially when crossing the border, have been remarked. Some borders were temporarily closed and disrupted.

Empty shelves and stockouts in markets occurred. Many populations have been exposed to suffering, hunger, malnutrition, and perhaps decease. In addition, there was a severe issue of labour shortage at all stakeholders, resulting in inflation and the rising costs on one hand and the delays (and/or absences) of production and distribution of commodities on the other hand. Last but not the least, some businesses along chain faced loss of business opportunities, bullwhip-effect inventories, exceeding expenses, cash flow problems, layoffs, and business shutdown (Mefford, 2009; Zighan, 2021).

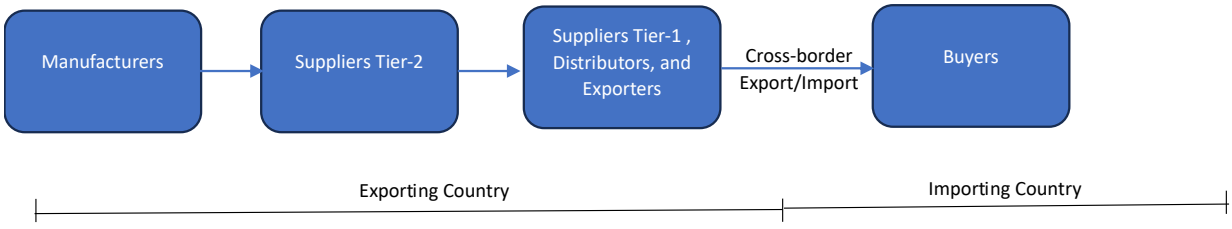

Figure 1: Cross-border supply chain mapping
Source: adapted from Yan *et al*. (2020)

Many scholars have attempted to help businesses and supply chains to better anticipate, prepare, respond to, and recover from the next disruption of any unprecedented incident within short timeframe. This is the so-called building supply chain resilience (Adobor and McMullen, 2018). One of the vital steps of building supply chain resilience is to identify, evaluate, and quantify potential capabilities of the supply chain to be able to respond to and cope with negative consequences of disruptions (Agarwal *et al*., 2022). Hence, more precise mitigating strategies, recommendation policies, and supply chain resilient initiatives could accordingly be devised and implemented to enhance the resilience. Common supply chain resilient capabilities include flexibility, redundancy, agility, and collaboration (Shekarian and Parast, 2021; Tukamuhabwa *et al*., 2015).

As far as the authors are concerned, however, evaluating supply chain resilience are commonly conducted using complex mathematical calculations (e.g. Agarwal *et al*., 2022; Aguila and ElMaraghy, 2019; Zhang *et al.,* 2023), which could not easily be replicated. Another type of evaluation is conducted through a qualitative basis (see examples in Alem-Fonseca *et al*., 2023). In addition, almost all supply chain resilience evaluations and resilience initiatives recommended by scholars have attempted to evaluate and build supply chain resilient capabilities through the lens of enterprises (or the buyers in our case) (Jain *et al*., 2017). Some initiatives were not appropriate (or applicable or incomplete) in the context of cross-border supply chain. Also, they might affect and worsen cross-border supplier tier-1.

Therefore, this paper aims at quantitatively evaluating cross-border supply chain resilience. In particular, the supplier tier-1 is the focus for measuring its supply chain resilient performances. Our goals are to adopt the well-known concept and consequently develop the conceptual framework containing essential resilient enablers and a set of questionnaires to evaluate supplier tier-1 resilient capabilities. The proposed framework can also measure resilient performances on the perspectives of supplier (i.e. when supplier tier-1 engages with buyers) and buyer (i.e. when supplier tier-1 engages and/or procures with other suppliers or manufacturers). Results from the questionnaires can computationally be converted to the supplier resilient performance index. This is a more user-friendly way to quantitatively evaluate the qualitative performances. Last but not the least, the proposed framework is validated with the experts so that the framework is assured to be used accurately and widely. The conceptual framework and its evaluation can be considered as a stepping-stone to precisely building supplier resilient capabilities and improving the cross-border supply chain resilience.

The organisation of the paper is as follows. Next session is the literature review, followed by an explanation of the methodology. Next, the conceptual framework is described in results and discussions. Last session concludes the paper.

Literature Review

Definition of supply chain resilience

The supply chain resilience is an evolving concept, which has been built on top of the supply chain risk management (SCRM) (Pettit *et al*., 2013). In the SCRM, the enterprises (or buyers) are encouraged to mitigate losses by identifying risks and vulnerabilities — possibilities of affecting supply chains and their performance measures — occurred in the supply chains due to previous, existing, foreseen, and predefined incidents (Shahbaz *et al*., 2017). Common risks include supply risk, demand risk, operation process risk, control risk, environmental risk, and so on. Then, risks can be measured by considering level of likelihoods together with consequence magnitudes. Mitigation actions can eventually be proposed to cope with given incidents and their high risks (Tummala and Schoenherr, 2011).

Supply chain resilience differs from the SCRM by proactively adding supply chain capabilities to enable the enterprises (or buyers) to anticipate and prepare their supply chains to cope with unprecedented incidents (Ponis and Koroni, 2012). Tukamuhabwa *et al*. (2015) comprehensively defined the supply chain resilience as follows: "*The adaptive capability of a supply chain to prepare for and/or respond to disruptions, to make a timely and cost effective recovery, and therefore progress to a post-disruption state of operations – ideally, a better state than prior to the disruption"*.

Building supply chain resilience through adaptive supply chain capabilities (and their key enablers)

Different adaptive supply chain capabilities have been proposed to assist the enterprises (or buyers) in preparing and dealing with supply chain disruptions. In each supply chain capability, there are a few key enablers to enable the achievements of the respective supply chain capability. According to Shekarian and Parast (2021) and Tukamuhabwa *et al*. (2015), these supply chain capabilities can systematically be grouped into four categories as follows. Supply chain flexibility is an ability (of the enterprise) to adapt (the supply chain) to be more flexible to cope with the changing requirements. It can be considered having alternative options, having spare resources, and increasing skillset and productivity. Key enablers to achieve the supply chain flexibility include flexible supplier/supply base and flexible resource. Supply chain redundancy is an ability to withstand any failure or disruption by using backup (or alternative) resources. Their key enablers include having backup resource or diversifying supply network. Supply chain collaboration is an ability to work effectively and efficiently with other stakeholders towards mutual objectives. Their key enablers include supply chain visibility, supply chain coordination, and supply chain communication. Supply chain agility is an ability to rapidly respond to changing requirements. Their key enablers include supply chain visibility and supply chain velocity (Tukamuhabwa *et al*., 2015).

Since supply chain resilience is dependent on a supply chain's ability to prepare and respond to unprecedented incidents. Evaluating supply chain resilience can be conducted by measuring resilient capabilities of the supply chain (i.e. there are four main supply chain resilient capabilities in our case as mentioned above). This is called supply chain resilient index measurement (Soni *et al*., 2014). As mentioned, many scholars have proposed to measure the supply chain resilient index using complex mathematical calculations (e.g. Agarwal *et al*., 2022; Aguila and ElMaraghy, 2019; Soni *et al*., 2014; Zhang *et al.,* 2023), which could not easily be replicated. Our proposed concept of supply chain resilient performance index measurement is an alternative (and user-friendly) way to quantitatively evaluate the cross-border supplier resilient performances.

Methodology

In the initial steps of our research work, the concept to measure cross-border supplier resilient performance index has been constructed. The proposed concept was adopted from the well-known Logistics Performance Index (LPI). The LPI is an interactive benchmarking tool created by World Bank, which aims at providing feedback and indicators on national logistics performances of 139 countries. The logistics performances, which are the weighted average index of each country on six key logistics dimensions, can be computed using the surveys of international logistics operators on the ground. Survey participants are requested to rate (i.e. very low to very high or much worsened to much improved) each survey questionnaire of the six key dimensions (see more details in (https://lpi.worldbank.org/).

In our supply chain resilience performance index measurement, key dimensions to measure resilient performances are four supply chain resilient capabilities. However, the proposed concept integrates two supply chain capabilities, supply chain flexibility and supply chain redundancy, into one dimension. The rationale behind this integration is that both capabilities are interrelated and share some common characteristics. Flexibilities of the supply chain can be achieved by having backup or alternative resources (i.e. definition of the supply chain redundancy) (Tukamuhabwa *et al*., 2015). Both also result in similar enablers and supply chain resilient initiatives in the cross-border supply chain context. Supply chain collaboration and supply chain agility are also interrelated, which can be integrated into one dimension. For instance, supply chain visibility plays a vital role in achieving supply chain agility. Visibility gives better visualisation and clearer view of the end-to-end supply chain, which assists in detecting negative signals of potential disruptions and accelerating decision making ahead of time (Tukamuhabwa *et al*., 2015). To achieve the end-to-end visibility, collaboration and information sharing among stakeholders need be established. Therefore, the proposed concept also integrates these two supply chain capabilities.

After the concept was constructed, the conceptual framework containing key enablers of each respective supply chain capability and a set of questionnaires was developed. The proposed concept as well as the conceptual framework have then been validated with cross-border experts and practitioners in Thailand who were members of Federation of Thai Industries. Feedback from the validation resulted in the revised conceptual framework, which could be described in the next session.

Results and Discussions

The conceptual framework

Tables 1 and 2 show key enablers and sub-enablers to achieve the integrated supply chain flexibility & redundancy capabilities as well as the integrated supply chain collaboration & agility capabilities, respectively. As mentioned, the proposed conceptual framework needs to focus on measuring resilient performances on two perspectives of the cross-border supplier tier-1, including supplier (i.e. when supplier tier-1 engages with buyers) and buyer (i.e. when supplier tier-1 engages and procures with other suppliers or manufacturers). Summary of each enabler can be found below.

In table 1, there are three key enablers. The first enabler is flexible supply. This is an ability of the supplier tier-1 when acquiring, sourcing, and procuring commodities (i.e. materials/products). This capacity is to ensure that the supplier tier-1 always has alternative commodities or alternative sourcing options to fulfil the changing requirements. On the other hand, when engaging with buyer, it is also defined as an existing (or potential) ability of the supplier tier-1 to provide flexible supply to serve the buyer. To have (or to provide) flexible supply, the supplier tier-1 should possess 1) an ability to apply (or to assist the buyer in having) appropriate purchasing portfolio categorisation (note that purchasing portfolio categorisation is a foundation of building supply chain resilience (Bhusiri *et al*., 2021)), 2) an ability to have (or to provide) an expansion and/or diversification of locations and/or sources of supply (Juttner and Maklan, 2011), 3) an ability to have (or to provide) a strengthened partnership with its strategic supplier (or the buyer) and request (or prepare)

to have safety stock of important commodities to ensure smooth supply (Juttner and Maklan, 2011; Scholten *et al*., 2020), and 4) an ability to have (or to provide) a strengthened partnership with its strategic supplier (or the buyer) and request (or provide) for increased supplies in a short notice (having spare capacity) (Qazi *et al*., 2022).

Next enabler is flexible inbound (or outbound) transport and distribution channel (Tukamuhabwa *et al*., 2015). This capacity is to ensure that the supplier tier-1 always has (or provide) alternative transport options and distribution channels for constant inbound (or outbound) deliveries. Under this enabler, the supplier tier-1 should possess 1) an ability of the supplier tier-1 to have (or to provide) an expansion (or diversification) of inbound distribution channels (and/or transport modes), 2) an ability to redeploy and expand own transport resources for inbound (or outbound) deliveries, and 3) an ability to have (or to provide) an expansion and/or diversification of transport outsourcing options.

Another enabler is flexible workforce arrangement (Tukamuhabwa *et al*., 2015). This enabler is to ensure that supplier tier-1 always has (or provide) alternative workforce options including: 1) an ability to have (or to provide) a strengthened partnership and request other suppliers (or to be requested by the buyer) to build capacities of workforces to be more productive and multi-skilled and 2) an ability to have (or to provide) a strengthened partnership and request other suppliers (or to be requested by the buyer) to redeploy and expand workforce.

Supply Chain Resilient Capabilities: Flexibility & Redundancy		
Sub-enablers in perspective of buyer	**Enablers**	**Sub-enablers in perspective of supplier**
1) an ability to have (or apply) appropriate purchasing portfolio categorisation 2) an ability to have an expansion and/or diversification of locations and/or sources of supply 3) an ability to have a strengthened partnership with its strategic supplier and request to have safety stock of important commodities to ensure smooth supply 4) an ability to have a strengthened partnership with its strategic supplier and request for increased supplies in a short notice (having spare capacity)	**Flexible supply**	1) an ability to assist (or provide information or participate) buyer in analysing and categorising purchasing portfolio 2) an ability to provide expansion of locations of supply by having inventories in multiple locations domestically and internationally 3) an ability to provide a strengthened partnership and store spare inventory (i.e. important commodities) for buyer 4) an ability to provide a strengthened partnership and increase supplies to be delivered within short notice (having spare capacity)

1) an ability to have an expansion (or diversification) of inbound distribution channels (and/or transport modes) 2) an ability to redeploy and expand own transport resources for inbound deliveries (in case the supplier tier-1 uses own transport resources) 3) an ability to have an expansion and/or diversification of transport outsourcing options	**Flexible transport and distribution channel**	1) an ability to provide expansion (or diversification) of outbound distribution channels (and/or transport modes) 2) an ability to redeploy and expand own transport resources for outbound deliveries 3) an ability to provide an expansion and/or diversification transport outsourcing options
1) an ability to have a strengthened partnership with its strategic supplier and request to build capacities of workforces to be more productive and multi-skilled. Also, an ability to build own capacities of workforces to handle inbound deliveries 2) an ability to have a strengthened partnership with its strategic supplier and request to redeploy and expand workforce. Also, an ability to redeploy and expand own workforces to handle inbound deliveries	**Flexible workforce arrangement**	1) an ability to provide a strengthened partnership and prepare to build capacities of workforces (to handle outbound deliveries) to be more productive and multi-skilled 2) an ability to provide a strengthened partnership and prepare to redeploy and expand own workforce (to handle outbound deliveries)

Table 1: Key enablers of the integrated supply chain flexibility & redundancy capabilities

In table 2, there are also three key enablers. The first enabler is supply chain visibility. This is an ability of the supplier tier-1 to have (or to assist in having) an efficient tracking performance of its supplier (or of the buyer) (Shekarian and Parast, 2021) including: 1) an ability to have (or to provide) information and performances exchanged, shared, received, tracked, and monitored from its suppliers (or for the buyer) and 2) an ability to analyse and evaluate the performances of the supply (or the forecasted demands). Next enabler is relationship orientation. This enabler is related to an ability of having (or assist the buyer in having) purchasing portfolio categorisation (Bhusiri *et al*., 2021). After purchasing portfolio and supplier are categorised, the supplier tier-1 should possess 1) an ability to prioritise its suppliers (or to assist the buyer in prioritising supply base) and 2) an ability to have an appropriate establishment of different levels of relationships with other suppliers (or to assist the buyer in establishing appropriate relationships). Last but not the least, supply chain communication is the enabler to have (or to provide) proactive, regular, and responsive communicate with other suppliers (or the buyer). Also, it includes an ability to have (or to provide) an alignment of communication channels.

Supply Chain Resilient Capabilities: Collaboration & Agility		
Sub-enablers in perspective of buyer	**Enablers**	**Sub-enablers in perspective of supplier**
1) an ability to have information and supply chain performances exchanged, shared, received, tracked, and monitored from other suppliers 2) an ability to analyse and evaluate the performance of supply (from other suppliers)	**Supply chain visibility**	1) an ability to share and exchange its information for the buyers to track and monitor the performances and receive useful information from the buyer 2) an ability to analyse and forecast demands from the buyer
1) an ability to prioritise its suppliers 2) an ability to have an appropriate establishment of different levels of relationships with other suppliers	**Relationship Orientation**	1) an ability to assist the buyer in prioritising supply base 2) an ability to assist the buyer in establishing appropriate relationships
1) an ability to have proactive, regular, and responsive communicate with other suppliers. Also, it includes an ability to have an alignment of communication channels	**Supply Chain Communication**	1) an ability to provide proactive, regular, and responsive communicate with the buyer. Also, it includes an ability to provide an alignment of communication channels

Table 2: Key enablers of the integrated supply chain collaboration & agility capabilities

Examples of questionnaire

After defining key enablers and sub-enablers, a set of survey questionnaires has been developed and revised according to feedback and comments from the validation. There might be more than one question corresponded to each sub-enabler. Each question requests survey participants to rate (or answer at the most appropriate level). The ratings have five levels. Scores from 0 to 2 can be computed and consolidated to feedback the resilient performances of the supplier tier 1. Table 3 shows an example of questions related to the first sub-enabler of flexible supply of supply chain resilient capabilities; flexibility & redundancy.

Enabler	Question	Please choose an appropriate answer				
		Not at all/ Hardly ever/ Very low/ Disagree	Rarely/ Low/ Somewh at agree	Sometimes / Average/ Agree	Often/ High/ Very agree	Nearly always/ Very High/ Totally agree
Flexible supply (1st sub-enabler)	Do you know who is your strategic supplier or what is your strategic item?					
	Do you involve risks and difficulties of acquiring and procuring items as criteria when you differentiate between strategic supplier (strategic item) and others?					
	Do you know (or have you applied) the concept of Kraljic model (or something similar) when differentiating between strategic supplier (strategic item) and others? (i.e. it can result in four categories; non-critical, leverage, bottleneck, and strategic)					

	Do you know what (or have you implemented) appropriate sourcing strategies for the above-mentioned four categories are?					

Table 3: Example of survey questionnaires

Examples of supply chain resilient performance index

To calculate the resilient performance index, the survey questionnaires need to be fulfilled by of staff from different levels (i.e. from operators, managers until C-suite) of the supplier tier-1. Figure 2 depicts an example of supply chain resilient performance index on integrated supply chain flexibility and redundancy capabilities. It can be said that there is a room for improvement in flexible transport and distribution channel and in flexible workforce arrangement when this supplier tier-1 engages and/or procures with other suppliers. More transport outsourcing options for inbound deliveries, more delivery routing options, and multi-skillset capacity building are recommended resilient initiatives.

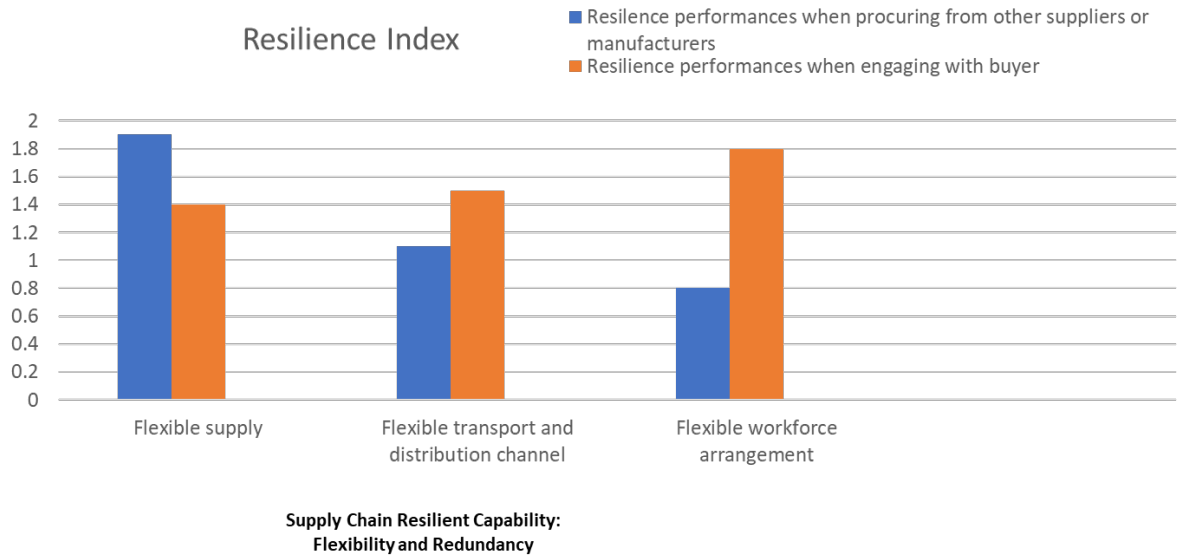

Figure 2: An example of supply chain resilient performance index on integrated supply chain flexibility and redundancy capabilities.

Source: the authors

Conclusions

This paper aims at quantitatively evaluating cross-border supplier resilient performance index by adopting the concept of the well-known LPI. Consequently, the conceptual framework containing essential resilient enablers, sub-enablers, and a set of questionnaires to evaluate cross-border supplier resilient capacities has been developed. The proposed framework could measure the resilient performances on the perspectives of supplier (i.e. when supplier tier-1 engages with buyers) and buyer (i.e. when supplier tier-1 engages and/or procures with other suppliers or manufacturers). This is a more user-friendly way to quantitatively evaluate the qualitative performances. Validation of the conceptual framework with the experts could ensure its applicability. Evaluation of supply chain resilient performance index can be considered as a stepping-stone to precisely building supplier resilient capabilities and improving the cross-border supply chain resilience. Building supplier resilience eliminate the supplier from being the bottleneck of the cross-border supply chain. The cross-border supply chain can also increase its resilience to ensure the continuous supply and distribution of commodities across the border for the benefits of both communities

and population along the border. In the next steps of our research work, the conceptual framework will be used on the case study of Thai-Laos cross-border supply chains to evaluate and measure the supplier resilient performances on actual cross-border supply chain operations between Thailand and Laos.

References

Adogor, H. and McMullen, R.S. (2018), "Supply chain resilience: a dynamic and multidimensional approach", *The International Journal of Logistics Management*, Vol. 29 No. 4, pp. 1451-1471.

Agarwal, N., Seth, N. and Agarwal, A. (2022), "Evaluation of supply chain resilience index: a graph thepry based approach", *Benchmarking: An International Journal*, Vol. 29 No.3, pp735-766.

Aguila, J.O. and ElMaraghy, W. (2019), "Supply chain resilience and structure: an evaluation framework", *Procedia Manufacturing*, Vol. 28, pp. 43-50.

Alem-Fonseca, M., Nie, W., Tsolakis, N. and Kumar, M. (2023), "Evaluating supply chains from a resilience and cost perspective: a scoping literature review and future research directions", paper presented at the 30th EurOMA Conference 2023, 3 July 2023.

Bhusiri, N., Banomyong, R., Julagasigorn, P., Varadejsatitwong, V. and Dhami, N. (2021), "A purchasing portfolio model for humanitarian supply chain resilience: perspectives from a development aid context", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 11 No. 4, pp. 639-660.

Jain, V., Kumar, S., Soni, U. and Chandra, C. (2017) "Supply chain resilience: model development and empirical analysis", *International Journal of Production Research*, Vol 55, pp. 1-22.

Jazdzewska-Gutta, M. and Borkowski, P. (2022), "As strong as the weakest link. Transport and supply chain security", *Transport Reviews*, Vol. 42 No. 6, pp. 762-783.

Jüttner, U. and Maklan, S. (2011), "Supply chain resilience in the global financial crisis: an empirical study", *Supply Chain Management. An International Journal*, Vol. 16 No. 4, pp. 246-259.

Mefford, R.N. (2009), "The financial crisis and global supply chain", *AIB Insights*, Vol. 9 No. 3, pp. 8-11.

Pettit, T. J., Croxton, K.L. and Fiksel, J. (2013), "Ensuring supply chain resilience: development and implementation of an assessment tool", Journal of Business Logistics, Vol. 34 No. 1, pp. 46-76.

Ponis, S. and Koronis, E. (2012), "Supply Chain Resilience: Definition of Concept and Its Formative Elements", *Journal of Applied Business Research*, Vol. 28 No.5, pp. 921–930.

Qazi, A.A., Appolloni, A. and Shaikh, A.R. (2022), "Does the stakeholder's relationship affect supply chain resilience and organizational performance? Empirical evidence from the supply chain community of Pakistan." *International Journal of Emerging Markets*, https://doi.org/10.1108/IJOEM-08-2021-1218

Scholten, K., Stevenson, M. and VanDonk, D.P. (2020), "Dealing with the unpredictable: supply chain resilience", *International Journal of Operations & Production Management*, Vol. 40 No. 1, pp. 1-10.

Shahbaz, M.S., Rasi, R.Z.R.M., Ahmad, M.F.B. and Rehman, F. (2017), "What is supply chain risk management? A review", *Advanced Science Letters*, Vol. 23, pp. 9233-9238.

Shekarian, M. and Parast M.M. (2021), "An integrative approach to supply chain disruption risk and resilience management: a literature review", *International Journal of Logistics: Research and Application*, Vol, 24 No. 5, pp. 427-455.

Soni, U., Jain, V. and Kumar, S. (2014), " Measuring supply chain resilience using a deterministic modeiling approach", Computers & Industrial Engineering, Vol. 74, pp. 11-25.

Tukamuhabwa, B.R., Stevenson, M., Busby, J. and Zorzini, M. (2015), "Supply chain resilience: definition, review and theoretical foundations for further study", *International Journal of Production Research*, Vol. 53, pp. 5592-5623.

Tummala, R. and Schoenherr, T. (2011), "Assessing and managing risks using the supply chain risk management process (SCRMP)", *Supply Chain Management: An International Journal*, Vol. 16 No. 6, pp. 474-483.

Yan, C., Wang, X., Zhang, Y. and Ding, Q. (2020), "Analysis of cross-border supply chain network system", proceedings of the 5th International Conference on Electromechanical Control Technology and Transportation (ICECTT), Nanchang, China, pp. 603-606.

Zhang, H., Jia, F. and You, J.X. (2023), “Striking a balance between supply chain resilience and supply chain vulnerability in the cross-border e-commerce supply chain”, *International Journal of Logistics: Research and Application*, Vol. 26 No. 3, pp. 320-344.
Zighan, S. (2021), “Managing the great bullwhip effects caused by COVID-19”, *Journal of Global Operations and Strategic Sourcing*, Vol. 15 No. 1, pp. 28-47.

MORAL DILEMMA FACING AUTONOMOUS VEHICLES: INSIGHTS FROM STATED PREFERENCE SURVEY IN THE CONTEXT OF SINGAPORE

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ABSTRACT

Purpose: With the rapid development of autonomous vehicles, the transportation industry is experiencing significant changes in recent years. Level 5 autonomous vehicles possess the highest level of vehicle automation, where drivers' intervention is no longer needed. Nevertheless, the moral dilemma arises accordingly as the autonomous vehicle needs to control and regulate its own driving pattern and make the optimal decision when it is involved in any traffic accident. This preliminary study explores the perception of moral issues from potential autonomous vehicle users and how the perception affects the design of autonomous vehicles facing moral dilemmas.
Design/methodology/approach: In this study, we conduct a stated preference survey to explore the preferences of prospective users regarding different decision-making models in the context of Singapore when they are presented with moral dilemma situations involving Level 5 autonomous vehicles, where descriptive analysis and discriminant analysis are utilised to analyse the survey results.
Findings: Analytical results indicate that different levels of expectations for autonomous vehicles lead to stronger beliefs in the artificial intelligence (A.I.) algorithms handling moral dilemmas. However, gender and respondents' hazard perception do not significantly influence the attitudes of respondents towards the development of decision-making models for autonomous vehicles. The results also show that rebates in insurance premiums and legal liability were effective in engendering a change in respondents' preferences towards a moral model developed by A.I. as the autonomous vehicle decision-making model. Moreover, two groups regarding the expectation of autonomous vehicles are identified based on the discriminant analysis.
Research limitations/implications (if applicable): Level 5 autonomous vehicles are not yet reached marketability in Singapore. A stated preference survey, instead of a revealed preference survey, was thus employed, in which respondents might overstate their valuation or expectation of a particular good, service or outcome.
Originality/value: The results of this study can provide policy implications to transportation planners and manufacturers in developing the decision-making model when Level 5 autonomous vehicles face moral dilemmas.

Keywords: Level 5 autonomous vehicle, Moral dilemma situations, Stated preference survey, Discriminant analysis, Policy implications

1. Introduction

In recent years, the transportation industry has undergone significant changes due to the rapid development of autonomous vehicles (AVs). On the domestic front, the Singapore Government earmarked AV as a Smart Nation Initiative (Smart Nation, n. d.) and allocated the entirety of western Singapore, comprising 1,000 km of public roads, for AV testing and development (Abdullah, 2019). This underscores the sheer importance accorded to AV development and eventual usage in Singapore. Furthermore, the advancement of 5G technology worldwide and in Singapore, with an ambitious goal of complete island coverage by 2025 (Loh, 2020), could further fuel AV demand since 5G networks enable the usage of C-V2X technology interface by AVs in proximity with each other to communicate and synchronise speeds, enhancing AV safety (Shankland, 2019). These factors are poised to persist well into the future, precipitating the proliferation of AV usage worldwide and in Singapore, forming the impetus for addressing the moral dilemma without delay.

The definition of AVs, derived from the Society of Automotive Engineers (SAE) J3016 standard, spans six entries, levels 0 to 5, ascending in incremental autonomy progression, from completely dependent on human control to completely autonomous. The chief complexity of operating level 5 AVs stems from their complete autonomy, omitting the need for human driver intervention. This means the AV onboard system logic must make traffic decisions by itself and will face decision-making conflicts during traffic accidents if loss of life is determined to be inevitable, by weighing the lives of pedestrians versus those of passengers, making snap decisions minimise the costs from a traffic accident in terms of human lives.

The pressing issue of implementing the most optimal decision-making model for AVs is exacerbated by the increasing costs in terms of human lives. In 2018, Elaine Herzberg was the first person killed by an AV, owned by Uber, which failed to identify Herzberg as a collision danger rapidly enough (Cellan-Jones, 2020). This indicates greater urgency to upgrade the decision-making capacities of AVs to avoid similar tragedies in future.

Ultimately, the moral dilemma is about sussing out the most optimal trade-off between the lives of pedestrians and passengers in traffic accidents for a Level 5 AV. Furthermore, the optimal trade-off would serve as a behaviour guide or course of action for the AV to adopt when engaged in potentially deadly traffic situations. This moral dilemma should be addressed promptly more than ever owing to the rising proliferation of AV usage worldwide and in Singapore. Thereby, in this study, we aim to investigate the expectations of prospective AV users in Singapore when they are presented with moral dilemma situations involving Level 5 AVs based on a stated preference (SP) survey. We utilise descriptive statistics to analyse the survey results, and further discuss the related insights and policy implications regarding Level 5 AVs' decision-making models.

The remainder of this paper is organised as follows: Section 2 reviews recent research on the pros and cons of AV development, followed by its applications in Singapore. Section 3 presents the data collection and the research approaches. The results and discussions are expressed in Section 4, while Section 5 shows a conclusion.

2. Literature Review

A number of studies have addressed the AV decision-making issue and moral judgement. For example, Awad *et al.* (2018) uncovered cross-cultural ethical variations in the expected behaviour of AVs in collisions, deriving three distinct clusters of responses, and discussed how these preferences could be the basis for a global and socially accepted set of guidelines for AV decision-making. Pickering *et al.* (2019) investigated the application of an ethical Model-To-Decision (M2D) procedure for AVs to abide by during collisions and formulated a mathematical model of collision scenarios for determining collision severity in terms of overall injuries suffered. Kallioinen *et al.* (2019) explored the distinct moral beliefs pertaining to human drivers and AVs in dilemma situations, from the perspectives of AV occupants, pedestrians, and observers, based on two case studies using virtual reality and animation, respectively.

Mosquet *et al.* (2015) found that nearly 1,500 drivers surveyed in the United States expressed strong sentiments towards purchasing a partially or fully autonomous vehicle, of which 20% were willing to pay $5,000 more for enhanced in-vehicle features. The growth rate of global AV market demand is projected to be sustained at a compound annual growth rate of 63.1% between 2020 and 2027 (Grand View Research, 2020). This is indicative of changing consumer mindset in favour of AV, notwithstanding higher ownership costs.

In the context of Singapore, KPMG's (2020) Autonomous Vehicle Readiness Index 2020 evaluated the preparedness of 30 countries in supporting and implementing AVs on a nationalised scale. Their findings revealed that Singapore clinched the pole position ranking for public policy and legislation. Chng and Cheah (2020) intended to understand the general opinion on the usage of AV as public transport in Singapore, where a survey of 210 respondents has been conducted in Singapore in 2018. This study aims to further

investigate respondents' preferences for different AV decision-making models in situations where they are confronted with the moral dilemma of choosing between sacrificing the AV's occupant or a pedestrian.

However, examining a one-to-one moral dilemma where the lives of AV occupants are weighed against those of non-in-vehicle pedestrians presents inherent challenges in systematic analysis. The choices made in these situations can lead to adverse consequences for car occupants, other road users, and pedestrians (Kallioinen *et al.*, 2019). This dilemma directly highlights the moral conflict between self-preservation (protecting oneself) and pro-social behaviour (protecting others). Bonnefon *et al.* (2016) proposed a scenario involving an AV with a single passenger, confronted with the decision to steer towards an unmovable barrier or continue on the current path and collide with a pedestrian. The results indicated a preference for prioritising human lives based on factors such as age, gender, and social status.

3. Research Approaches

The survey strategy entails the use of web-based questions to query and understand respondents' perspectives on AV decision-making in Singapore. An online self-completion questionnaire has been utilised, as shown in the Appendix. Descriptive analysis results on the SP survey questionnaires regarding the attitudes of the respondents and their preferred moral decision-making model for AVs when confronted with a moral dilemma. Individual *t*-tests were adopted to clarify whether are significant differences in the expected moral model development, i.e., Questions 4-6 in the Appendix, among the attributes, such as gender, AV design and hazard perception of respondents listed in Questions 1-3, respectively.

In addition, this study further discusses the potential influences of personal/emotional connection with AVs, insurance motivation, and legal liability on the decision-making of moral model determination by using Questions 8-10. The questions were aimed at probing respondents' attitudes and preferred AV moral decision-making models when faced with moral dilemmas, as shown in Table 1.

AV DECISION-MAKING MODELS	ENCODING VALUE
Random choice	1
Moral norms of car owner learnt by A.I.	2
Moral model developed by A.I.	3

Table 1: AV Decision-Making Models

Random choice refers to AV modelling their decision-making using random choice. Moral norms of car owners learnt by A.I. indicate AV modelling their decision-making based on AV owner's decisions. Moral norms developed by A.I. denote AV manufacturers modelling their decision-making based on the A.I. algorithm.

Moreover, discriminant analysis was utilised in this study to classify the respondents' preference in AV moral model determination based on the diversity of their individual attributes. Discriminant analysis refers to a multivariate technique to distinguish between two or more sets of observations considering *k* variables that are measured for each experimental unit, ultimately determining the significance of each variable's role in the separation of these groups.

Equation 1 lists the linear discriminant function, where Z_{jk} refers to the discriminant *Z* score of discriminant function *j* for object *k*, W_i refers to the discriminant coefficient for independent variable *i*, and X_{ik} refers to the independent variable *i* for object *k*.

$$Z_{jk} = \sum_{i=1}^{n} W_i X_{ik} \tag{1}$$

A major limitation of discriminant analysis is the fact that it requires more observations than variables and the predictors to be independent (Buzzini *et al.*, 2021). Thus, correlations between all variables measuring multicollinearity were analysed prior to conducting discriminant analysis.

4. Results and Discussions

The survey responses were derived from 108 unique respondents, including 64 female and 44 male respondents. 92.59% of respondents agreed that a well-designed autonomous vehicle should minimise human casualties, whereas only 8 respondents disagreed. Furthermore, there were 54.63% of respondents preferred to minimise pedestrian casualties, while 49 respondents suggested protecting the AV occupants.

Table 2 lists the results of individual *t*-tests with the assumption of non-equal variances for Questions 4-6. Table 2 reveals that there is no difference in perception of the A.I. moral algorithm between male and female respondents. In the context of AV design, the level of conviction among respondents, who agree that a well-designed AV should minimise human casualties, believing that "the AV moral dilemma model developed by the A.I. would make a better decision than random choices" is stronger than that among respondents who hold the opposing view.

Moreover, respondents who prioritised safeguarding pedestrians from casualties exhibit less confidence in the AV's ability to decide whose life should be sacrificed even if it proposed a good A.I. moral model, in contrast to those respondents who prioritised the well-being of occupants in AVs, at the significance level $p < 0.1$.

Perception of A.I. moral algorithms	Groups	*t*-value	Sig. (2-tails)
A.I. algorithm will be better than random (Question 4)	Gender (Question 1)	0.678	0.500
	AV design (Question 2)	-2.408	0.044**
	Hazard perception (Question 3)	-0.668	0.505
Consensus built by humans (Question 5)	Gender (Question 1)	0.246	0.806
	AV design (Question 2)	-1.166	0.280
	Hazard perception (Question 3)	-0.738	0.462
A.I. is unable to decide (Question 6)	Gender (Question 1)	-0.703	0.484
	AV design (Question 2)	0.522	0.616
	Hazard perception (Question 3)	1.849	0.068*

** $p < 0.05$; * $p < 0.1$

Table 2: Analytical Results of the *t*-test

Figure 1 illustrates respondents' preference in the AV decision-making models among the different scenarios. If the AV was able to build emotional connections with respondents, e.g., communicating with in-vehicle occupants, making recommendations, or assisting in their decision-making process, 61.11% of respondents preferred the AV decision-making model to be the moral norms of car owners learnt by A.I.

If insurance companies provided policyholders with a 40% rebate in insurance premiums for AVs, 51.85% of respondents still preferred the AV decision-making model to be the moral norms of car owners learnt by A.I. However, the response count for "the AV decision-making model to be the moral model developed by A.I." increased drastically from 26.85% to 43.52%. Thus, a reduction in insurance premium was 16.67% effective in incentivising a warmer reception towards a moral model developed by A.I., whereas the random choice possesses the lowest preference of less than 5%.

If AV owners were held criminally liable for accidents if their AV's decision-making model was that of moral norms of car owner learnt by A.I., but would be exempted if their AV's decision-making model was either of random choice or moral model developed by A.I., then 45.37% of respondents most preferred the AV decision-making model would be the moral model developed by A.I., while 17.59% of respondents prefer

random choice. Thereby, the result shows that legal liability is successful in inducing a shift in the respondents' preferences towards an AI-developed moral model as the decision-making model for AVs.

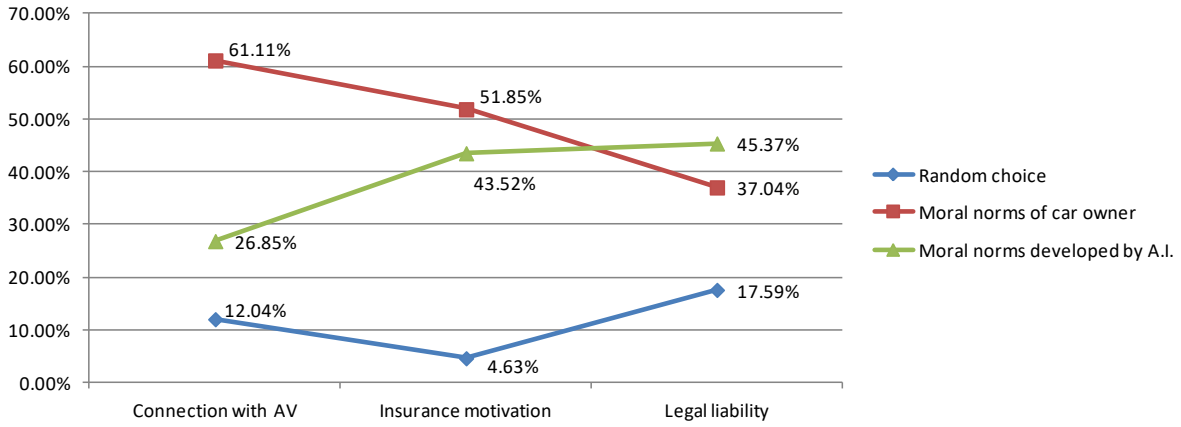

Figure 1: Preferences in AV Decision-Making Models

To investigate which respondents' attributes are most useful to discriminate among their 3 unique groups of preferred AV decision-making models, Question 7 was used to be the dependent variable, while Questions 1-6 were adopted as independent variables in the linear discriminant analysis. Table 3 represents the correlation matrix results of dependent variables, showing that the results exhibited a low occurrence of multi-collinearity, as the correlation coefficients were all below at least ± 0.50 recommended by Ratner (2009). This thus avoids the generation of unreliable predictive performance for the predictive model caused by high correlation among predictors (Daoud, 2017).

Correlation	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6
Question 1	1.000	0.091	0.041	-0.062	-0.017	0.069
Question 2	0.091	1.000	0.030	0.307	0.202	-0.043
Question 3	0.041	0.030	1.000	0.064	0.072	-0.156
Question 4	-0.062	0.307	0.064	1.000	0.475	-0.144
Question 5	-0.017	0.202	0.072	0.475	1.000	-0.140
Question 6	0.069	-0.043	-0.156	-0.144	-0.140	1.000

Table 3: Correlation Matrix Results

To improve the variable scaling and interpretability, we derive the standardised canonical discriminant function coefficients, where the Structure Matrix that displays the correlations between independent variables and the discriminant functions. Questions 1-6 refer to the independent variable *i* in Eq. (1), i.e., *i = 1, 2, 3, …, 6*, while the number of object *k* in this study is 108. Eqs. (2) and (3) show the results of the discriminant function.

$$Z_{1k} = 0.016X_{1k} - \mathbf{0.499}\boldsymbol{X_{2k}} - 0.132X_{3k} + \mathbf{0.574}\boldsymbol{X_{4k}} + \mathbf{0.627}\boldsymbol{X_{5k}} + 0.029X_{6k} \quad (2)$$

$$Z_{2k} = -0.040X_{1k} + \mathbf{0.357}\boldsymbol{X_{2k}} + \mathbf{0.425}\boldsymbol{X_{3k}} + 0.011X_{4k} + 0.021X_{5k} - \mathbf{0.739}\boldsymbol{X_{6k}} \quad (3)$$

The independent variables with coefficient values above ± 0.3 are considered important in this study, as they better discriminate between group memberships, as highlighted in bold in discriminant functions 1 and 2. Gender plays an insignificant role in both discriminant functions, this is consistent with the individual *t*-test results, whereas the trust in AV design for minimising human casualties plays a critical role in both discriminant functions, although the coefficients are in opposite signs.

In general, Z_{1k} is influenced negatively by X_{2k}, while it is influenced positively by X_{4k} and X_{5k}. In contrast, Z_{2k} is influenced positively by X_{2k} and X_{3k}, while it is influenced positively by X_{6k}. The results show that the respondents described by discriminant function 1 believe that the moral model developed by A.I. would make better decisions than random choices and it should be a strong consensus built by humans because they do not trust that AVs, even well-designed, are able to minimise human casualties. On the other hand, the respondents described by discriminant function 2 agree that well-designed AVs should prioritise minimising human casualties and are open to considering scenarios where the in-vehicle passengers' safety is endangered to prioritise minimizing pedestrian casualties but believe that A.I. can have the authority to decide whose life should be sacrificed based on a good moral model.

The classification results are provided in Table 4, which indicate an overall 56.5% accuracy in predicting the respondents' choices correctly on average, displaying moderately satisfactory predictive performance. Nonetheless, this arose due to the generation of imbalanced data since the majority of respondents' selections skewed towards the response "Moral norms of car owners learnt by A.I." for their preferred AV decision-making model.

Predicted / Count	Random choice	Moral norms of car owners	Moral norms developed by A.I.
Random choice	2	12	0
Moral norms of car owners	2	54	7
Moral norms developed by A.I.	0	26	5

Table 4: Classification Results

5. Conclusion

With the highest level of vehicle automation have a large potential to assist people in their daily lives. Nevertheless, in this case, where drivers' intervention and assistance are no longer needed, the moral dilemma arises since AV is the one who regulates its driving behaviour and makes decisions when a traffic accident happens. This study has utilised an SP survey in the context of Singapore to gather information about respondents' choices when they are faced with moral dilemma situations involving level 5 AVs.

In summary, the results suggest that the expectation level for AVs can affect the beliefs in the A.I. algorithms handling moral dilemmas, whereas respondents' gender does not significantly influence the attitudes of respondents towards the development of decision-making models for AVs. The results also show that rebates in insurance premiums and legal liability were effective in engendering a change in respondents' preferences towards a moral model developed by A.I. as the AV decision-making model. Moreover, two groups regarding the expectation for AV are identified based on the discriminant analysis.

The study suggests that individuals' expectations concerning AVs play a pivotal role in shaping their beliefs about the efficacy of A.I. algorithms in handling moral dilemmas. As people's anticipation of AV capabilities rises, so does their confidence in A.I.'s decision-making. Therefore, manufacturers and developers should not only focus on technological advancement but also manage and set appropriate expectations for AVs to foster positive attitudes towards A.I. moral algorithms.

The study underscores the effectiveness of offering rebates for insurance premiums and addressing legal liability concerns in shifting respondents' preferences towards accepting A.I.-developed moral models for AVs. This implies that tangible benefits can serve as powerful motivators for individuals to embrace innovative technologies and ethical decision-making frameworks. Policymakers and companies should consider implementing such incentives to promote positive behavioural shifts.

The analysis reveals two distinct belief groups: one group that distrusts AVs' ability to minimise human casualties and seeks a strong consensus driven by human decisions, and the other group that is more open to AVs prioritising human safety, even if it means endangering in-vehicle passengers. Understanding these belief clusters can guide targeted communication efforts. The first group may need reassurance about the human role in ethical decision-making, while the second group could benefit from information emphasising the potential of A.I. moral models.

This study is limited to the fact that level 5 AVs are not yet reached marketability in Singapore. Thereby, an SP survey, instead of a revealed preference survey, was employed, in which respondents might overstate their valuation or expectation of a particular good, service or outcome. Accordingly, future studies are recommended to conduct a revealed preference survey in the context where sufficient level 5 AV-related data is available. In addition, more advanced statistical modelling can be applied to further investigate respondents' behaviour when they are faced with AV-involved moral dilemma situations.

References

Abdullah, Z. (2019). *Entire western part of Singapore to become testing ground for driverless vehicles.* Retrieved from https://www.channelnewsasia.com/news/singapore/autonomous-vehicles-western-singapore-testbed-12029878

Awad, E., Dsouza, S., Kim, R. et al. (2018), "The moral machine experiment", *Nature*, Vol. 563, pp. 59-64.

Bonnefon, J.F., Shariff, A. and Rahwan, I. (2016), "The social dilemma of autonomous vehicles", *Science*, Vol. 352 No. 6293, pp. 1573-1576.

Buzzini, P., Curran, J. and Polston, C. (2021), "Comparison between visual assessments and different variants of linear discriminant analysis to the classification of Raman patterns of inkjet printer inks", *Forensic Chemistry*, Vol. 24, 100336.

Cellan-Jones, R. (2020). *Uber's self-driving operator charged over fatal crash.* Retrieved from https://www.bbc.com/news/technology-54175359

Chng, S. and Cheah, L. (2020), "Understanding autonomous road public transport acceptance: A study of Singapore", S*ustainability*, Vol. 12 No.12, 4974.

Daoud, J.I. (2017), "Multicollinearity and regression analysis", *Journal of Physics: Conference Series*, Vol. 949, 012009.

Grand View Research. (2020), *Autonomous Vehicle Market Size, Share & Trends Analysis Report By Application (Transportation, Defense), By Region (North America, Europe, Asia Pacific, South America, MEA), And Segment Forecasts, 2021 – 2030.* Retrieved from https://www.grandviewresearch.com/industry-analysis/autonomous-vehicles-market?utm_source=prnewswire&utm_medium=referral&utm_campaign=ict_6-april-20&utm_term=autonomous-vehicle-market&utm_content=rd

Kallioinen, N., Pershina, M., Zeiser, J., Nosrat Nezami, F., Pipa, G., Stephan, A. and König, P. (2019), "Moral judgements on the actions of self-driving cars and human drivers in dilemma situations from different perspectives", *Frontiers in psychology*, Vol. 10, 2415.

KPMG. (2020). *2020 Autonomous Vehicles Readiness Index.* Retrieved from https://assets.kpmg/content/dam/kpmg/es/pdf/2020/07/2020_KPMG_Autonomous_Vehicles_Readiness_Index.pdf

Loh, D. (2020). *Singtel faces challenges in Singapore's 5G era with new CEO.* Retrieved from https://asia.nikkei.com/Business/Telecommunication/Singtel-faces-challenges-in-Singapore-s-5G-era-with-new-CEO

Mosquet, X., Dauner, T., Lang, N., *et al.* (2015), "Revolution in the driver's seat: The road to autonomous vehicles", Boston Consulting Group, Retrieved from https://www.bcg.com/publications/2015/automotive-consumer-insight-revolution-drivers-seat-road-autonomous-vehicles

Pickering, J.E., Podsiadly, M. and Burnham, K.J. (2019), "A model-to-decision approach for the autonomous vehicle (AV) ethical dilemma: AV collision with a barrier/pedestrian(s)", *IFAC-PapersOnLine*, Vol. 52 No.8, pp. 257-264.

Ratner, B., (2009), "The correlation coefficient: Its values range between +1/−1, or do they?", *Journal of Targeting, Measurement and Analysis for Marketing*, Vol. 17 No. 2, pp. 139-142.
Shankland, S. (2019). *5G could make self-driving cars smarter and commutes safer.* Retrieved from https://www.cnet.com/news/5g-could-make-self-driving-cars-smarter-commutes-safer/
Smart Nation. (n. d.). *Autonomous Vehicles.* Retrieved from https://www.smartnation.gov.sg/initiatives/transport/autonomous-vehicles/
Tesla. (2016). *All Tesla Cars Being Produced Now Have Full Self-Driving Hardware.* Retrieved from https://www.tesla.com/blog/all-tesla-cars-being-produced-now-have-full-self-driving-hardware?redirect=no

Appendix

This document provides key information on the Moral Dilemmas Facing an Autonomous Vehicle Research Project that you have been invited to participate in. Your participation is voluntary but very important to the advancement of knowledge in the human-machine interface of autonomous vehicle (self-driving car) applications in Singapore.

With this study, we would like to examine the moral dilemma facing a level 5 autonomous vehicle. There is NO pedals and steering wheel in a level 5 autonomous vehicle (or self-driving car), leading to the impossibility for humans to intervene. Waymo, developed by Google, is an example of a level 5 autonomous vehicle. Similar to trolley dilemmas, there would be moral dilemmas if an autonomous vehicle experiences a sudden mechanical failure (e.g., brake failure). Staying on course would result in the death of pedestrians, whereas swerving would endanger in-vehicle passengers. When the harm is unavoidable, how an autonomous vehicle should decide on behalf of human becomes critical.

Part I

1.	Gender	□ Male	□ Female
2.	Do you agree that a well-designed autonomous vehicle should minimise human casualties?	□ Agree	□ Disagree
3.	Would you consider an autonomous vehicle, which might endanger the in-vehicle passenger (i.e., you) but minimise pedestrian casualties?	□ Yes	□ No

Part II

		Strongly disagree	Disagree	Undecided	Agree	Strongly agree
4.	I think the moral model developed by Artificial Intelligence (A.I.) for the autonomous vehicle dilemma would make a better decision than random choices.	□	□	□	□	□
5.	Using the moral model developed by A.I. to solve the autonomous vehicle dilemma would be a strong consensus built by humans.	□	□	□	□	□
6.	I do NOT think A.I. is able to decide whose life should be sacrificed even if it proposed a good moral model.	□	□	□	□	□

7. Which of the following decision logic for an autonomous vehicle facing a moral dilemma is most accepted by you? (**Select only one**)
   □ Random choice □ Moral norms of car owner learnt by A.I. □ Moral model developed by A.I.

8. When you travel in the self-driving car, the virtual assistant of your autonomous vehicle would chat with you, answer your questions, make recommendations, and assist your decisions. Assume that you trust and

emotionally connect with your autonomous vehicle. (**Select only one**)

□ Random choice □ Moral norms of car owner learnt by A.I. □ Moral model developed by A.I.

9. If insurance companies inform you that you can enjoy 40% off in insurance premium of your autonomous vehicle policy when the moral model developed by A.I. is adopted, which of the following decision logic would you prefer? (**Select only one**)

   □ Random choice □ Moral norms of car owner learnt by A.I. □ Moral model developed by A.I.

10. If the Act containing regulations for autonomous vehicles indicates that after an incident involving an AV, the owner should be investigated if he/she decides to follow the moral norms of car owners as the decision logic, whereas the owner is exempted from criminal liability if he/she adopted random choice or moral model developed by A.I. Based on the situation, which of the following decision logic would you prefer? (**Select only one**)

    □ Random choice □ Moral norms of car owner learnt by A.I. □ Moral model developed by A.I.

PERFORMANCE IMPROVEMENT OF COFFEE BEAN PRODUCTION BY LEAN TECHNIQUE

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ABSTRACT

Purpose: This project aims to increase the efficiency of the coffee bean processing process through lean techniques.
Design/methodology/approach: Lean technique by analyzing and recommending ways to optimize the production process according to the study of Flow Process Chart to use Motion and Time Study analysis and evaluate process efficiency with Value Stream Mapping (VSM), then analyze the problem or waste condition. Including improving work with the ECRS principle and compare the results of improving the production process.
Findings: The results of the research were able to improve non-value-added but necessary operations in the production process in 3 steps, resulting in a 10.02% increase in value-generating activities, including a reduction in time by 1.79 minutes, representing 13.57%. The distance was reduced by 2,190.25 meters, representing 96.31%, resulting in an increase in the efficiency of the coffee bean processing process
Research limitations/implications (if applicable): -
Practical implications (if applicable): -
Originality/value: This project can be implemented in other production line to improve the efficiency of the processing due to the reduction of non-value added operation using Lean technique.

Keywords: Coffee Processing, Lean, VSM, ECRS, Motion and time study, Performance improvement

Introduction

Nowadays, coffee is a caffeinated drink that has a large number of consumers, both school and working age, because of its unique aroma and taste, as well as helping to increase alertness, not drowsiness. Coffee is one of the world's most traded agricultural commodities, and growing it requires environmental factors. In Thailand, the northern region is popular for growing Arabica coffee varieties because it is an area higher than sea level and cool weather.

This research was conducted at one of a company which produces coffee bean products in Chiang Mai, Thailand. The focused activity of this study was the production of coffee bean. Lean manufacturing technique is implemented to analyze problems, limitations of the current situation, as well as to classify value of each activity in the production line. Consequently, productivity improvement techniques such as Motion and time study, VSM and ECRS are employed to identify and suggest improving strategy to increase production line efficiency in terms of production time reduction, and transportation distance

Literature Reviews

To identify and improve the current production line; (1) motion and time study (2) VSM and (3) ECRS technique are together applied in this study. The details of both concepts are briefly explained as follows.

1) Motion and Time Study

Motion study is a study and analysis of the motion of working parts in the production, including machine, tool, equipment, and work station, or workplace. This chart is a tool, which the systematic study of works systems with the purpose of (1) developing the preferred system and method usually the one with the lowest cost; (2) standardizing this system and method; (3) determining the time required by a qualified and properly trained person working at a normal pace to do a specific task or operation; and (4) assisting in training the worker in the preferred method. Marks are utilized in the

process chart to clearly identify working processes, and easier to read. The recorded processes started from obtaining raw material and follow up through production line. Signs used in process chart include "O" for Operation, "⇒" for Transportation, "□" for Inspection, "D" for Delay, and "∇" for Storage [2].

1) VSM

Value stream mapping is one of the techniques which is used as a tool for emphasizing the supply chain in order to improve the supply chain efficiency by eliminating unnecessary activities or reducing the processing time. The VSM technique was applied to categorize the activities in the supply chain into three major types: value-added (VA), non-value-added (NVA), and necessary-non- value-added (NNVA) activities.

2) ECES

ECRS principles are the technique that help generate an approach to improve productivity of the production line each character has its meaning which are: E = Eliminate: is the elimination of unnecessary processes during the production. The seven areas of detected loss in present processes, which has been eliminated, are including over-production, waiting time, unnecessary change, unnecessary job, over-stocking, unnecessary transportation, and damages to products. C = Combine: is the combination of processes that allows the producer to save more time and energy used in the production. Some processes can be combined together; for instance, the production line used to have

5 steps to produce, which some of these steps could be done together at the same time, the processes then are being combined. As a result, the overall steps are reduced, allows the whole production process to complete faster and more efficient. This also eliminates the transit between processes that requires different tools to get the job done. R = Rearrange: is the rearrangement of the required processes. The rearranged processes allow the production to complete faster by removing unnecessary transit to another process, or to eliminate waiting time.

Research Methodology

The methodology for this study includes:

1) Data Collection

This research is to study the coffee bean production process which is a wet process in Chiang Mai. In the beginning, the study was focus on data collection based on factory maps, production processes, and process activity maps of each work station, in order to clarify the current situation of the production line.

2) Problem Identification

The information received from the data collection process is used to create a process activity mapping to identify critical points in the production processes. There are several signs being employed to represent these critical points, including: "D" represents delays and/or waiting time, "⇒" to represent transportation of the product from one point to another. Moreover, each activity is classified based on VSM concept into: VA (value added), NVA (non-value added), and NNVA (necessary but non-value added).

3) System Designing for Improvement

According to the flow chart previously created from ECRS and VSM techniques, a new flow chart is being designed to eliminate non-value added works in the process, in order to minimize production time, transportation, and other unnecessary works.

4) Performance Measurement Comparison

The results between before and after improvement will be compared based on total time, transportation distance, and total number of tasks.

Results and Discussion

A. Data collection

In this study, the researcher has studied the coffee bean production process. The production line consists of 3 main steps: coffee cherry processing, green coffee bean processing, coffee bean roasting and product packaging. This can be divided into 33 activities, and the VSM is then used to visualize the current state of the coffee bean production process before improvement. From the process flow analysis, it was found that the time of production activities according to the cycle time of each process was 20.64 minutes while the total transportation distance was 3,831.5 meters as shown in Table I.

B. Problem Identification

Table I shows that the production process has a process time of 20.64 minutes. The total transportation is 3,831.5 meters. The number of activity is 33. The activity consists of 16 steps of operation, 13 steps of transportation, 1 steps of inspection, and 1 stages of storage. According to VSM, the process consists of 11 VA activities, 20 NNVA activities and 2 NVA activities. Then, ECRS technique was performed to evaluate the problem condition and propose ideas for improvement.

C. System Designing for Improvement

ECRS has been employed to cut processes and reduce the transportation problem, as well as recommend an improvement of the work process, as the followings:

1) E-Eliminate: according to Table I, the transportation of raw materials has a large distance because the warehouse is far from the factory area, causing more distance and time. In addition, the process of containing coffee beans into sacks does not create value and adds complexity to the work process.

2) C-Combine: according to Table I, the coffee cherry imperfect sorting step and the coffee cherry color sorting step can be combined into one successive step to increase product value and reduce waste.

3) S-Simplify: Simplifying the process by developing equipment or machinery, as well as placing the warehouse in the factory area to increase process efficiency.

TABLE I. CURRENT PROCESS ACTIVITY MAPPING

Activity Mapping		○	⇨	D	□	∇	VA	NNVA	NVA	Time (Minutes)	Transportation length (Meters)
Details of processes											
Coffee Cherry Processing											
1	Move coffee cherry to the well		⇨					√		0.05	0.75
2	Sort out imperfect coffee cherry	○					√			0.17	
3	Sent to coffee cherry machine		⇨					√		0.05	0.75
4	Pulping (Mill coffee cherry skin)	○					√			0.12	
5	Fermenting	○					√			1.44	
6	Clear the mucus	○					√			0.12	
7	Contain in sacks	○						√		0.05	
8	Move to drying place		⇨					√		1.00	20.00
9	Pour into the sieve	○						√		0.08	
10	Drying	○					√			5.04	
11	Moisture check				□			√		0.05	
12	Contain in sacks	○						√		0.05	
13	Move to warehouse		⇨					√		0.16	750.00
14	Store					∇	√				
Green Coffee Beans Processing											
15	Move to hulling		⇨					√		0.16	750.00
16	Hulling	○					√			2.92	
17	Move to sort out sizes machine		⇨					√		1.25	25.00
18	Sort out sizes of green beans	○					√			0.24	

19	Contain in sacks	○						√		0.05	
Activity Mapping Details of processes		○	⇨	D	□	∇	VA	NNVA	NVA	Time (Minutes)	Transportation length (Meters)
20	Move to warehouse		⇨					√		0.16	750.00
21	Move substandard coffee		⇨					√		0.04	10.00
22	Sorting of coffee beans (by hand)	○					√			5.00	
23	Contain in sacks	○						√		0.05	
24	Move to warehouse		⇨					√		0.04	10.00
25	Store					∇			√		
Coffee bean roasting and packaging											
26	Move to roasting factory		⇨					√		0.48	750.00
27	Move to roasting machine		⇨					√		0.04	5.00
28	Roasting	○					√			1.05	
29	Contain in sacks	○						√		0.06	
30	Move to warehouse		⇨					√		0.48	750.00
31	Move to packing		⇨					√		0.04	10.00
32	Packaging	○					√			0.13	
33	Store					∇			√	0.07	
<----------Total >		**16**	**13**	**0**	**1**	**3**	**11**	**20**	**2**	**20.64**	**3,831.50**

After using ECRS technique, the improved flow process activity mapping can be illustrated in Table II.

TABLE II. PROCESS ACTIVITY MAPPING AFTER IMPROVEMENT

Activity Mapping Details of processes		○	⇨	D	□	∇	VA	NNVA	NVA	Time (Minutes)	Transportation length (Meters)
Coffee Cherry Processing											
1	Move coffee cherry to the well		⇨					√		0.05	0.75
2	Sorting imperfect coffee cherry and color sorting machines	○					√			0.33	0.75
3	Sent to coffee cherry machine		⇨					√		0.05	0.75
4	Pulping (Mill coffee cherry skin)	○					√			0.12	
5	Fermenting	○					√			1.44	
6	Clear the mucus	○					√			0.12	
7	Move to drying place		⇨					√		1	20.00
8	Pour into the sieve	○						√		0.05	
9	Drying	○					√			3.60	
10	Moisture check				□			√		0.05	
11	Contain in sacks	○						√		0.05	
12	Move to warehouse		⇨					√		0.03	28.00
13	Store					∇	√				
Green Coffee Beans Processing											
14	Move to hulling		⇨					√		0.05	40.00
15	Hulling	○					√			2.92	
16	Move to sort out sizes machine		⇨					√		1.25	25.00
17	Sort out sizes of green beans	○					√			0.24	
18	Contain in sacks	○						√		0.05	
19	Move to warehouse		⇨					√		0.01	15.00
20	Move substandard coffee		⇨					√		0.01	2.00
21	Sorting of coffee beans (by hand)	○					√			5.00	
22	Contain in sacks	○						√		0.05	
23	Move to warehouse		⇨					√		0.01	2.00
24	Store					∇			√		
Coffee bean roasting and packaging											
25	Move to roasting machine		⇨					√		0.04	5.00
26	Roasting	○					√			1.05	
27	Contain in sacks	○						√		0.06	
28	Move to packing		⇨					√		0.01	2.00
29	Packaging	○					√			0.13	
30	Store					∇			√	0.07	

<----------Total >	15	11	0	1	3	11	17	2	17.84	141.25

D. Performance Measurement Comparison

The comparison of existing and the proposed system is illustrated in Table III. The total duration of the process was reduced from 20.64 to 17.84 minutes. The total transportation is reduced by 2,190.25 meters. With the ECRS technique, the number of activities can be decreased by 3 activities. Therefore, percent improvement in terms of Time and Distance are 13.57% and 96.31%, respectively.

TABLE III. COMPARISON OF BEFORE AND AFTER IMPROVEMENT

	Before	**After**	**Difference**	**% Reduction**
Total time (Minutes)	20.64	17.84	770.00	13.57
Total distance (Meters)	3,831.50	141.25	2,190.25	96.31
No. of activities	33	30	3	9.09

Conclusion

This study emphasized on the improvement of the coffee bean production process. The core processes of this line consist of 3 main steps: coffee cherry processing, green coffee beans processing, coffee bean roasting and product packaging. Prior to the study, the total production time was 20.64 minutes, and total of 3,831.5 meters of total transportation length.

According to the process activity mapping, all of the processes, this section contains total of 33 work steps; 22 of which were NVA and NNVA processes. Hence, ECRS technique was applied in order to improve efficiency in production. The technique was applied by eliminate the long distance transportation of raw materials and contain coffee beans in sacks that do not create value. Combine coffee cherry imperfect sorting and coffee cherry color sorting steps. Developing equipment or machines to simplify the process. Including placing a warehouse in the factory area to increase process efficiency.

The production line in the coffee bean production process using lean manufacturing techniques shows that the processing time can be reduced by 13.57%. Total transportation distance can be reduced by 96.31%.

References

[1] W. Wattanutchariya, and A. Ounjai. “Efficiency Improvement of Dried Longan Production Line Using ECRS Principles” The 7th International Conference on Logistics and Transport, November 17-20, 2015, Lyon, France.

[2] Barnes, R. M. (1980). Motion and Time Study: Design and Measurement of Work (7 ed.).

[3] Kartika, N., & Setiawan, F. P. (2020). Lean Production Implementation on Coffee Beans Business. Jurnal Manajemen Teori dan Terapan| Journal of Theory and Applied Management, 13(3). https://doi.org/10.20473/jmtt.v13i3.19577

[4] Yotsaphat Kittichotsatsawat, K. Y. T. (2021, March 7-11). Conceptual Framework of Performance Improvement in Coffee Production Using Integrated Lean Technique. the 11th Annual International Conference on Industrial Engineering and Operations Management, Singapore.

RESILIENT SUPPLIER RELATIONSHIP MANAGEMENT FRAMEWORK FOR HUMANITARIAN ORGANISATION

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ABSTRACT
Purpose: Supplier Relationship Management (SRM) involves different strategic processes and principles of supplier development and maintenance. SRM has been proven to assist commercial firms in achieving upstream supply chain resilience. As opposed to businesses, there has been a lack of critical SRM strategic processes to help humanitarian organisations achieve their upstream resiliency. Therefore, almost all humanitarian supply chains are far from being resilient. This paper extends the work done by Banomyong et al (2022) and Bhusiri et al (2021) by adapting additional strategic processes of performance measurement guidelines from SRM to the context of humanitarian supply chain. The SRM processes are then integrated into a framework to provide a more holistic and integrative viewpoint to help organisations enhance the consistency of humanitarian assistance.
Design/methodology/approach: This paper reviewed and adapted the SRM strategic processes from well-known SRM approaches used in the commercial supply chain context. The integrated framework contains a set of SRM strategic processes with information flows configuration. The framework was validated by humanitarian experts to ensure its usefulness and applicability.
Findings: The SRM framework can be used as a guideline to streamline and implement humanitarian sourcing strategies, action plans, metrics, and processes for better relationship management with suppliers and more resilient supply chains.
Research limitations/implications: The SRM framework integrates a set of paramount processes validated by humanitarian experts and provides general guidelines for humanitarian organisations. Some adaptation might be required in case of a specific humanitarian supply chain.
Practical implications: Operating humanitarian supply chains, especially ones supporting long-term development aid programmes, requires humanitarian organisations to source and procure large amount of relief commodities from suppliers annually. More precise and systematic relationship engagement approaches with suppliers play a vital role in ensuring supply consistency and efficiency to minimise suffering of beneficiaries.
Originality/value: This framework is among the first to provide an integrative view of the SRM for humanitarian organisations to increase their upstream supply chain resilience. The integrated SRM framework covers the principles of purchasing and supplier segmentation, relationship implementation guidelines, and supplier performance measurement.
Keywords: Humanitarian supply chain, supplier categorisation, supplier relationship management, performance metrics, supply chain resilience

Introduction

Supplier Relationship Management (SRM) has comprehensively been defined by Lambert and Schwieterman (2012) as one of the macro business processes of commercial firms that could contribute to more effective and resilient upstream supply chains. It consists of individual tasks, activities, strategic processes, and principles to structure how relationships between buyers (i.e. commercial firms) and suppliers should be developed and maintained including supplier categorisation, sourcing strategies, supplier and business relationship establishment, supplier performance measurement, and continuous process improvement to name but a few. The implementation of the SRM strategic processes involves and interfaces with all other macro business processes of the firm such as customer relationship management, demand management, order fulfilment, manufacturing flow management, and so on.

The SRM processes have become more and more important to businesses in decreasing costs, utilising resources, increasing profitability, maintaining level of services to customers, and staying competitive in today's market (Amoako-Gyampah *et al*., 2019; Simchi-Levi *et al*., 2003). The SRM processes have also been recognised as strategic approaches for businesses to prepare and mitigate risks of supply shortages (Datta, 2017). Therefore, many businesses and commercial firms who applied and implemented SRM can cope with supply disruptions within short periods of time amidst the coronavirus pandemic and other external shocks.

Several strategic processes of SRM are obviously interrelated and influenced by each other. Consequently, a good information system to manage and control the flows of information (i.e. inputs and outputs of each process) is required. In addition, from the practical perspective, conducting the SRM strategic processes requires strong collaboration and coordination among business functions, divisions, departments, and stakeholders within the organisation as well as the involvement of suppliers. One single staff might be responsible for more than one process of the SRM. Therefore, it is essential to integrate a set of strategic processes from SRM into a single framework to provide a holistic and integrative viewpoint. Expected outcomes could be more superior to focusing on each specific process (Lambert and Schwieterman, 2012; Park *et al*., 2010).

As opposed to businesses and their commercial supply chains, almost all humanitarian supply chains are far from being resilient. One of the rationales is that there has been a lack of important SRM strategic processes in the humanitarian supply chain context. As far as the authors are concerned, only a few SRM processes have individually been proposed for humanitarian organisations to apply to their supply chains such as purchasing portfolio and supplier categorisation (Bhusiri *et al*., 2021; Lamenza *et al*., 2019) and supplier relationship guideline development (Banomyong *et al*., 2022). While the integrative framework for the SRM to guide humanitarian organisations in the processes of managing relationships with suppliers has not been observed yet.

Disasters and other uncertainties over the past few years have shown humanitarian organisations how essential upstream supply chain resilience was. Temporary border closure followed by panic buying and stockpiling caused empty shelves. Many organisations have consequently faced supply interruptions. Many projects and operations were delayed or cancelled. With more frequency and larger magnitude of disasters in addition to global economic recessions and other uncertainties, supply disruptions could more easily take place, causing interrupted humanitarian supply chains. Therefore, it is imperative to boost humanitarian supply chain resilience.

This paper considers extending the previous works of Bhusiri *et al*. (2021) and Banomyong *et al*. (2022) by introducing and adapting additional strategic processes of supplier performance measurement development in the SRM to the context of humanitarian supply chain. The SRM processes are then integrated into a framework to provide a more holistic and integrative viewpoint to help humanitarian organisations ensure the consistency of humanitarian assistance. These SRM strategic processes for humanitarian organisations include:

- The process of categorising purchasing portfolios and suppliers. This is to achieve a better understanding of the importance of different suppliers against the purchasing power of the buying organisation so that more appropriate sourcing strategies and actions towards different suppliers can be devised to decrease operating costs and resources and to ensure the availabilities of strategic commodities (i.e. items and services);
- The process of developing supplier relationship establishment guidelines. This is to cope with the needs of practical guideline to ensure the right engagement level, resources allocated, and planning developed for the success of implementing and maintaining the SRM;
- Developing guidelines for opportunities to engage with suppliers and measuring supplier performances. This is an additional SRM strategic process developed in this paper to define the guidelines of business opportunities & requirements and performance metrics with different

suppliers to regularly measure and monitor supply performances and risks, especially from strategic suppliers. This can also be considered as a proactive management of strategic suppliers (Campbell, n.d.) and proactive improvement of humanitarian supply chain resilience.

The organisation of the paper is as follows. The next section is the literature review, followed by an explanation of the methodology. Then SRM framework for humanitarian organisations to apply to their supply chains is described. The last section concludes the paper.

Literature Review

Commercial supply chain and the SRM

Lambert and Schwieterman (2012) defined five strategic processes for SRM under a single framework that businesses could use to implement in their supply chains as follows. The first two processes are to review corporate, marketing, manufacturing, and sourcing strategies as well as to identify criteria for supplier segmentation. First, a review of products & services that are critical to the organisation's success is executed. Then, initial identification of suppliers who are also critical to the organisation's success can be executed. A mapping of organisation's supply chain can be drawn to have a better visualisation on issues, risks, and opportunities with suppliers. The organisation preliminarily identifies the suppliers with whom it needs to develop long-term relationships (i.e. the so-called strategic suppliers) according to corporate, marketing, manufacturing, and sourcing strategies. Suppliers can further be segmented into a 2x2 matrix using two defined dimensions (i.e. supply risks and potential to add value). It must be noted that the matrix of Lambert and Schwieterman (2012) is similar to one proposed by Kraljic (1983) with dimensions of importance of purchasing and complexity of supply market. There are criteria on each dimension such as volume and competitive pricing for potential to add value dimension and quality, capacity, and complexed specification for supply risk dimension.

After the matrix is constructed, four categories of purchasing portfolios and suppliers can be formed including strategic, bottleneck, leverage, and non-critical categories. Each category results in different approaches, strategies, and action plans towards suppliers in that category. For example, the organisation can seek to obtain major cost savings from suppliers in the leverage category, while the organisation should look into having close relationships with strategic suppliers. Outputs from the 2x2 matrix are valuable information for the organisation to develop relationship implication guidelines for implementing strategies and actions towards different suppliers. Involvement should be at the right level. Resources should appropriately be allocated. These are to ensure the success of implementation whilst also utilising organisational resources. Next process is to develop strategic guidelines for different business opportunities, requirements, and terms and conditions of the transactions (i.e. product and service agreement or PSA) with suppliers, which could lead to the next process of developing performance metrics once required specifications and deliverables of suppliers are known. Continuous improvement process to explore new enhancement possibility can also be executed. As a result, new projects with suppliers can be executed.

Having an understanding of the importance and complexity of different suppliers could assist the businesses in having appropriate approaches towards suppliers. Cost reduction can be expected through negotiation, economy-of-scale purchasing and transporting, fixed purchasing cost against seasonal and panic buying. Resources can be utilised by mitigating unnecessary workloads and burdens. Also, availability and continuity of supply can be ensured through supply network diversification, strategic partnership development, safety and spare stocks, and item substitution. Upstream supply chain can be more resilient (Datta, 2017; Ketchen *et al*., 2014; Pereira *et al*., 2014).

Humanitarian supply chain and SRM

Humanitarian organisations need to operate their supply chains under uncertain environments. Humanitarian supply chains encompass operational activities in the domains of emergency relief operations and development aid programmes (Haavisto and Kovacs, 2014; Van Wassenhove, 2006). Operating

humanitarian supply chains to support long-term development aid programmes is similar to the commercial supply chains, where large amounts of relief commodities from different suppliers need to be searched, sourced, procured, purchased, and managed annually (Bhusiri *et al*., 2021). A lack (or incompleteness) of important SRM strategic processes in humanitarian supply chain context result in humanitarian supply chain delays and disruptions. For instance, it has been reported by HELP Logistics *et al*. (2020) that some humanitarian organisations faced challenges of up to 30 days of delays when procuring relief commodities from international suppliers amidst the pandemic.

Few research works have adapted the individual processes of the SRM into humanitarian supply chain context. These include the works of Lamenza *et al*. (2019) and Bhusiri *et al*. (2021) with an aim of introducing the categorisation matrixes to humanitarian organisations. Different matrix dimensions have been redefined to achieve the goals and purposes of the focused humanitarian supply chains. A set of validated criteria has also been provided. The difference between these two studies is that the former focused on emergency relief supply chain, while the latter worked on humanitarian supply chain to support development aid agency. Later Banomyong *et al*. (2022) developed relationship implication guidelines as a consequence of the work of Bhusiri *et al*. (2021).

From a practical perspective, there are few humanitarian organisations implementing SRM such as International Federation of Red Cross and Red Crescent Societies (IFRC) and World Food Programme (WFP) (Rucha and Abdallah, 2017). However, they could not fully achieve the outcomes expected from SRM. As mentioned, there is a lack of important SRM strategic processes in the humanitarian supply chain context. Also, there is no existence of the integrative framework for the SRM in humanitarian supply chain context.

Methodology

The additional SRM strategic process of development of guidelines for business opportunities and performance metrics has been adapted from the work of Lambert and Schwieterman (2012) and Keith *et al*. (2016). The adaptation has been conducted to meet goals and objectives in the context of humanitarian supply chain in general and development aid programme in particular. Then, this additional process has been combined with the SRM strategic processes that have already been adapted in the work done by Bhusiri *et al*. (2021) and Banomyong *et al*. (2022). This step formed the SRM framework for humanitarian organisations. The framework has then been validated with (and modified by) humanitarian experts through online meetings. These humanitarian experts have extensive experiences in international humanitarian organisations at regional as well as national offices. Their mandates have covered development and relief practices. The humanitarian experts have also been equipped with goals, purposes, and contents of the study. Feedback from the validation resulted in the revised framework, which is described in the next section.

Results and Discussions

Adapting the SRM framework into humanitarian supply chain context

Figure 1 depicts the proposed SRM framework, where five main strategic processes are included. The main differences between commercial supply chain and humanitarian supply chain are the stakeholders and processes involved. Therefore, the set of supply chain macro processes and functions have been redefined including humanitarian preparedness, operation and distribution management (i.e. assessment, sourcing, transport, warehousing, distribution, last-mile), demand fulfilment, demand management, aid programme management, and donor and partnership management (Raillani *et al*., 2020). The implementation of the SRM strategic processes presented in figure 1 needs to involve and interface with other macro processes.

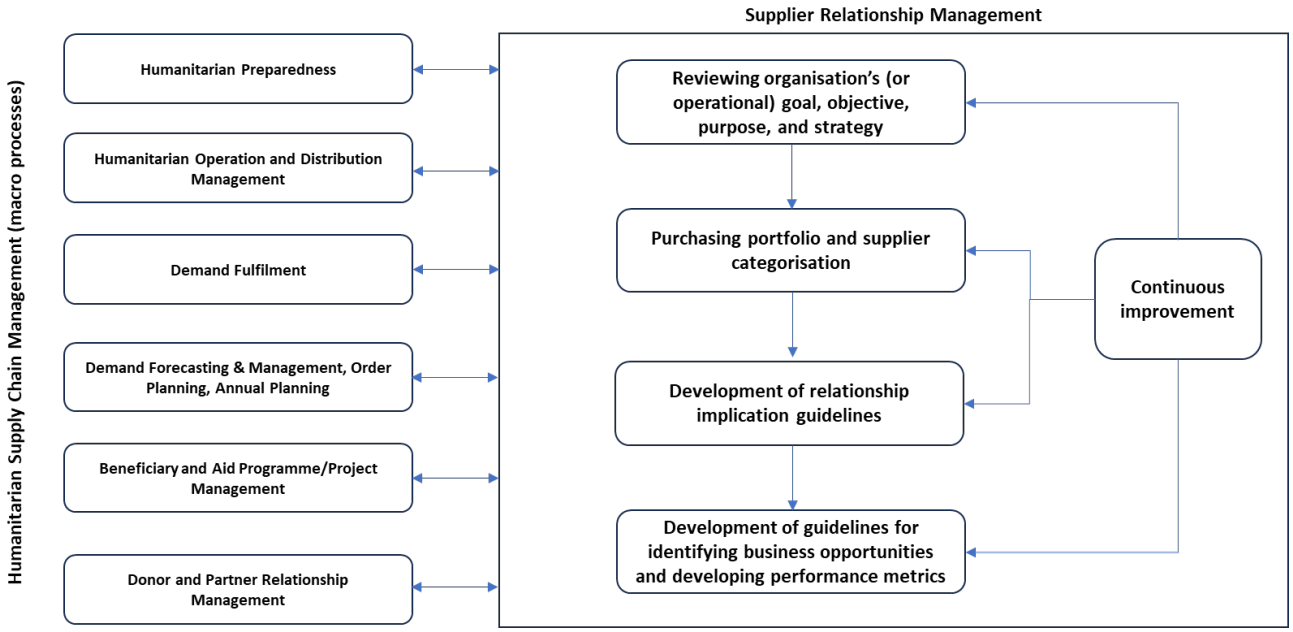

Figure 1: The proposed SRM framework
Source: adapted from Lambert and Schwieterman (2012) and Raillani *et al*. (2020)

Comprehensively reviewing, identifying goals and strategies of the aid agency and its operations need to be first conducted. This will lead to properly define matrix dimensions and criteria for purchasing and supplier segmentation. Sourcing strategic and engagement approaches can consequently be devised, followed by a development of implementation guidelines according to each obtained category of the segmentation. Based on observation, there is a severe lack of knowledge and understanding of how to implement the engagement approaches with suppliers. Therefore, relationship implication guidelines are crucial in humanitarian supply chain context. Each category can result in different business transaction opportunities (or business models) with suppliers in that category. The guidelines for business opportunities and performance metrices, which are interconnected, are required to drive improvement. In addition, continuous improvement can be employed to enhance the SRM strategic processes.

Review of humanitarian supply chain for development aid programme: goals and objectives

Different development aid programmes governed by different agencies in different countries have similar goals and purposes to mitigate the suffering and improve the quality of lives of vulnerable people. These could be captured from our questionnaires fulfilled by humanitarian practitioners. The role of supply chain to support the development aid programmes is to source, procure, and purchase commodities for generic purposes (e.g. office and administration activities) and specific purposes (e.g. construction projects and sanitation projects). Common purchased commodities include construction materials, agricultural seeds, school kits, stationeries, and so on. An absence or insufficiency of critical commodities may cause project delay, project disruption or organisation's ineffectiveness (Bhusiri *et al*., 2021). The natures of suppliers and markets that development aid agencies procure from are either monopoly or oligopoly. These further create challenges to the aid agencies to secure commodities at reasonable prices. Categorising and managing relationships with suppliers are based on total volumes purchased or spending. Suppliers with high spending annually can easily be defined as strategic suppliers to the aid agencies, and negotiation takes place as a sourcing strategy. Item or service costs offered by suppliers are ones of simple performance metrics.

Purchasing portfolio and supplier categorisation

Two matrix dimensions are defined for the supply chain supporting development aid programme. One dimension is defined as the strategic importance of purchase, which refers to the influence of the purchased commodities and suppliers on the overall performances of the aid agency. These strategic importance criteria can go beyond volume purchased, cost, and finance, which additionally include effectiveness, responsiveness, and reliability of the purchased commodities and suppliers. Another dimension is risks and vulnerabilities of the supply that potentially result in sourcing difficulties and supply disruptions. Three main types (or criteria) of supply risks are comprised including market risk, commodity risk, and logistics risk. More details can be found in Bhusiri *et al*. (2021). As a consequence of the matrix development, four categories of purchasing portfolio and supplier can be formed as shown in figure 2. Each category is associated with its characteristics, objectives, and strategic actions to enhance upstream supply chain resilience.

Relationship implication guidelines

Once sourcing strategies and approaches are defined for each purchasing portfolio segment, the implementation action plans should be defined. The guidelines for relationship implementation in humanitarian supply chain context consist of four main aspects. The first aspect is resource aspect, where the guidelines should indicate responsible (or accountable/dedicated) person for building and fostering relationships. A responsible person can be for each (strategic) supplier in the segment or for the entire segment in other categories. Level of business engagement and business meeting with the suppliers should be defined. Next is strategic planning aspect. Types of organisation plan and business transaction should be defined for each (strategic) supplier or each segment. Also, the organisation should define what type (and how deep) of information can be shared to the suppliers. Since the customer in humanitarian supply chain context is either beneficiary or donor (Rucha and Abdallah, 2017), the third aspect is revised to beneficiary/donor aspect. This is the aspect to collaborate with suppliers to align with requirements, specifications, and expectations from beneficiaries and donors and to reduce supply risks. The last aspect is measurement aspect. This is to develop standard supplier metrics that can be used to assess the supplier's performance. Figure 3 shows a summary of relationship implication guidelines for humanitarian organisations. More details can be found in Banomyong *et al*. (2022).

Guidelines for business opportunities & requirements and performance metrics

Different types of business opportunities and performance metrics with suppliers in different categories can briefly be explained in this sub-session. In non-critical category, business opportunities with suppliers can be traditional transactions (or arm's length transactions), where simple exchanges of commodities for monetary gained are conducted (Keith *et al*., 2016). In the traditional transactions, developing relationships between the humanitarian organisation and suppliers are not required. No contract or the PSA is also required if no benefit is gained, or no risk is involved. Suppliers are just requested to deliver the agreed amount of works such as one bag of construction cement, one hour of training programme delivered, and one month lease. Payments in the form of cash, cheque, bank transfer, and so on can be made once the transactions are completed (or in later time) (Keith *et al*., 2016). Basic information of commodity specification, amounts requested, and preferred delivery options can be shared to the suppliers. Simple delivery performances (e.g. delivery in-full and on-time (DIFOT) and commodity return rate) can be employed to measure the supplier performances.

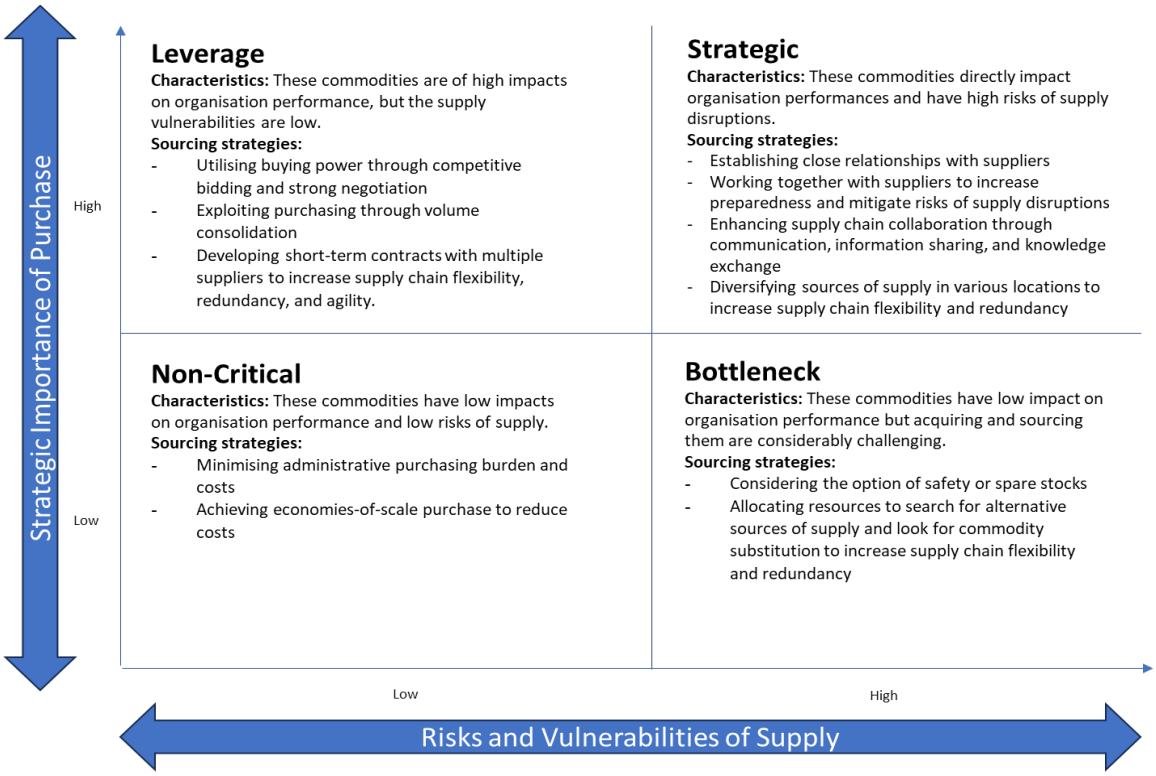

Figure 2: The purchasing portfolio segmentation for development aid agency
Source: adapted from Bhusiri *et al*. (2021)

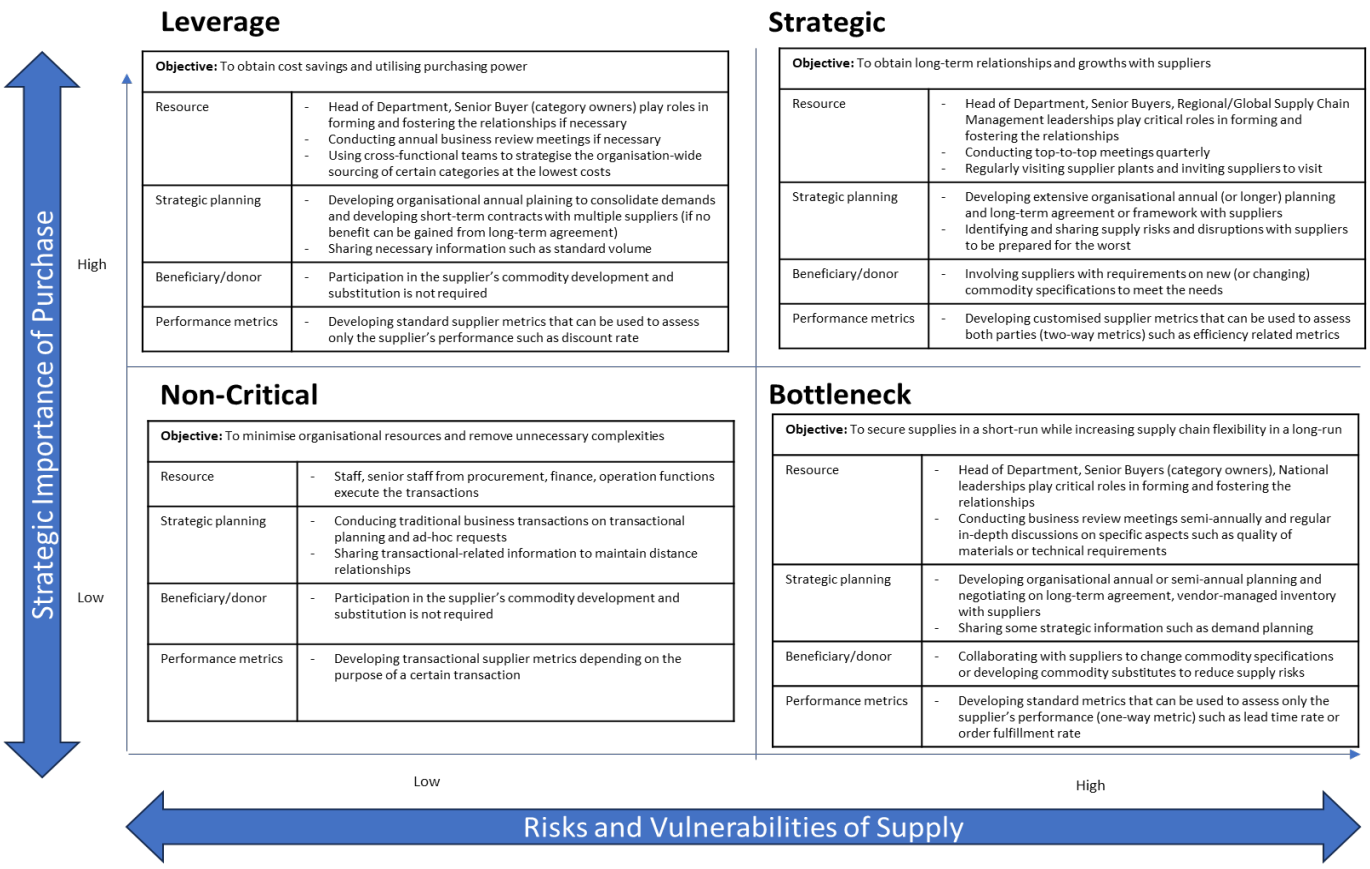

Figure 3: Relationship implication guidelines for humanitarian organisations
Source: adapted from Banomyong *et al*. (2022)

In the leverage category, the organisation can consider having short-term contracts with multiple (approved) suppliers. More business and transaction information such as annual volume (or a part of it), preferred prices and payment terms, preferred qualities, supplier code of conduct, compliance, and other requirements can be shared to the supplier (Keith *et al*., 2016). The PSA according to above-mentioned information can be developed for suppliers to follow. Long-term contracts with suppliers can be options if cost reduction or risk reduction can be achieved. In this case, developing relationships with suppliers with minimum resource allocation is required. Similarly, the transaction model is still the traditional one. Since level of relationship is formed, additional performance metrics can also be defined such as discount rate and satisfaction level. A supplier scorecard can be developed (de Sousa *et al*., 2020).

In the bottleneck category, for some types of commodities that are very complicated to be sourced, a performance-based (or output-based) business model suggested by Keith *et al*. (2016) can be applied. This is the model that supplier performances are measured by outputs or targets. In our case, the humanitarian organisations target to achieve the supply consistency (without large investment as these are low important commodities). The organisations can set the level of performances (or targets such as 98% order fulfilment rate) in the long-term agreement or the PSA for suppliers to work out. Also, the organisations and suppliers can agree to work on the collaborative projects such as vendor-managed inventory (VMI). Strong relationships might be required as the suppliers need to allocate budgets for investment. Strategic information to influence the target achievement such as demand & procurement planning, detailed process and activities, beneficiary & donor requirements, commodity specifications, and common operational risks needs to be shared with suppliers. Supplier performance metrics include order fulfilment rate, lead time rate, safety stock level over time spanning, and occurrence of stockouts. Payment method can be similar

to the traditional transactions with additional penalties applied when the targets are not met. Also, payment can be made with proportional to the success rate.

In strategic category, the business models can be either the output-based model to ensure supply consistency or the outcome-based model to fulfil missions, objectives, and goals of projects/programmes/operations/organisations. These models seek strong collaboration between humanitarian organisations and suppliers. Detailed operations, projects, programmes, and organisations must be shared with suppliers along with demand projections, beneficiary & donor requirements, and supply risk identifications. Large (and long-term) investments on strengthening relationships, information sharing, and perhaps humanitarian supply chain preparedness from both parties are required. Strong collaboration can lead to innovative solutions from suppliers (Keith *et al*., 2016) such as optimising and designing their processes and plans for cost-efficiency, effectiveness, and responsiveness, extending their supply network to mitigate supply risks, and commodity substitution to increase quality. Both parties need to develop (and agree) the customised performance metrics that can be used to assess supplier performances such as maintaining (or having better) order fulfilment rate at a lower cost, improving responsiveness, and reducing lead times and the metrics that can assess both parties such as return on investment (ROI). Payment method can be similar to the traditional transactions with additional incentives applied when the targets or outcomes are met. Or payment can be made with proportional to the success rate.

Conclusions

Humanitarian supply chain operations have been operated with low upstream resiliency. These have led to interrupted humanitarian supply chains and ultimately more suffering and decease of beneficiaries. These have been due to a lack of the comprehensive SRM framework with a set of paramount strategic processes. This paper adapted the SRM strategic processes from the well-known SRM approaches in the commercial supply chain perspective and formed the SRM framework for humanitarian organisations to use as guidelines to streamline and implement humanitarian sourcing strategies, action plans, processes, and metrics for better relationship management with suppliers and more resilient upstream supply chain.

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References

Amoako-Gyampah, K., Boakye, K.G., Adaku, E. and Famiyeh, S. (2019), "Supplier relationship management and firm performance in developing economies: a moderated mediation analysis of flexibility capability and ownership structure", *International Journal of Production Economics*, Vol. 208, pp. 160-170.

Banomyong, R., Julagasigorn, P., Varadejsatitwong, V., Rowel, W.S.L., Dhami, N. and Hulu J.A. (2022), "Relationship implication guidelines for developing supplier relationship management", *proceedings of the 12th International Conference on Logistics & Transport 2022*, Krabi, Thailand, pp. 40-43.

Bhusiri, N., Banomyong, R., Julagasigorn, P., Varadejsatitwong, V. and Dhami, N. (2021), "A purchasing portfolio model for humanitarian supply chain resilience: perspectives from a development aid context", *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 11 No. 4, pp. 639-660.

Campbell, M. (n.d.), "Resilience: A journal of strategy and risk", available at https://www.pwc.com/gx/en/governance-risk-compliance-consulting-services/resilience/publications/assets/supplier-scorecard.pdf (accessed on 4 August 2023).

Datta, P. (2017), "Supply network resilience: a systematic literature review and future research", *The International Journal of Logistics Management*, Vol. 28 No. 4, pp. 1387-1424.

De Sousa, T.B., Melo, I.C., de Oliveira, P.H., Lourenco, C.M., Guerrini, F.M. and Esposto, K.F. (2020), "Balanced scorecard for evaluating the performance of supply chains: a bibliometric study", *Journal of Engineering Research*, Vol. 8 No. 1, pp. 294-313.

Haavisto, I. and Kovács, G. (2014), “Perspectives on sustainability in humanitarian supply chains”, *Disaster Prevention and Management*, Vol. 23 No. 5, pp. 610-631.
HELP Logistics, Global Logistics Cluster, Kuehne Logistics University, and Center for Humanitarian Logistics and Regional Development (2020), “Coronavirus pandemic”, available at: https://www.help-logistics.org/fileadmin/user_upload/Dateien_HELP/documents/report/COVID-19_Supply_Chain_Impact_2_GLC_2020-04-28_v4.pdf (accessed on 4 August 2023).
Keith, B., Vitasek, K., Manrodt, K. and Kling, J. (2016), *Strategic Sourcing in the New Economy*, Palgrave Macmillan, New York, NY.
Ketchen Jr, D.J., Crook, T.R. and Craighead, C.W. (2014), “From supply chains to supply ecosystems: implications for strategic sourcing research and practice”, *Journal of Business Logistics*, Vol. 35, No. 3, pp. 165-171.
Kraljic, P. (1983), “Purchasing must become supply management”, *Harvard Business Review*, Vol. 61 No. 5, pp. 109-117.
Lambert, D.M. and Schwieterman, M. A. (2012), “Supplier relationship management as a macro business process”, *Supply Chain Management: An International Journal*, Vol. 17 No. 3, pp. 337-352.
Lamenza, A.A.d.S., Fontainha, T.C and Leiras A. (2019), “Purchasing strategies for relief items in humanitarian operations”, *Journal of Humanitarian Logistics and Supply Chain Management*, Vol. 9 No. 2, pp. 151-171.
Park, J., Shin, K., Chang, T.W. and Park, J. (2010), “An integrative framework for supplier relationship management”, *Industrial Management & Data Systems*, Vol. 110 No. 4, pp. 495-515.
Pereira, C.R., Christopher, M. and Da Silva, A.L. (2014), “Achieving supply chain resilience: the role of procurement”, *Supply Chain Management: An International Journal*, Vol. 19 No. 5/6, pp. 626-642.
Raillani, H., Hammadi, L., Samed, M.M.A., Ballouti, A.E. and Barbu, V.S. (2020), “Humanitarian logistics in the disaster relief supply chain: state of the art”, *WIT Transactions on Engineering Sciences*, Vol. 129, pp. 181-193.
Rucha, K.M. and Abdallah, A.N. (2017), “Effect of supplier relationship management on humanitatian supply chain performance at the World Food Programme in Somalia”, European Scientific Journal, Vol. 13 No. 6, pp. 250-272.
Simchi-Levi, D., Kaminsky, P. and Simchi-Levu, E. (2003), *Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies (2nd Edition)*, McGraw-Hill, Boston, MA.
Van Wassenhove, L.N. (2006), “Humanitarian aid logistics: supply chain management in high gear”, *Journal of the Operational Research Society*, Vol. 57 No. 5, pp. 475-489.

SMART CITY LOGISTICS FOR SUSTAINABILITY: A CASE STUDY OF SUSTAINABLE CITY LOGISTICS IN HELSINKI

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ABSTRACT

Purpose: There is an increased need for more sustainable city logistics solutions. Challenges like global warming has made city actors increasingly aware of their role in finding sustainable city logistics solutions. The goal of this study is to explore the development of sustainable city logistics solutions from a city-internal perspective, utilizing technological frames as a lens.
Approach: A single case study methodology, investigating various actors in the city of Helsinki, was taken. Interviews and secondary data were used, and respondents included city department officials responsible for traffic, environment, and business development as well as regional development companies and programs running last mile and urban development pilots.
Findings: Based on the reports and interviews, we observed that in general, Helsinki city has a clear innovation and technology emphasis pertaining to sustainable city logistics. However, at the same time a fragmentation of efforts and a lack of cohesion is present observed in the discrepancy between the importance of the overall goal of carbon neutrality and anchoring sustainable city logistics solutions to it through actions. The heightened emphasis on innovation to reach city logistics sustainability may result in a more passive role for the city.
Practical implications: This research offers novel insights for policy guidelines for cities and company managers engaged with city logistics. The study can help in guiding development of sustainable city logistics solutions.
Originality/value: The research contributes to a better understanding of the role and influence of the internal city actors on sustainable city logistics development. The technological frame perspective provides a better understanding of how internal city actors, and their activities are aligned and how potential incongruence in goals is manifested.

Keywords: City logistics, sustainability, innovation, actors, technological frames

Introduction

City logistics research delves into a multifaceted realm, where the complex interplay between resident well-being, logistics and transport systems, and the intricate web of administrative decision-making and policy frameworks governing urban sustainability and livability has gained significance (Cardenas et al., 2017). Reducing and managing city traffic and freight in cities is of heightened importance due to climate change (Paddeu et al., 2018). As an example, one fifth of carbon emissions in Helsinki come from traffic, and the City of Helsinki has an ambitious target of being climate neutral by 2030 (City of Helsinki, 2021). Yet, the complexity of the city logistics system makes sustainability development challenging for cities and other local authorities, and comprehensive approaches are needed to address sustainability concerns (Bjørgen et al., 2021). Cities need to cater and balance both resident, business, and other stakeholder needs. This balance becomes more complicated when new technologies like drones, curb side robots, and various electric vehicles become more common on city streets.

In the complex city logistics context, it is crucial to understand how the dual effort of both sustainability and innovation is executed to foster sustainable city logistics solutions. This study explores the sustainable city logistics actions and goals of city actors utilizing a lens of technological frames. Technological frames describe the underlying assumptions, expectations and knowledge people have about technology (Orlikowski & Gash, 1994), and they are dynamic and context dependent (Lin & Silva, 2005). Understanding the frames is important since differences in the frames held by cooperating actors have been found to

significantly affect the progress and outcomes in many contexts. We argue that the lens of technological frames is particularly relevant in this context because city logistics activities involve a complex network of actors with varying objectives. The technological and innovative actions that these objectives are centered around is under development, meaning it is a both flexible, adaptable and malleable stage. sustainability development in city logistics is likely characterized by multiple interpretations, which may conflict with each other. The purpose of this study is to examine how the goal (in)congruence of various city actors influences the efforts to develop innovative and sustainable city logistics. The study answers the following research questions:

- How is sustainability framed in the city logistics goals of various actors?
- How are goals and (in)congruence of these goals manifested in actions towards sustainable city logistics?

We investigate a single case. We investigate the City of Helsinki and its internal actors. The joint goal of the city actors is illustrated by the sustainability strategy of the city of Helsinki (City of Helsinki, 2018) and specifically the target of carbon neutrality by 2030 (City of Helsinki, 2021).

Literature Review

The city logistics landscape is becoming increasingly complex (Boysen et al., 2021). Complexity is added by the many heterogenous stakeholders involved (Mangano & Zenezini, 2019), including residents, shippers, receivers, logistics service providers (LSPs), and local authorities (Kiba-Janiak, 2016). All these actors have varying expectations and goals (Lindholm & Browne, 2013), that can be hard to find unified views on (Gammelgaard, 2015). The biggest group of city logistics research focuses on commercial and customer perspectives (Kiba-Janiak et al., 2021), so there is need for a variety of perspectives. Previous research has provided understanding of stakeholders in city logistics including, for example on city logistics project implementation involving stakeholders from an organizational change perspective (Gammelgaard, 2015), actor roles and public–private interactions in networks (Lindkvist et al., 2022), and stakeholder reactions to urban freight policy innovation (Stathopoulos et al., 2012).

The role of cities and other local authorities in developing sustainable city logistics solutions is crucial, as they carry the role of improving the quality of life for the inhabitants (Kiba-Janiak, 2016; Kiba-Janiak et al., 2021). Still many local authorities struggle with designing incentives and regulation that would support sustainable city logistics (Fontaine et al., 2023), and there is a need to better include city logistics in urban planning and development (Kiba-Janiak et al., 2021). A more strategic approach as well as specific measures are needed in city logistics to support high-level goals such as emission reduction (Akgün et al., 2019). City logistics policy can take the form of regulatory measures such as vehicle size and weight restrictions, market-based solutions such as congestions charges, land use and planning measures such as parking spaces, or infrastructure developments including space for urban consolidation centres (Cardenas et al., 2017). Yet, many studies have focused on the city as one homogenous actor amongst other stakeholders. Within the context of sustainable city logistics innovation assumes a pivotal role, serving as a driving force for achieving sustainability in logistics (Roscoe et al., 2016). It is imperative for policymakers and regulators to promote both digitalization and innovation, thus nurturing the growth of sustainable solutions (Ardito, 2023). Government policies and investments can play a key role in initiating sustainable business models and often a local authority can be the customer of innovative services (Guo et al., 2022). In this context, it is crucial to understand how municipalities work with the combined effort of innovation and sustainability to reach sustainable city logistics. Before a city can function as an entity, its internal processes need to align. Alignment of goals, activities and other measures has been pinpointed as crucial for city logistics efforts (Akgün et al., 2019; Fontaine et al., 2023; Gammelgaard, 2015; Kiba-Janiak et al., 2021). Previous research, such as Akgün et al. (2019), has looked at factors influencing local authorities' policy making, focusing on aspects such as policy context and resource availability.

Using the perspectives of technological framing could increase the understanding of the underlaying interpretations that impact decision-making processes. For example, difficulty in the use or implementation of a technology can arise when different people in an organization have different technological frames i.e., differing cognitive structures to deal with technology (Orlikowski & Gash, 1994). Different actors also rely on their technological frames when coping with complexity and uncertainty (Spieth et al., 2021), and the nature of these frame differences is called congruence (Orlikowski & Gash, 1994). Technological frames have, for example, been used to; investigate how stakeholders' perceptions and beliefs are influenced by social and political processes (Lin & Silva, 2005), look at the relationship between techno-ethical orientation and ethical decision-making in supply chains (Verma et al., 2022), understand how managers use their individual technological frames for sensemaking during technology foresight activities (Klos & Spieth, 2021), and to understand generative mechanisms of the adoption of logistics innovation (Tanskanen et al., 2015). The context of technology use is important, as technological frames are dynamic and change over time, and adoption of new technologies is both a social and political process here all stakeholders frame and reframe their perceptions of technology (Lin & Silva, 2005)

Methodology

A case study approach, that investigates various at the actors inside the City of Helsinki (Finland) was taken, to give deep insight in the phenomenon studied (Yin, 2018). The unit of analysis is the organizational units within the City of Helsinki and their respective goals and actions towards furthering innovative and sustainable city logistics. The City of Helsinki provides a good case as the city has communicated specific city logistics and sustainability targets, has good data availability in policy documents and other reports, access to experts, as well as the complex environment of a capital city with more than 600 000 inhabitants. Interviews and secondary data, such as policy documents and reports, are used. Respondents include city department officials responsible for traffic, environment, and business development as well as regional development companies and programs running last mile and urban development pilots. Respondents were purposefully sampled (Patton, 2002) aided by a snowballing technique (Noy, 2008). Due to the intricacy of city organization, the researchers approached selected city departments, but discussed with them to select appropriate respondents with knowledge on the topic at hand. Respondents also suggested new respondents within their or other organizations. Respondents are presented in table 1. When the interviews were completed, manual pre-coding was used to get an overview of the data, and later structural coding was applied (Saldaña, 2009).

Code	Actor	Respondent	Roles and Organization
Core01	Mobility Lab (part of testbed Helsinki): an administratively a cooperation between Business Helsinki and Forum Virium, also strongly supported by the Urban Environment Division	CR1	Project Manager at Business Helsinki, Testbed Helsinki
		CR2	Project Manager at Forum Virium Smart Mobility Division
Core02	Urban Environment Division	CR3	Traffic Engineer
Core03	Forum Virium, Helsinki City Development Company	CR4	Project Manager at City Logistics Project division t Forum Virium
Core04	Business Helsinki	CR5	Leading Specialist, Business Helsinki Innovation Services
		CR6	Business Helsinki, Ecosystem Services
Supp01	Helsinki City Climate Unit	SR1	Project Director, Climate unit

Supp02	Urban Tech Incubator for clean and sustainable urban technology	SR2	Program Manager

Table 1: Actors and Respondents

To triangulate interview findings, secondary data was analyzed and compared to increase validity (Voss et al., 2002). The researchers selected the City of Helsinki reports and other secondary data in accordance with relevance for the research topic and with the aid of the respondents who suggested further readings. In total 23 reports and secondary data documents were reviewed to complement the primary data.

Result: Smart and Green City Logistics

Our data indicates that respondents have an affinity to look at new technology as something positive and as a driver for city logistics development. However, there is a discrepancy between the goals related to innovation and sustainability and the balance between sustainability and innovation that indicates incongruence in how goals are manifested. For example, last mile was specifically mentioned as a challenge in the Action Plan for City Logistics, but aside from this report, the last mile and most commercial logistics was missing from planning and reporting, and no specific actions were mentioned. On the other hand, the action plan for city logistics did have few and vague sustainability measures. This creates a gap between actions planned for city logistics and the reported action plans for carbon neutrality. The actors within the city of Helsinki would need to interact and collaborate to meet the overall carbon neutrality goal, but also to support sustainability development of city logistics.

We were able to identify a core group of actors (see table 1) including the Mobility Lab, the Urban Environment Division, Forum Virium (Helsinki City Development Company) and Business Helsinki as well as the supporting actors Helsinki City Climate Unit and the Urban Tech Incubator. These actors were identified in discussions with the City of Helsinki as core players in taking actions towards innovative and sustainable city logistics. The sustainability aspects of city logistics span several departments and organizations across the city of Helsinki. None of the individuals interviewed had full knowledge of the topic, i.e., the full spectrum of city logistics, innovation, and sustainability, but the combination of respondents provided a full picture. We observed that actions were spread out through actors and reports. All respondents whished for more sustainable city logistics development, but sustainable city logistics development did not really reside on anyone's desk, creating fragmentation and a focus on only some parts of the city logistics system though limited measures. To understand how the sustainable city logistics goal is manifested in practice, we looked at sustainable city logistics actions taken by the actors (table 2). Based on the reports and interviews, we observed that in general, the City of Helsinki has a clear innovation and technology emphasis pertaining to sustainable city logistics. However, at the same time we observed a fragmentation of efforts and a lack of cohesion, as presented next.

The efforts towards sustainable city logistics in Helsinki have been primarily led by the Mobility Lab ('Core01'). This actor leads a collaborative initiative with Core02, Core03, and Core04 operationalizing testing and piloting activities. Their primary focus is testing and developing smart and digital mobility solutions that enhance sustainability. This effort involves private sector actors, and the city is a "testbed" for their solutions. The importance of utilizing big projects that don't limit the activities of private sector actors, but leave space for their innovation, was highlighted. It was seen as a tool to achieve the overreaching goal of climate neutrality by 2030 (respondent SR1). Respondent SR1 emphasized that cities can be forerunners and have a lot of impact on emissions and climate neutrality. However, other respondents (e.g., CR1, CR2, CR5) hold different views. They highlighted a market-driven approach to sustainability, where companies align with the broader "sustainability trend" due to their own volition. This perspective reduces the city's role as a driver of sustainable solutions. One respondent (CR3) mentioned parking policies and other policy instruments outlined in literature (Cardenas et al., 2017), but at the same time they did not see the city having a big influence on sustainability.

"Aside from the city's own transportation I don't think the city has much influence over what or how anyone transports anything […] of course the city can put in environmental zones or similar restrictions and maybe help with the location of distribution hubs." (CR3)

The respondents emphasized that the private sector, such as actions by logistics service providers, enable e.g., sustainable innovation in when executed in city-initiated projects. The purpose of leaving innovation to the companies was to not interfere with their interests but let them come up with the most suitable innovative solutions themselves (mentioned by SR1, CR3, CR1). The influence of the political city actors on supporting the goals was also evident in the data, for example in statements like "we could not do this [sustainability work] without political support" (SR1). The need for political support was also mentioned by CR6 who discussed the interplay with the democratically elected city council and its sub-committees, mentioning the Economic Development Sub-committee that approves the reports and activities of the Helsinki innovation fund that is providing resources for, for example, the activities of Core01 (mobility lab) and Supp02 (incubation program focusing on innovative and sustainable urban technologies).

However, all respondents agreed that actions need to be focused on a clear goal, be that more sustainability or innovation, but letting private sector players choose the specific actions. For example, if the goal was low-carbon transport, then companies should choose if cargo bikes, electric vans or other vehicles best suit this goal. In this context, SR3 mentioned that the risk in these scenarios is that the city doesn't get the solutions needed or the most suitable innovations, as the city goals might not align with commercial interests. Another challenge associated with the actions was the project nature of funding and the "personification of projects" (CR4) that hinders long-term development after pilots are concluded. Also, SR1 mentioned they were "allergic to pilots" specifically because these types of activities are hard to scale up. This creates a challenge as, from a sustainability viewpoint the built environment, construction and circular economy all came prioritized before logistics and transport, leaving sustainable city logistics development dependent on actions like small-scale pilots. CR6 also said "on the innovation side we must make priorities. You can't do it all even if there is demand", implying logistics is not a specific innovation priority.

City Goal	Selected Actor Goals	Example measures and activities	Actor(s)
Carbon Neutrality 2030	Smart, sustainable, and innovative urban technology solutions for city logistics	• Testing and developing smart and digital mobility solutions that promote sustainability. • Mandate to execute and operationalize pilots. • Bringing solutions to real urban environments to be tested and getting input from residents. • Incubate promising urban tech startups. • Innovation funding (EU and other) • Wide variety of company services • Promoting cooperation and ecosystem building	Mobility Lab (Core01), Forum Virium (Core03), Business Helsinki (Core04), Urban tech Incubator (Supp02)
	Develop sustainable traffic and transport solutions	• Promote electrification (vehicles) • Implementing new service concepts (e.g., in mobility) • Land use and city planning • Procurement guidelines • Policy and regulation (e.g., parking, low-emission zones) • Reducing emissions from heavy traffic with equipment choices and environmental criteria	Urban Environment Division (Core02), Climate Unit (Supp01), Business Helsinki (Core04)
	Attract innovative and	• Execution of large-scale projects • Helsinki Innovation funding	Forum Virium (Core03),

	sustainable ("smart and clean") companies to Helsinki	• Distributing EU funds and city innovation funds • Focus on goal and give space for e.g., companies to innovate or execute towards goals, not limiting their specific activities.	Business Helsinki (Core04), Climate Unit (Supp01)

Table 2: Actor goals aligning with sustainable city logistics and the city strategic carbon neutrality goal

We observed that in developing city logistics the focus is more on innovation and technology, than it is on sustainability. In this sense city logistics activities are not fully aligned with the overreaching sustainability goals in the City of Helsinki strategy. For example, in terms of resources, the Core01 actor (the Mobility Lab) is fully funded by the Helsinki innovation fund and projects are primarily technology oriented. However, implicitly, many piloted solutions have sustainability elements like the Shared Micro depots for Urban pickups and Delivery, that focused on enabling deliveries with cargo bikes, that in turn represent low-emission vehicles. Looking at reports and documentation beyond the Carbon neutrality 2030 actions, the city strategy and UN SDG documentation (City of Helsinki, 2023) has a much wider view on sustainability including social aspects and other environmental aspects like biodiversity, but also here innovation is mentioned as a "key way" (City of Helsinki, 2023, p. 18) of supporting sustainable development. (Fontaine et al., 2023) has noted that sustainability and profit goals might be conflicting, but in Helsinki, it seems the city is trying to solve this challenge by being innovation and market-solutions oriented in its sustainability work, exemplified by the selected actor goals and activities in table 2.

Discussion and Conclusions

This study contributes to city logistics and sustainability research by utilizing technological frames to gain a deeper understanding of how innovation plays into the development of sustainable development and how the roles and actions of cities interplay with innovation in a city logistics context. Our study investigated how the technological framing (in)congruence impacts the efforts towards sustainability development in city logistics. Previous research has established the significant role that cities play in the development of sustainable city logistics. However, this case study highlights a potential shift in the city's role as an enabler of innovation and technology efforts. As Gammelgaard (2015) has previously noted it can be hard to find unified views on common goals in city logistics. In Helsinki the view on the joint goal (caron neutrality) seems clear, but the execution of the actions is fragmented into small projects. Importantly, the heightened emphasis on innovation to reach city logistics sustainability may result in a more passive role for the city itself. Rather than actively driving the development of sustainable solutions, the city is increasingly viewed as a platform for private sector entities to develop and implement their own innovative approaches. This is likely to affect the goals and alignment of the internal city actors that create this platform, as there is a discrepancy between the importance of the overall goal of carbon neutrality and anchoring sustainable city logistics solutions to it through actions. In the goals presented in table 2, it is clearly visible that technology and innovation is highly integrated in sustainability goal setting. Sustainability development is tied to a belief and framing that sustainability is achieved through technological development. Emerging from the data came the framing of technology resembling Ecological Modernization Theory (EMT) (Spaargaren & Mol, 1992). Respondents and secondary data alike seemed to believe in the notion that the private sector must transform and become ecologically modernized to support sustainable development (Huber, 2000). Here the City of Helsinki strategy coincides with EMT in that continued technological innovation is a solution to environmental sustainability issues (Fisher & Freudenburg, 2001) as environmental problems can be best addressed by further advancements in technology (Spaargaren & Mol, 1992).

Looking at only one city provided a possibility to delve into these intricacies, even if the focus is also a limitation of the study, as is the Nordic context. A factor limiting this research is the lack of data on the private sector and political actors. This shortcoming needs to be addressed by further research. Future work could also look closer into interdependencies as well as risks involved with goalsetting in sustainable city logistics development. The prominent role of innovation also provides ample ground for further inquiries,

such as using Ecological modernization theory (EMT), where the institutional reform needed to substantially reduce damage to the environment is the base (Spaargaren & Mol, 1992).

References

Akgün, E. Z., Monios, J., Rye, T., & Fonzone, A. (2019). Influences on urban freight transport policy choice by local authorities. Transport Policy, 75, 88–98. https://doi.org/10.1016/j.tranpol.2019.01.009

Ardito, L. (2023). The influence of firm digitalization on sustainable innovation performance and the moderating role of corporate sustainability practices: An empirical investigation. Business Strategy and the Environment, 1–21. https://doi.org/10.1002/bse.3415

Bjørgen, A., Bjerkan, K. Y., & Hjelkrem, O. A. (2021). E-groceries: Sustainable last mile distribution in city planning. Research in Transportation Economics, 87, 1–9. https://doi.org/10.1016/j.retrec.2019.100805

Boysen, N., Fedtke, S., & Schwerdfeger, S. (2021). Last-mile delivery concepts: a survey from an operational research perspective. OR Spectrum, 43(1), 1–58. https://doi.org/10.1007/s00291-020-00607-8

Cardenas, I., Borbon, Y., Verlinden, T., Van de Voorde, E., Vanelslander, T., & Dewulf, W. (2017). City logistics, urban goods distribution and last mile delivery and collection. Competition and Regulation in Network Industries, 18(1–2), 22–43. https://doi.org/10.1177/1783591717736505

City of Helsinki. (2018). The Carbon-neutral Helsinki 2035 Action Plan.

City of Helsinki. (2021). Making Helsinki carbon-neutral. https://www.myhelsinki.fi/en/think-sustainably/making-helsinki-carbon-neutral

City of Helsinki. (2023). From Agenda to Action: Implementation of the UN Sustainable Development Goals in Helsinki 2023.

Fisher, D. R., & Freudenburg, W. R. (2001). Ecological Modernization and Its Critics: Assessing the Past and Looking Toward the Future. Society & Natural Resources, 14(8), 701–709. https://doi.org/10.1080/08941920119315

Fontaine, P., Minner, S., & Schiffer, M. (2023). Smart and sustainable city logistics: Design, consolidation, and regulation. European Journal of Operational Research, 307(3), 1071–1084. https://doi.org/10.1016/j.ejor.2022.09.022

Gammelgaard, B. (2015). The emergence of city logistics:The case of Copenhagen's Citylogistik-kbh. International Journal of Physical Distribution and Logistics Management, 45(4), 333–351. https://doi.org/10.1108/IJPDLM-12-2014-0291

Guo, L., Cao, Y., Qu, Y., & Tseng, M.-L. (2022). Developing sustainable business model innovation through stakeholder management and dynamic capability: A longitudinal case study. Journal of Cleaner Production, 133626. https://doi.org/10.1016/j.jclepro.2022.133626

Huber, J. (2000). Towards industrial ecology: sustainable development as a concept of ecological modernization. Journal of Environmental Policy & Planning, 2(4), 269–285. https://doi.org/10.1080/714038561

Kiba-Janiak, M. (2016). Key Success Factors for City Logistics from the Perspective of Various Groups of Stakeholders. Transportation Research Procedia, 12, 557–569. https://doi.org/10.1016/j.trpro.2016.02.011

Kiba-Janiak, M., Marcinkowski, J., Jagoda, A., & Skowrońska, A. (2021). Sustainable last mile delivery on e-commerce market in cities from the perspective of various stakeholders. Literature review. Sustainable Cities and Society, 71. https://doi.org/10.1016/j.scs.2021.102984

Klos, C., & Spieth, P. (2021). READY, STEADY, DIGITAL?! How foresight activities do (NOT) affect individual technological frames for managerial SENSEMAKING. Technological Forecasting and Social Change, 163. https://doi.org/10.1016/j.techfore.2020.120428

Lin, A., & Silva, L. (2005). The social and political construction of technological frames. European Journal of Information Systems, 14(1), 49–59. https://doi.org/10.1057/palgrave.ejis.3000521

Lindholm, M., & Browne, M. (2013). Local Authority Cooperation with Urban Freight Stakeholders: A Comparison of Partnership Approaches. EJTIR Issue, 13(1), 20–38. www.ejtir.tbm.tudelft.nl

Lindkvist, H., Lind, F., & Melander, L. (2022). Actor roles and public–private interaction in transitioning networks: the case of geofencing for urban freight transport in Sweden. Journal of Business & Industrial Marketing, 38(6), 1376–1389. https://doi.org/10.1108/JBIM-10-2021-0494

Mangano, G., & Zenezini, G. (2019). The Value Proposition of innovative Last-Mile delivery services from the perspective of local retailers. IFAC-PapersOnLine, 52(13), 2590–2595. https://doi.org/10.1016/j.ifacol.2019.11.597

Noy, C. (2008). Sampling knowledge: The hermeneutics of snowball sampling in qualitative research. International Journal of Social Research Methodology, 11(4), 327–344. https://doi.org/10.1080/13645570701401305

Orlikowski, W. J., & Gash, D. C. (1994). Technological Frames: Making Sense of Information Technology in Organizations. ACM Transactions on Information Systems, 12(2), 174–207.

Paddeu, D., Parkhurst, G., Fancello, G., Fadda, P., & Ricci, M. (2018). Multi-stakeholder collaboration in urban freight consolidation schemes: Drivers and barriers to implementation. Transport, 33(4), 913–929. https://doi.org/10.3846/transport.2018.6593

Patton, M. Q. (2002). Qualitative research & evaluation methods (3rd ed.). Sage.

Roscoe, S., Cousins, P. D., & Lamming, R. C. (2016). Developing eco-innovations: A three-stage typology of supply networks. Journal of Cleaner Production, 112, 1948–1959. https://doi.org/10.1016/j.jclepro.2015.06.125

Saldaña, J. (2009). The Coding Manual for Qualitative Researchers. SAGE Publications Ltd.

Spaargaren, G., & Mol, A. P. J. (1992). Sociology, environment, and modernity: Ecological modernization as a theory of social change. Society and Natural Resources, 5(4), 323–344. https://doi.org/10.1080/08941929209380797

Spieth, P., Röth, T., Clauss, T., & Klos, C. (2021). Technological Frames in the Digital Age: Theory, Measurement Instrument, and Future Research Areas. Journal of Management Studies, 58(7), 1962–1993. https://doi.org/10.1111/joms.12720

Stathopoulos, A., Valeri, E., & Marcucci, E. (2012). Stakeholder reactions to urban freight policy innovation. Journal of Transport Geography, 22, 34–45. https://doi.org/10.1016/j.jtrangeo.2011.11.017

Tanskanen, K., Holmström, J., & Öhman, M. (2015). Generative mechanisms of the adoption of logistics innovation: The case of on-site shops in construction supply chains. Journal of Business Logistics, 36(2), 139–159. https://doi.org/10.1111/jbl.12089

Verma, S., Garg, N., & Arumugam, T. (2022). Being ethically resilient during COVID-19: a cross-sectional study of Indian supply chain companies. International Journal of Logistics Management. https://doi.org/10.1108/IJLM-05-2022-0203

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. International Journal of Operations and Production Management, 22(2), 195–219. https://doi.org/10.1108/01443570210414329

Yin, R. K. (2018). Case Study Research and Application: Design and Methods (6th ed.). SAGE.

SUPPLY CHAIN ASSESSMENT AND ALIGNMENT FOR SPECIAL ECONOMIC DEVELOPMENT ZONE

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ABSTRACT

Purpose: The paper investigates the supply chain alignment for Northern Economic Corridor (NEC) as a rising special economic development zone in Thailand.
Design/methodology/approach: The paper assesses NEC using concepts of SEZ Competitiveness Model to analyze the demand and supply within the scope using Triple Helix model.
Findings: There are differences in targeting clusters in areas of interest. This is suggestive for devisingpromotion and support measures by government.
Originality/value: The finding will be used as input for developing NEC master plan.

Keywords: Special Economic Zone (SEZ), Northern Economic Corridor (NEC), BCG Economy

Introduction

Special Economic Zone (SEZ) has been used as a policy tool for stimulating economic development world-widely (Aggarwal, 2023; Walsh, 2022). Defined broadly, SEZs can be free-trade zones, industrial parks, economic development zone, science and technology park, etc. (Zeng, 2016).

Despite the variety of incentives, the objectives are to attract foreign investment within a specific geographic region ((Shah, 2008; Akinci and Crittle, 2008; Wang 2013). However, sustainable success is dependent on the political economy framework, rights of people, growth, sustainability, and supply-demand alignment (Moberg, 2015; Salangsing et al., 2019; Bartlett et al., 2019; Frick et al., 2019).

Special Economic Zone (SEZ) in Thailand

According to the official report from Thailand's Office of the National Economic and Social Development Council, Thailand's GDP was US$495.2 billion in 2022 with a real GDP growth of 2.6%. Thailand is the 9th largest economy in Asia. Bywhich the industrial and service sectors are the main sectors, accounting for 39.2% of GDP, Thailand is recognized as a newly industrialized country.

Before Thailand's latest 20-Year National Strategy and the 13th National Economic and Social Development Plan, SEZs in Thailand have been presented as industrial estate development. To date, there are 67 industrial estates in Thailand operated the by Industrial Estate Authority of Thailand and 42 jointly operated with developers (Krungsri Research, 2023). The incentives of the industrial estates are, for example, the right to receive non-tax privileges, the right to receive additional tax privileges, the right to receive exemptions of import duty, the right to receive exemptions of export duty, etc.

In 2015, Thailand launched a new SEZ theme as Border Economic Zones (BEZs), comprising 10 main border provinces of Thailand. The designated area was announced and incentives were offered such as additional corporate income tax exemption, reduction of corporate income tax, deduction of the costs of installation or construction of facilities, and permission to own land and employ foreign unskilled and skilled labor (Ramingwong et. Al., 2016).

In 2018, Thailand introduced the Eastern Special Development Zone Act, specifically promoting Eastern Economic Corridor (EEC), comprising 3 Eastern provinces, namely Rayong, Chonburi, and Chachoengsao, formerly known as the Eastern Seaboard in the 1980s. The EEC offers further incentives, e.g., the lowest personal income tax rate (17%) in Southeast Asia, a five-year work visa to investors, specialists, scientists, and matching grants for investment, R&D, innovation development, and human resources development.

EEC has been a concrete success investment-wise. In 2022, more than 45% of Thailand's FDI, accounting for US$8.5 billion, was within EEC (Board of Investment of Thailand, 2023).

Recently, in 2022, the National Committee for the Development of Special Economic Zones (see Figure 1) announced 4 new special economic corridors, namely NEC, NeEC, CWEC, and SEC (see Figure 2).

- Northern Economic Corridor (NEC), comprising Chiang Mai, Chiang Rai, Lamphun, and Lampang, targeting creative economy and digital businesses (Creative LANNA)
- Northeastern Economic Corridor (NeEC), comprising Khon Kaen, Udon Thani, Nakhon Ratchasima, and Nong Khai, targeting Bioindustries Food for the future
- Central–West Economic Corridor (CWEC), comprising Ayutthaya, Nakhon Phathom, Suphan Buri, and Kanchanaburi, targeting industries related to technology, innovation, and research
- Southern Economic Corridor (SEC), comprising Chumphon, Ranong, Surat Thani, and Nakhon Si Thammarat, targeting logistics and trade connectivity.

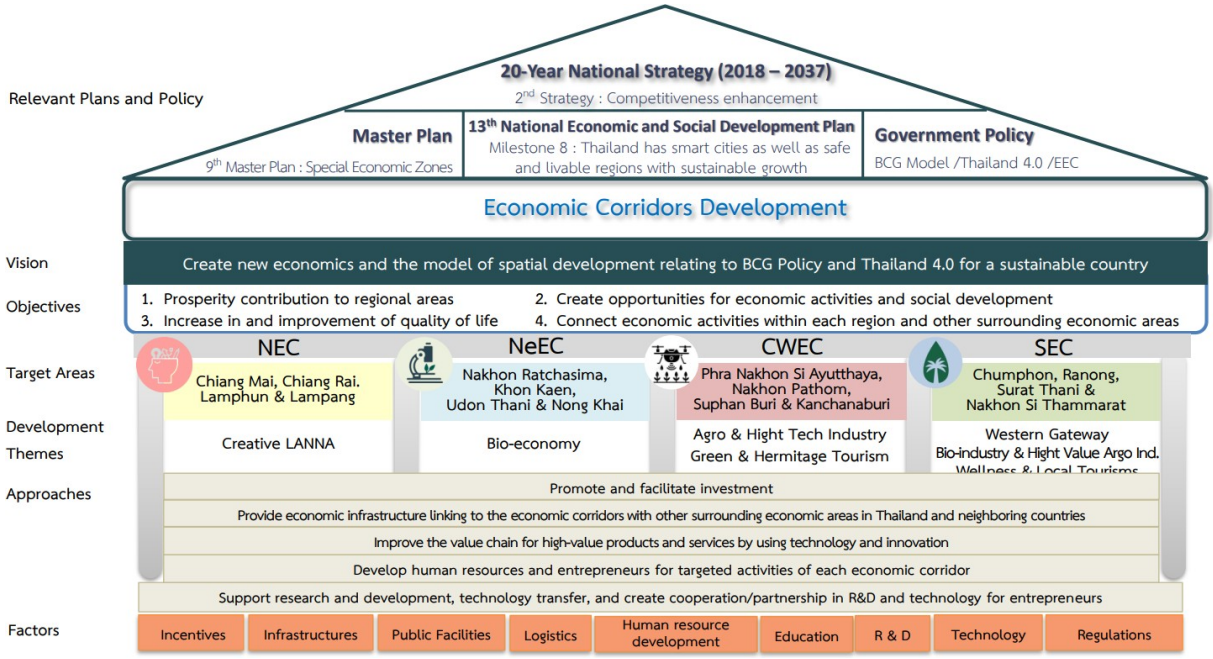

Figure 1: Thailand's Economic Corridors Development Program Framework (Source: nesdc.go.th)

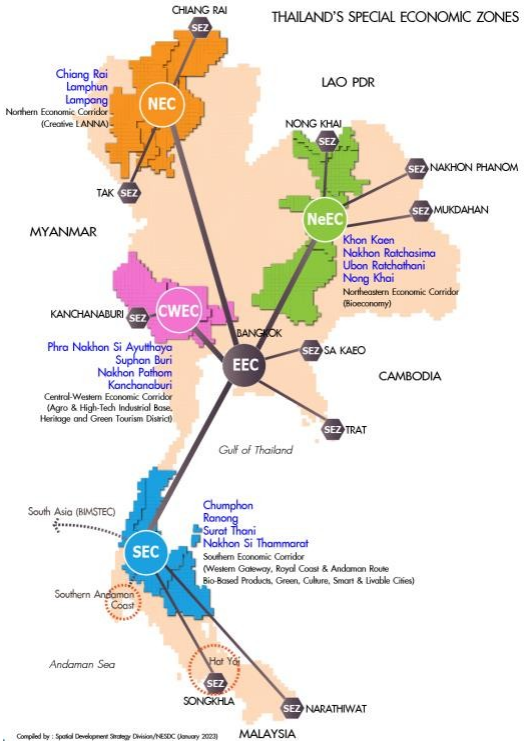

Figure 2: Thailand's economic corridors and border economic zones (Source: nesdc.go.th)

NEC in brief

The case study of the study is NEC. Where NEC is located in northern Thailand bordering Myanmar and Lao PDR as part of the Greater Mekong Subregion (GMS) (Banomyong, 2012), the geographic strength and international development potential of NEC are superior. The corridor aims at promoting sustainable development of the area with a creative economy, income equality, and quality of life while strengthening border security and increasing competitiveness and connectivity with neighboring countries. NEC scheme highlights Bio-Circular-Green Economy Model (BGC) with Sustainable Development Goals (SDG) for regional sustainable growth (Kongbuamai et al., 2022).

BCG Economy

Referring to publications from Scopus in 2013-2023, there are 79 papers related to BCG Economy. There are 4,268 references with 297 keywords. The document's average age is 3.7 per year. The topic's annual growth is 3.42%. Using Three Field Plot to preliminarily investigate the topics, it can be seen that Thailand is highly related to topics of Applied Science and Engineering Progress, Biodegradable Polymers, Blends and Composites, Agriculture and Natural Resources, etc (see Figure 3).

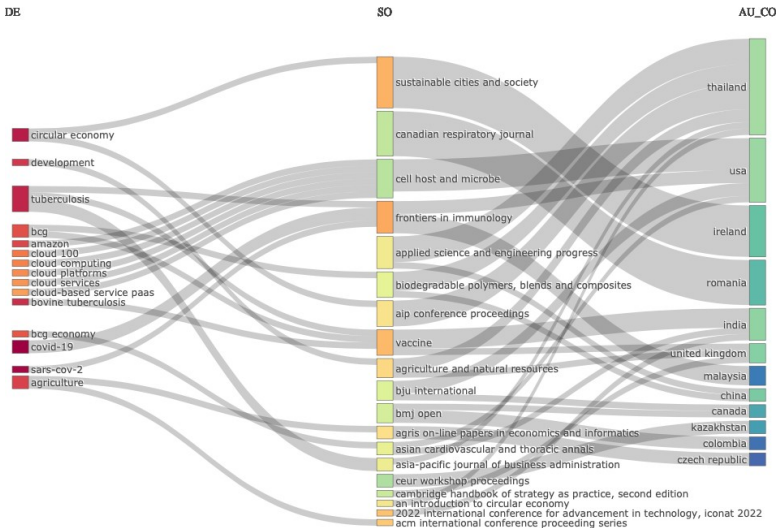

Figure 3: Bibliometric of BCG Economy (Source: Authors)

NEC Basic Information

The objectives of NEC are to create a creative ecosystem for creative cities, support creative products and services development, promote brands and marketing for the creative industry and develop creative R&D, and support the workforce in the creative industry. The approaches of SEZ are to promote and facilitate investment, provide economic infrastructure linking to the economic corridors with other surrounding economic areas in Thailand and neighboring countries, improve the value chain for high-value products and services by using technology and innovation, develop human resources and entrepreneurs for targeted activities of each economic corridor and support research and development, technology transfer, and create cooperation/partnership in R&D and technology for entrepreneurs.

Table 1 summarizes basic information on 4 provinces within NEC. Gross Provincial Product (GPP) at current prices, GPP Per capita, GDP share by sectors, and population are reported by Thailand's Office of the National Economic and Social Development Council in 2021. Strengths are taken from literature as well as interviews with related stakeholders.

		Chiang Mai (CMI)	Chiang Rai (CRI)	Lamphun (LPN)	Lampang (LPG)
GPP (Million THB)		239,981	103,000	88,614	73,161
GPP per Capita (THB)		133,306	90,203	226,464	104,744
GDP share by main sectors	**Agriculture**	18.9%	22.8%	14.1%	11.1%
	Industrial	12.4%	11.2%	55.8%	34.6%
	Services	68.5%	65.9%	30.0%	54.2%
Population (1,000 persons)		1,798	1,142	391	698
Area (sq.km.)		22,135	11,503	4,478	12,488
Economic Strengths		The second largest city in Thailand; well-developed logistics; human capital	Border with Myanmar and Lao PDR, connecting to China PRC	Industrial estate	Energy and green energy plan in 30 years

Chiang Mai is the biggest economy in NEC and is also mostly populated and largest in terms of area. In the non-agriculture sector, wholesale and retail, and manufacturing is the mostly contributed to ChiangMai'seconomy with upto 13.4% and 10.0% share of GDP, respectively.

Chiang Rai is the northernmost city of Thailand, neighboring Myanmar and Lao PDR. On top of that, thereare 253-km.-R3W highway in Myanmar and 228-km.-R3E highway in Lao PDR that extendedly connect Thailand to China (Ruth, 2008).

Lamphun is a small province but highly known as the northern industrial hub, thanks to the Northern Industrial Estate. With more than 80 large multi-national factories located within the estate, the supply chain, supporting industries, and businesses in the area have enjoyed constant economic growth. GPP per capita of Lamphun is the highest among NEC and other northern provinces of Thailand.

Lampang is the second largest city in the north. 15.7% of Lampang's GDP is from mining and quarrying activities as Mae Moh Power Plant, the largest coal-fired power plant in Southeast Asia, is there. However,according to Mae Moh's roadmap by the Electricity Generating Authority of Thailand (EGAT), the plant willbe closed, and green and clean energy will replace the power generation within the next 30 years.

NEC Targeted Clusters

Based on the potential of the area, the National Economic and Social Development Council has introduced4 targeted clusters, i.e.,

1. Creative Industry (CI), e.g., R&D centers, Product Design centers, Products for Lifestyle, MovieTown
2. Digital Industry (DI), e.g., Digital Park, Data Center, Cloud Service
3. Wellness and Tourism Industries (WTI), e.g., Amusement parks, Cultural centers, Museums, Thaiwellness services
4. Agricultural and Food Industries (AFI), e.g., GAP farming products, Organic farming products,Future Food, Products from natural extracts, including Agricultural and food industrial estate

Assessment and Alignment Methodology

The paper presents an investigation of the supply and demand analysis to see if they are aligned. The SEZcompetitiveness model, triple helix model, and supply-demand analysis are combined and used as the guideline of the investigation (Wahyuni et al., 2013; Leydesdorff, 2000; Cornwall and Cornwall, 2002)

SEZ Competitiveness Model

SEZ Competitiveness Model (Wahyuni et al., 2013) gives significant to 5 factors including (1) input factors,i.e., natural resources, human resources, and physical infrastructure, (2) quantity and cost, i.e., scientific, and technological infrastructure, administration infrastructure, (3) role of the government, (4) SEZ performance, i.e., contribution to GDP, and (5) related & supporting industries, i.e., presence of capable, locally based suppliers.

Triple Helix

The Triple Helix model is a framework describing the collaboration between universities, industries, and government in the development of an innovation-driven economy (Santonen et al., 2015; Galvao et al., 2013).

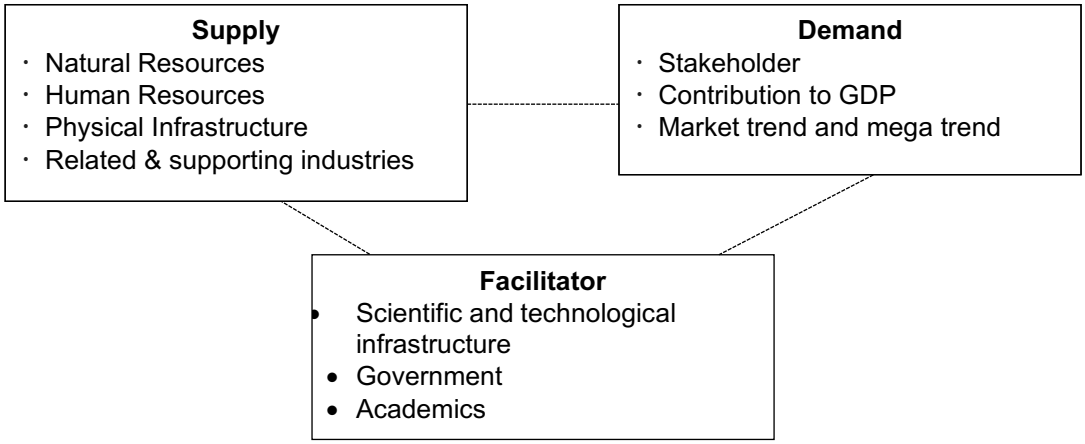

Figure 4: Supply and Demand Alignment Framework

Supply Chain Assessment and Alignment - Supply-Demand Analysis

To gain critical information of interest (see Figure 4), a series of focus groups and interviews with key stakeholders have been held during 2023. The information also comes from the intensive review of published provincial strategy plans, news, and white papers from related parties such as the Federation of Thai Industry chapters, provincial Chambers of Commerce, universities, etc.

The focuses are on the demand and supply alignment as well as the supportment by related parties. The assessments are as in Table 2 and Figure 5.

		Chiang Mai (CMI)	Chiang Rai (CRI)	Lamphun (LPN)	Lampang (LPG)
Creative Industry (CI)	**Demand**	· Lanna and Heritage culture · High-touch handicraft		· textile and garment	· traditional and advanced ceramic
	Supply	· distinctive craftsmanship · skilled labor availability	· artistic city · handicraft	· distinctive craftsmanship	· raw materials · strong ceramic industry
Digital Industry (DI)	**Demand**	· needs from service sectors	· needs from the logistics and tourism sectors	· needs from the industry and agriculture sectors	· needs from the industry and agriculture sectors
	Supply	· Digital Nomads · Co-working space			
Agricultural and Food Industries (AFI)	**Demand**	· Needs for food safety	· Border connectivity - exporting	· Food processing	
	Supply	· Northern food valley			
		· R&D facilities	· Border connectivity – imported supply · Tea, coffee, herb	· Agriculture and food industry	· Geographical logistics hubs for northern Thailand

			· R&D facilities		
Wellness and Tourism Industries (WTI)	**Demand**	· Top tourist destination Long stay destinations	· Wellness Industry · Border connectivity		Connectivity to secondary tourism cities
	Supply	Medical hub	· Sports and · recreation activities		· Medical hub in the specializedarea

Table 2: Demand and Supply within NEC

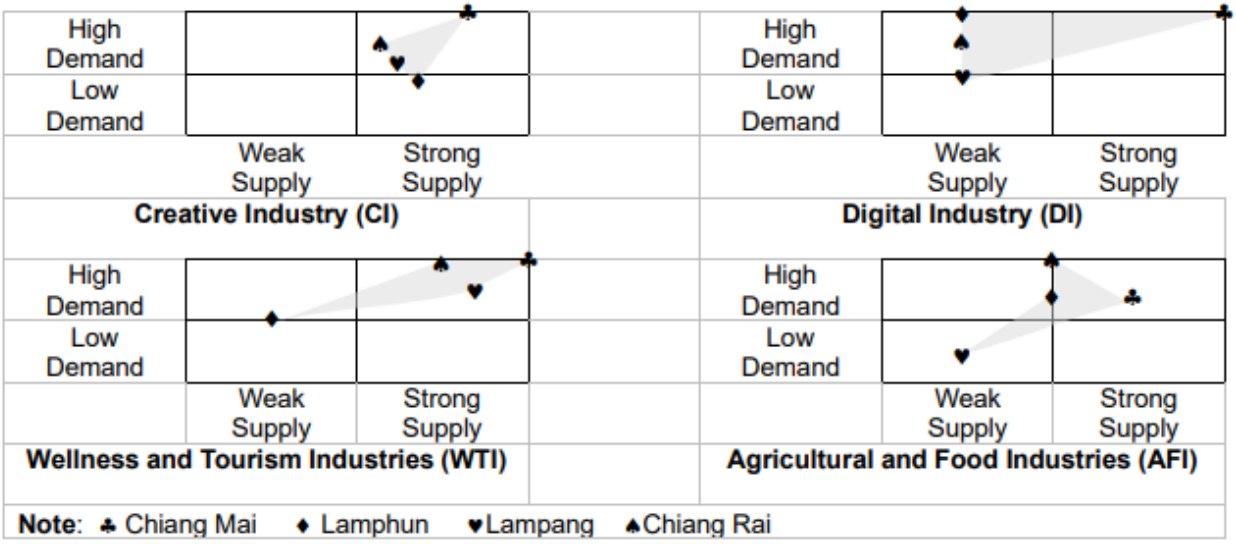

Figure 5: Demand and Supply Alignment within NEC

The Creative Industry (CI) is the only nominated sector of NEC due to the unfair advantage of the rich Lanna and heritage capital, delivered by a variety of Lanna high-touch products and cultural soft power. The by-born LANNA identity is supportive of NEC tourism industry as a whole.

The strength of the Digital Industry (DI) is quite questionable where technical, business, and creative roles in NEC are rather sparse. However, the demand for supporting other industries is undoubtfully high.

For Wellness and Tourism Industries (WTI), it is conclusive that NEC is a well-known tourist destination. The medical hub has been strongly promoted and invested as well as a wide range of wellness facilities to support the movement of the target visitors. NEC can provide both quality and competitive services at satisfactory prices.

Agricultural and Food Industries (AFI) are the backbone of Thailand. However, the traditional players have marginal bargaining power in the global supply chain. Thus, the setup of Northern Thailand Food Valley as a quadruple helix project within the region is used to promote the industry using R&D and collaboration to explore new sectors such as functional food, elderly food, novel food, extraction technologies (Ramingwong and Tippayawong, 2014).

Supply Chain Alignment - Closing Gap

NEC has a big target of doubling NEC's GPP within 5 years. This is a colossal challenge.

The findings here are only considered a preliminarily input for an ongoing NEC master plan development where the strengths of each industry and each province will later be combined vertically and horizontally

Aligning the AS-IS situation with the TO-BE scenarios, closing gap projects will then be explored. The master plan shall drive the development direction in the aligning scheme. In addition, the flagship projects will be investigated and proposed as the NEC stimulus. Detail includes responsible, stakeholders, timeline, activities, and impact. The project will be aligned with other corridor investments, such as infrastructure, human capital development, and regulations.

References

Aggarwal, A., 2023. How Special are Special Economic Zones: Evidence from South Asia. The World Economy.

Akinci, G. and Crittle, J., 2008. Special economic zone: performance, lessons learned, and implication for zone development (No. 45869, pp. 1-83). The World Bank.

Banomyong, R., 2012. The greater Mekong sub-region of Southeast Asia: improving logistics connectivity. In Handbook of global logistics: Transportation in international supply chains (pp. 69-96). New York, NY: Springer New York.

Banomyong, R., 2008. Logistics development in the north-south economic corridor of the greater mekong subregion. Journal of GMS Development Studies, 4, pp.43-58.

Bartlett, W., Krasniqi, B. and Ahmetbašić, J., 2019. Attracting FDI to the Western Balkans: Special economic zones and smart specialisation strategies. Croatian Economic Survey, 21(2), pp.5-35.

Board of Investment of Thailand, 2023, Foreign Direct Investment Statistics and Summary.

Cornwall, J. and Cornwall, W., 2002. A demand and supply analysis of productivity growth. Structural Change and Economic Dynamics, 13(2), pp.203-229.

Frick, S.A., Rodríguez-Pose, A. and Wong, M.D., 2019. Toward economically dynamic special economic zones in emerging countries. Economic Geography, 95(1), pp.30-64.

Galvao, A., Mascarenhas, C., Marques, C., Ferreira, J. and Ratten, V., 2019. Triple helix and its evolution: a systematic literature review. Journal of Science and Technology Policy Management, 10(3), pp.812-833.

Kongbuamai, N., Khoifin, K. and Uttama, N.P., 2022. The "Lanna" Project: Redefining Hope for a Sustainable and Creative Economy in the Northern Economic Corridor of Thailand. CREATIVE ECONOMY 2030.

Krungsri Research, 2023, THAILAND INDUSTRY OUTLOOK 2023-25 INDUSTRIAL ESTATE.

Leydesdorff, L., 2000. The triple helix: an evolutionary model of innovations. Research policy, 29(2), pp.243-255.

Moberg, L., 2015. The political economy of special economic zones. Journal of institutional economics, 11(1), pp.167-190.

Ramingwong, S., Sopadang, A. and Tippayawong, K.Y., 2016. Supply chain redesign strategies for agro-industry in Chiang Rai special economic zone. Science International, 29, pp.201-204.

Ramingwong, S. and Tippayawong, K.Y., 2014. On multi-criteria area selection for promoting Thailand northern food valley. International Journal of Applied Engineering Research, 9(18), pp.4377-4382.
Salangsing, P.T., Potiwan, P. and Sasanasupin, P., 2019. People's Development Rights under the Special Economic Zone: Case Study of Special Economic Zone Mukdahan. Dhammathas Academic Journal, 19(1), pp.133-150.
Santonen, Teemu & Kaivo-oja, Jari & Suomala, Jyrki. (2015). The Next Steps in Developing the Triple Helix Model: A Brief Introduction to National Open Innovation System (NOIS) Paradigm. Journal of Systemics, Cybernetics, and Informatics (JSCI). 12. pp.74-81.
Shah, S., 2008. Special economic zones in South Asia: A comparative analysis of Bangladesh, Sri Lanka, and India. John F. Kennedy School of Government.
Wahyuni, S., Astuti, E.S. and Utari, K.M., 2013. Critical outlook at special economic zone in Asia: a comparison between Indonesia, Malaysia, Thailand and China. Journal of Indonesian Economy and Business, 28(3), pp.336-346.
Walsh, J., 2022. The new colonialism of special economic zones in the Mekong subregio. Journal of Language and Culture, 41(2), pp.25-45.
Wang, J., 2013. The economic impact of special economic zones: Evidence from Chinese municipalities. Journal of development economics, 101, pp.133-147.
Zeng, D.Z., 2016. Special economic zones: Lessons from the global experience. PEDL synthesis paper series, 1(1), pp.1-9.

SUSTAINABILITY OF SUPPLY CHAINS FOR ELECTRIC VEHICLES

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ABSTRACT

Purpose: The purpose of this paper is to evaluate the sustainability of chain chains for electric vehicles (EVs).
Design/methodology/approach: This is a conceptual paper. Academic literature and – due to the novelty of the product evaluated – articles from reputed journalistic sources are analysed.
Findings: While EVs hardly pollute the air during operation, they are advertised as environmentally friendly and ethically desirable. However, there are still problems to be solved in the supply chain, from the origin of raw materials (mining of cobalt and of rare earths) to the reuse and recycle steps. The three P's of sustainability are People (society), Planet (environment) and Profit (companies need to make profit, otherwise they cannot exist much longer and are therefore not sustainable), and problems with all three have been found.
Research limitations/implications: Companies tend to be tight-lipped about sustainability problems in their EV supply chains, because "being environmentally friendly" is their main marketing strategy, so the reliability of some sources is questionable. The author tries to compensate this by using sources from different sides of the opinion spectrum. Futhermore, this research is limited to battery-electric passenger cars (BEV), not plug-in hybrids (PHEV), hybrids, or hydrogen-powered vehicles.
Practical implications: Awareness of sustainability problems in the EV supply chains should be improved, so that companies and governments invest more into new technologies to improve the production in terms of societal and environmental impact, which the added benefit of increasing profits for the companies.
Originality/value: Improvement of sustainability will improve the value of EVs to the three P's, from which society at large, the environment and lastly also the producers of EVs will benefit.

Keywords: Sustainability, supply chains, electric vehicles

Introduction

There is currently an awareness of Global Warming – even called Global Boiling by the UN (UN News, 2023) – and general environmental problems with plastic and other chemicals polluting the air, water and land which humankind needs to survive in the long term. One of the polluting factors are vehicles using internal combustion engines (ICE vehicles). Vehicles that use electric motors instead of ICE are called electric vehicles (EVs). These EVs reduce air pollution during operation to a minimum as they do not use internal combustion of fossil fuels for propulsion. This is seen as one of the solutions to fight global warming and save the environment.

Rather than focussing on reduction of pollution during operation, the authors investigate the entire supply chain of these EVs to determine the sustainability. Sustainability has three dimensions: The environment needs to be protected during both operation and production; society at large needs to benefit; and any company producing EVs needs to be profitable to survive. This research paper discusses the current situation of these three dimensions for the supply chain of EVs, specifically electric passenger vehicles, such as sedans and Sport Utility Vehicles (SUVs).

Methodology: Literature review was conducted in academic databases with search parameters "supply chains of EV batteries", "lithium mining", "cobalt mining" and "recycling of lithium batteries" Furthermore, since this is a very new field, journalistic articles from credible sources were added.

Literature Review

Sustainability

Humankind has evolved to become the dominating species on planet earth. It was known very early on that what we would term now as sustainability is important in the way we manage our environment (Monastery Mauermünster, 1144; von Carlowitz, 1713). Then came the industrial revolution which brought steam and heat engines during the mechanical age 1785-1888, and electrical machines during the electrical age 1888-1948 (Bose, 2010).

The deteriorating natural environment became an issue for the United Nations to discuss. The first Human Environment Conference was held in Sweden in 1972 (UNCED, 1992). In the UN Brundtland Report (1987), sustainability was defined as:

> "Meeting the needs of the present without compromising the ability of future generations to meet their own needs."
> (UN Brundtland Report, 1987)

The three pillars of sustainability according to the UN Brundtland Report (1987) are environmental protection, economic growth and social responsibility. The so-called "Earth Summit" in Rio de Janeiro in 1992 resulted in many declarations (UNCED, 1992), and other conferences followed. The macro-economic concepts of the UN were mapped to the business environment, as companies are the ones implementing it on a practical level. Different models were created (Süß *et al.*, 2021) and can now be applied to businesses.

The United Nations Sustainable Development Goals are 17 Goals that were adopted in 2015 by the UN General Assembly. The five dimensions of the SDGs are People, Plant, Properity, Peace and Partnership (UN, 2015).

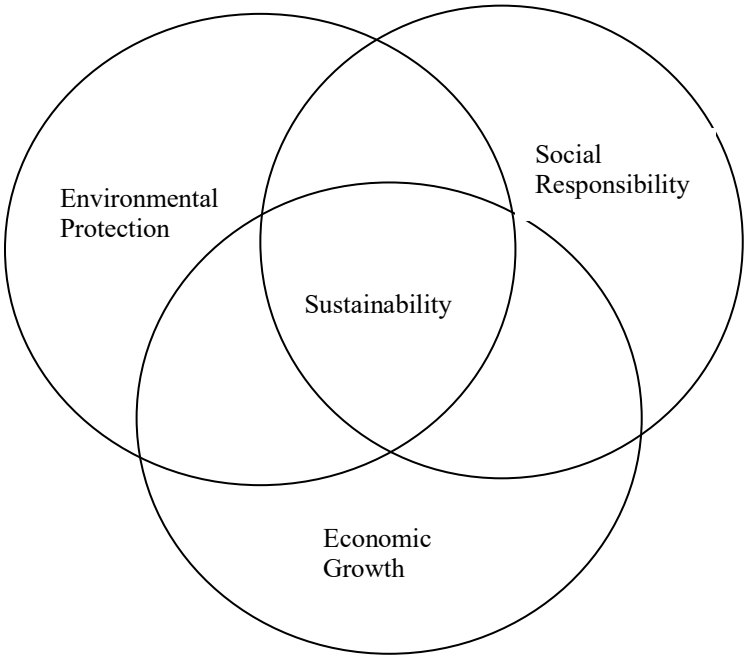

Figure 1: Sustainability. Adapted from: Carter and Rogers, 2008

The German Supply Chain Act (Bundesministerium der Justiz, 2021) which came into force on 01 January 2023 requires all companies in Germany with at least 3,000 employees to ensure that their whole supply chain is compliant with human rights and protects the environment:

The law strengthens human rights and environmental protection in global supply chains. It obligates companies in Germany to respect human rights by implementing defined due diligence obligations. These obligations apply to their own business area, the actions of their contracting partners and the actions of other (indirect) suppliers. This means that the responsibility of companies no longer ends at their own factory gate, but extends throughout the entire supply chain.(BMAS, 2023)

Circular Economy

A circular economy turns goods at their end of their life cycle into raw materials for new products, rather than following the familiar pattern of “make, use, dispose” (Stahel, 2016).

Figure 2: Circular Economy. Picture source: The Conversation (2010)

Supply Chains

Supply chains stretch from the origin of the raw materials to the final consumer. Today, reverse logistics including recycling is included:

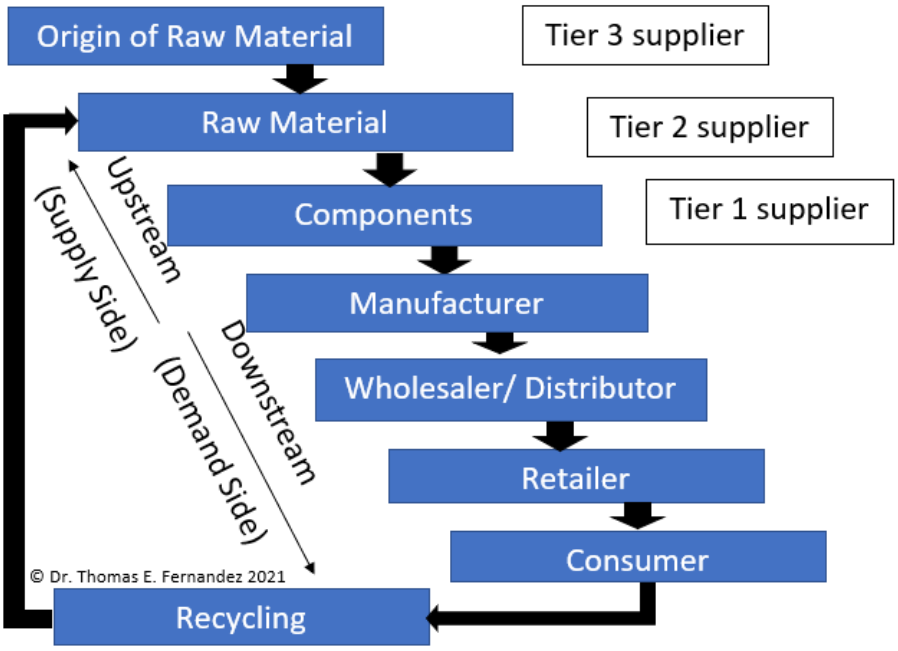

Figure 3: A simple chain for electric vehicles. Adapted from: Fernandez (2022)

The origins of raw materials for electric vehicles include steel mines, which is the case for all vehicles. EVs are different from ICE vehicles as they feature large lithium-ion batteries (LIBs). Raw materials for the batteries include lithium, cobalt, nickel, graphite and manganese. Main production countries of these materials are China (natural graphite and nickel), the DRC (cobalt), South Africa (manganese) and Chile (copper and lithium) (European Commission, 2018).

History of electric vehicles

The history of electric cars dates back to the early 19th century. The following is a brief overview (Guarnieri and Massimo, 2012):

- 1828: Hungarian inventor Ányos Jedlik builds a small-scale model electric car, considered to be one of the first electric vehicles.
- 1834: Thomas Davenport, an American blacksmith, invents the first practical electric vehicle, a small locomotive.
- Late 1800s: Electric cars gain popularity due to their simplicity, quietness, and lack of vibration compared to gasoline-powered vehicles. Companies like Baker, Detroit Electric, and Columbia Electric emerge as major manufacturers.
- Early 1900s: Electric vehicles reach their peak popularity, especially among urban dwellers. They are seen as clean, reliable, and easier to operate than gasoline cars.
- 1912: The electric starter motor is invented, making gasoline-powered cars more convenient and easier to start. This, along with the discovery of large oil reserves, leads to a decline in the popularity of electric cars.
- 1960s-1980s: Electric cars experience a resurgence due to concerns about air pollution and oil dependence. Various companies and universities develop electric prototypes and limited production vehicles, but widespread adoption remains limited.

- 1990s: The California Air Resources Board introduces the Zero Emission Vehicle (ZEV) mandate, requiring automakers to produce a certain percentage of electric vehicles. This leads to the development of modern electric cars like the GM EV1, Toyota RAV4 EV, and Nissan Altra EV.
- Early 2000s: Tesla Motors, spurred by major investor Elon Musk, introduces the Tesla Roadster, a high-performance electric car. This paves the way for the mainstream adoption of electric vehicles.
- 2010s: Electric vehicles become increasingly popular with the introduction of more affordable models like the Nissan Leaf and Chevrolet Volt. Tesla Motors introduces the Model S, a luxury electric sedan, and later the Model 3, which becomes one of the best-selling electric cars worldwide.

Electric cars continue to gain traction, with numerous automakers investing heavily in electric vehicle technology. Governments around the world are promoting electric mobility as part of their efforts to reduce greenhouse gas emissions and combat climate change. The International Energy Agency (IEA) predicts that electric car sales will continue to grow through 2023, with an expected 14 million sales by the end of the year, representing a 35% year-on-year increase. EVs could account for 18% of total car sales for the year. The report also highlights promising growth in emerging electric vehicle markets, such as India, Thailand, and Indonesia. (IEA, 2023)

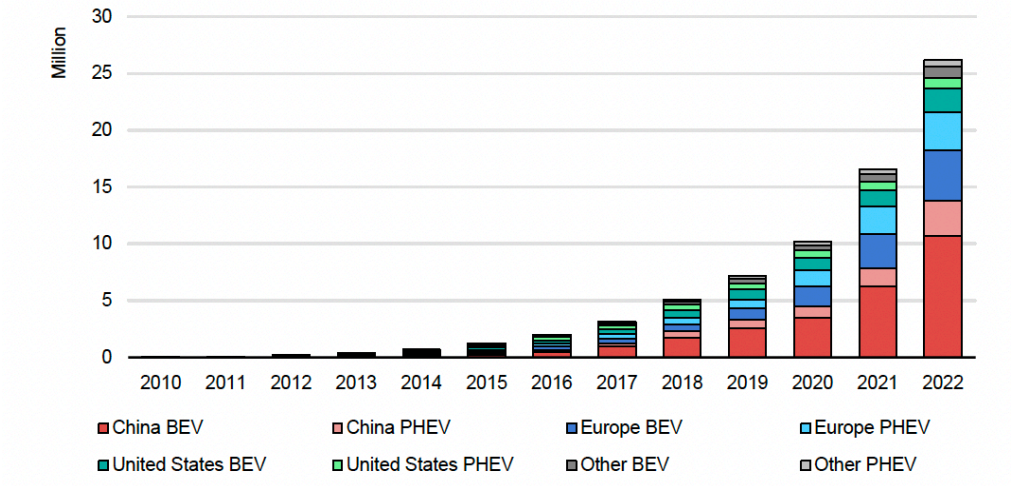

Figure 4: Global EV stock in selected regions 2010-2022.(IEA, 2023)

Mining of raw materials for batteries

More than 50% of all lithium is mined in the “lithium triangle”, namely Argentina (Salar de Olaroz), Bolivia (Salar de Uyuni) and Chile (Salar de Atacama). Lithium can be found in rock form, in which case the ore will be extracted by using drill rigs, explosives or other means, and then crushed further and roasted under intense heat, consuming nigh amounts of energy. After cooling, the ore concentrate is milled into powder and mixed with sulphuric acid and then processed further (Kaunda, 2020; Chaves *et al.*, 2021).

Lithium can also be extracted from brine (underground water reserves with saline solutions with higher concentrate of salt than that of standard seawater) and then left to dry through evaporation through sun and wind. Other processes follow. This is environmentally more desirable and is also very cost-effective (Kaunda, 2020; Chaves *et al.*, 2021), but it can take one to two years from pumping from the Salar brines to the usable product; the demand of lithium is increasing rapidly and is expected to grow by more than 500 percent by 2030 (Kaunda, 2020; Vera *et al.*, 2023). Fresh water can also be contaminated with brine, making it unusable for agriculture or fishery (Vera *et al.*, 2023).

In addition to the environmental impact, mining in general has the social impact of creating jobs and therefore income (Chavez *et al.*, 2019). However, this also results in migrations and workers leaving their ancestral sites (Augstinata *et al*, 2018).

Over half of the world's cobalt is mined in the Katanga region of the Democratic Republic of Congo (DRC) (Bamana *et al.*, 2021). Nukula *et al.* (2018) analysed the sustainability of cobalt mining in the DRC and came to the conclusion that in the sample of workers they studied, there is a high dust exposure to cobalt causing health problems. They furthermore found evidence among children of high excretion of uranium and manganese, which are metals associated with the ore. Child labour has been reported in the cobalt mining industry in the DRC (André and Godin, 2014).

According to Julia Poliscanova (2023), senior director at Transport & Environment (T&E), who carried out a study on the short-term availability of raw materials, there is enough lithium and nickel available to produce 14 million electric cars globally in 2023 even without Russian supplies.

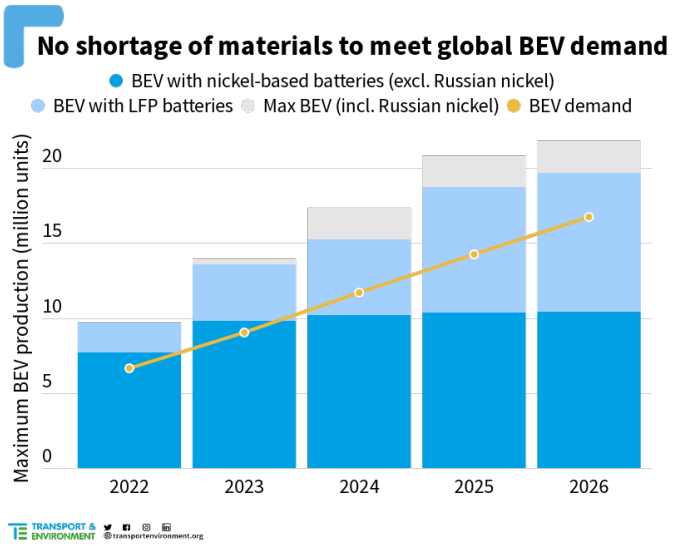

Figure 5: Available materials to meet glowbal BEV demand (Poliscanova, 2023)

Reverse logistics and recycling of batteries

According to Pitchbook.com data, globally, there are at least 80 companies involved in EV recycling, with more than 50 start-ups attracting at least US$ 2.7 billion, virtually all in the last six years, from corporate investors including automakers, battery makers and mining giants like Glencore (GLEN.L) (Carey *et al.*, 2023). The current LIB economy is quite linear rather than circular, however, in both the US and the EU, there is legislation in place that requires recycling of waste batteries (Meegoda *et al.*, 2022)

According to Mackinsey & Company (Breiter *et al.*, 2023), over five terawatt hours (TWh) per year of gigafactory capacity is expected globally by 2030. There is also considerable growth in EV battery volumes as they approach end-of-life, with over 100 million vehicle batteries expected to be retired in the next decade. With most EVs having been on the road well under six years, with almost 30% sold in 2022, there is simply not enough available data yet to articulate how long EV batteries can last. There is still have very little concrete real world data available of how batteries degrade over their lifetime - which carmakers claim should be as long as 20 years. Currently, it seems that EV batteries have much longer lifespans than anyone

could have anticipated, since very few of them have been replaced, even once the EV industry standard 8-year, 100,000 kilometres warranty period has ended (Najman, 2023).

Some industry officials anticipate rapid growth, which means 40% of battery materials used in new EVs could come from recycled stocks by 2040. (Breiter et al, 2023).

There is little existing U.S. recycling capacity today, and virtually none in Europe.

China handles virtually all EV battery recycling in a global market projected to grow from $11 billion in 2022 to $18 billion by 2028 (Breiter et al, 2023). As more EVs are introduced and age out of the vehicle fleet, that business will grow.

The minerals in those batteries - primarily lithium, cobalt and nickel - are worth on average between 1,000 euros (US$ 1,123) to 2,000 euros per car, as per BMW (BMWG.DE) sustainability chief Thomas Becker (Carey et al, 2023).

Discussion and Conclusion Coming back to the three dimensions of sustainability, namely the environment, society at large, and economic growth, we can conclude as follows: Lithium and cobalt mining is bad for the environment. Chemicals are used for extraction, and fresh water may be contaminated. Mining has positive and negative effects on society: Jobs are created and workers have income; however, workers may be moving away from ancestral grounds. In some countries, the workers are treated in a non-sustainable way, even child labour has been reported. On the economic side, there will likely be no shortage of raw materials, and the business is growing.

In conclusion, the idea of using electric vehicles to replace vehicles with internal combustion engines is very noble. It does require an update of the supply chain though; mining operations must become sustainable, for example. Stronger controls by companies that use the raw materials and governments of countries that import the raw materials or finished products need to implement and enforce laws. The German Supply Chain Act is newly in place and it must be seen how much it will be enforced.

Limitations and future research: This research focusses on the supply chains of the current lithium-ion batteries (LIBs) in EVs. There are other components, such as rare earths in the motors, which are worth evaluating. We did not take the new solid-state batteries into consideration, as they do not exist in the market yet. Also, this research does not cover comparison to internal combustions engines, especially with regards to fuel production. A comparison of the supply chains of fossil fuels versus electricity would be interesting for a future paper.

References

Agusdinata, D. B., Liu, W., Eakin, H., & Romero, H. (2018): “Socio-environmental impacts of lithium mineral extraction: towards a research agenda”, Environmental Research Letters, 13(12), 123001.

André, G and Godin, M: “Child labour, agency and family dynamics: The case of mining in Katanga (DRC)”, Childhood, Vol. 21(2) 161–174

Bamana, G., Miller, J.D., Young, S.L. and Jennifer B. Dunn (2021): “Addressing the social life cycle inventory analysis data gap: Insights from a case study of cobalt mining in the Democratic Republic of the Congo” , One Earth, Volume 4, Issue 12, pp. 1704-1714, https://doi.org/10.1016/j.oneear.2021.11.007. (https://www.sciencedirect.com/science/article/pii/S2590332221006552)

BMAS (Federal Ministry of Labour and Social Affairs) (2023): “Supply Chain Act – Act on Corporate Due Diligence Obligations in Supply Chains”, [online] Available at https://www.bmas.de/EN/Europe-and-the-World/International/Supply-Chain-Act/supply-chain-act.html Accessed 14 August 2023

Bose, B.K. (2010): “Global Warming – Energy, Environmental Pollution, and the Impact of Power Electronics”, IEEE Industrial Electronics Magazine, Volume: 4, Issue: 1, pp. 6-17. DOI 10.1109/MIE.2010.935860

Breiter, A., Linder, M., Schuldt, T., Siccardo, G. and Vekić, A (2023): “Battery recycling takes the driver’s seat”, [online] Available at https://www.mckinsey.com/~/media/mckinsey/industries/automotive%20and%20assembly/our%20insights/battery%20recycling%20takes%20the%20drivers%20seat/battery-recycling-takes-the-drivers-seat.pdf Accessed 13 August 2023

Bundesministerium der Justiz (Federal Ministry of Justice) (2021): „Gesetz über die unternehmerischen Sorgfaltspflichten zur Vermeidung von Menschenrechtsverletzungen in Lieferketten (Lieferkettensorgfaltspflichtengesetz - LkSG)“, [online] Available at https://www.gesetze-im-internet.de/lksg/ Accessed 14 August 2023

Carter, C.R. and Rogers, D.S. (2008): “A framework of sustainable supply chain management: moving toward new theory”, International Journal of Physical Distribution & Logistics Management, Vol. 38 No. 5, pp. 360-387

Carey, N., Lienert, P. and Waldersee, V. (2023): “Dead EV batteries turn to gold with US incentives”, [online] Available at https://www.reuters.com/business/autos-transportation/dead-ev-batteries-turn-gold-with-us-incentives-2023-07-21/ Accessed 13 August 2023

Chaves, C., Pereira, E., Ferreira, P., & Dias, A. G. (2021): “Concerns about lithium extraction: A review and application for Portugal. The Extractive Industries and Society, 8(3), 100928.

European Commission (2018): “Report on Raw Materials for Battery Applications. SWD(2018) 245/2 Final”, (OR. en) ST-9179-2018-REV 1.

Fernandez, Thomas E. (2022): “Blockchain Technology in Supply Chain Management”, In: S. J. S. Chelladurai, S. Mayilswamy, S. Gnanasekaran, & R. Thirumalaisamy (Eds.), “Logistics Engineering”, IntechOpen, UK ISBN 978-1-80355-751-9 https://doi.org/10.5772/intechopen.105761

Guarnieri and Massimo (2012): “Looking back to electric cars. HISTory of ELectro-technology CONference (HISTELCON)”. pp. 1–6. doi:10.1109/HISTELCON.2012.6487583

IEA (2023) Global EV Outlook 2023 Catching up with climate ambitions [online] Available at https://evmarketsreports.com/global-ev-outlook-2023-2/, Accessed 13 August 2023

JD Power (2023): “Shopping guide: [online] Available at https://www.jdpower.com/cars/shopping-guides/how-long-do-electric-car-batteries-last#:~:text=Buying%20a%20battery%20can%20set,affect%20that%20and%20reduce%20performance. Accessed 13 August 2023

Kaunda, R.B. (2020): “Potential environmental impacts of lithium mining”, Journal of Energy & Natural Resources Law, Vol 38, No 3, 237–244, https://doi.org/10.1080/02646811.2020.1754596

Meegoda, J.N.; Malladi, S.;Zayas, I.C.(2022): “End-of-Life Management of Electric Vehicle Lithium-Ion Batteries in the United States”. Clean Technol. 2022, 4, 1162–1174. https://doi.org/10.3390/cleantechnol4040071

Monastery Mauermünster (1144): “ Genealogica Zaringorum“, MGH SS XIII, p. 735. As cited in Götze U., Peças, P and Richter, F. (2019): “Design for eco-efficiency – a system of indicators and their Application to the case of moulds for injection moulding”, 16th Global Conference on Sustainable Manufacturing - Sustainable Manufacturing for Global Circular Economy, Lexington, Kentucky, USA

Najman, L. (2023), “New Study: How Long Do Electric Car Batteries Last?” [online] https://www.recurrentauto.com/research/how-long-do-ev-batteries-last Accessed 14 August 2023

Nukulu, C.B.L., Casas, L., Haufroid, V., De Putter, T., Saenen, N.D., Kayembe-Kitenge, T., Obadia, P.M., Mukoma, D.K.W., Ilunda, J-M. L., Nawrot, T.S., Numbi, O.L., Smolders, E. and Nemery, B. (2018): “Sustainability of artisanal mining of cobalt in DR Congo”, Nat Sustain. 2018 Sep; 1(9): 495–504, doi: 10.1038/s41893-018-0139-4

Poliscanova, J. (2023), [online] Available at https://www.transportenvironment.org/discover/enough-raw-metals-to-make-14-million-electric-cars-globally-in-2023-study/ , Accessed 13 August 2023

Stahel, W. R. (2016): “The circular economy”, Nature,531, pp. 435-438.

Süß, A.; Höse, K.; Götze, U. (2021): “Sustainability-Oriented Business Model Evaluation—A Literature Review”, Sustainability, 13, 10908, https://doi.org/10.3390/su131910908

The Conversation (2010): “Explainer: What is a circular economy?”, [online] Available at https://theconversation.com/explainer-what-is-a-circular-economy-29666 Accessed 13 August 2023

UN Brundtland Report (1987): “Report of the World Commission on Environment and Development: Our Common Future”, [online] Available at http://www.un-documents.net/our-common-future.pdf Accessed 06 August 2023

UN (2015): “Resolution adopted by the General Assembly on 25 September 2015”, Resolution A/RES/70/1 dated 21 October 2015, [online] Available at https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/291/89/PDF/N1529189.pdf?OpenElement Accessed 06 August 2023

UN News (2023): “Hottest July ever signals ‘era of global boiling has arrived’ says UN chief”, [online] Available at https://news.un.org/en/story/2023/07/1139162 Accessed 13 August 2023.

UNCED (1992): “United Nations Conference on Environment and Development”, Rio de Janeiro, Brasil, 3-14 June, [online] available at https://www.un.org/en/conferences/environment/rio1992 Accessed 13 August 2023.

Vera, M.L., Torres, W.R., Galli, C.I. and Chagnes, A. (2023): “Environmental impact of direct lithium extraction from brines”, Nat Rev Earth Environ 4, 149–165 (2023). https://doi.org/10.1038/s43017-022-00387-5

Von Carlowitz, H.C. (1713): “Sylvicultura oeconomica, oder haußwirthliche Nachricht und Naturmäßige Anweisung zur wilden Baum-Zucht [Sylvicultura oeconomica or the instructions for wild tree cultivation]. Leipzig: Braun; 1713. In German. Also available [online] https://www.digitale-sammlungen.de/en/view/bsb10214444?page=,1 Accessed 13 August 2023, as cited in: Süß, A.; Höse, K.; Götze, U. (2021): “Sustainability-Oriented Business Model Evaluation—A Literature Review”. Sustainability 2021, 13, 10908, https://doi.org/10.3390/su131910908

The Attitude of Thai Tourists Towards Green Logistics

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ABSTRACT

Purpose – This paper is aim to proposal conceptual framework for the investigation of the usage of green logistics and green transportation in tourism context.
Design/Methodology/Approach – The paper review literature in the field of green logistics, green transportation, especially in tourism context. It adopted physiological concept as it is believed that knowledge, attitude, and practice could encourage the usage of green logistics and green transportations.
Findings – From the literature review, the paper provides the conceptual framework. It reveals the linkage between green logistics, green transportations and knowledge, attitude and practice.
Original/value – The findings can be used to investigate link between green logistics, green transportations and knowledge, attitude and practice. It could lead to the development of proper policies to encourage the usage of green logistics and green transportations.
Keywords Green Logistics, Green Transportations, Attitude, Tourism.

INTRODUCTION

At present, environmental and green issues is considered as a socially responsible manner (Murphy, 2003). Numerous enterprises are agreed to the ecological repercussions entailed in their operational undertakings, and several factors underpin the decision of these entities to adopt eco-friendly practices, a choice that confers a distinct competitive edge. Moreover, there exists a visible demand from consumers, urging businesses to adopt environmentally sustainable practices (Saroha, 2014). Furthermore, it has been discerned that nurturing the ethos of sustainability through the propagation of environmentally conscious practices not only advances the localized sustainable development but also harmonizes economic, social, and environmental dividends (Li and Chen, 2021).

Logistics are considered as an important function of modern transport systems. The development of logistics industry has enhanced through the growth of national economy. Meanwhile logistics industry also plays an important role in supporting the development of the national economy (Li and Chen, 2021). At the same time, transportation negatively impacts environment. The impact have gained wide recognition and are set as the core of issues of sustainability (Jean Paul Rodrick, 2017). Therefore, it can be said that the logistics industry has promoted overall economic growth, but it has also caused a series of economic and environmental problems (Li and Chen, 2021). While, there are the development of contemporary technologies, it is believed that logistics can be improved in the way that are environmentally friendly with the concept of “green logistics” (Rodrigue et al., 2017).

PURPOSE OF PAPER

This paper is aim to proposal conceptual framework for the investigation of the usage of green logistics and green transportation in tourism context.

TOURISM AND ENVIRONMENT

Tourism is considered as the leisure activities which tourists visit a location. A tourist may spend days in a particular destination. During the stay, the tourist could have a multitude of purposes, including work, education, sightseeing, cultural and culinary exploration, family visits, and the pursuit of various enjoyments (Dharmaratne et al., 2023). Over several decades, tourism has continued to grow and diversify. It can be considered as one of the fastest growing economic sectors in the world (Abduganiev and Makhkamov, 2022). It is an industry that contributes significantly to broad benefits. For example, tourism provides direct

and indirect job possibilities. Tourism can support a nation's handicrafts and fine arts aids in the preservation of nature's beauty and cultural legacy of the country. It can strengthen the process of national integration and global brotherhood (Thommandru et al., 2021).

While tourism can be viewed as a key role that is a driver of socio-economic progress, it is also responsible for environmental deterioration, not only in areas popular with tourists, but also by enhancing climate change globally (Abduganiev & Makhkamov, 2022). The globalization progression has generated various undesirable consequences for the environment and society. This is including the increasing of environmental pollution, climate change and the exhaustion and destruction of resources. The impact of these procedures poses challenges in ensuring citizens' access to a pollution-free environment. It is also impotence that the right solutions are addressed (Perkumiene et al., 2020). Environmental pollution is not a new phenomenon. It is the world's greatest problem facing civilization. (Ukaogo et al., 2020). Environmental pollution is increasing gradually and causing a serious impact on living organisms including humans (Patel et al., 2022). Tourism today can consider as having a problem. It is addicted to progress, which is incompatible with sustainability goals. Although, sustainable tourism is discussed among scholars for several decades, it is believed that tourism authorities continue to promote tourism growth, despite the ecological and social limits of living on a finite planet (Higgins-Desbiolles, 2018).

Tourism can be considered as choices for people to earn income. These people can utilize the natural wealth around them. It is necessary that natural ecosystems are preserved so that they continue to balance. The idea of a green economy is emerged in order to inspire the development of tourism while still preserving the environmental ecosystem (Nugroho et al, 2023). Green economy aims to improve well-being of people. It also focuses on social equity. Green economy decreases environmental threats and ecological shortages (DeLacy & Jiang, 2019). It is believed that the development of tourism must achieves excellence in environmental conditions, accessibility, and infrastructure (Ciacci et al., 2021).

TOURISM AND LOGISTICS

Tourism industry is depending on transport, logistics and global supply chain. All transport modes play an important role of moving the tourists from place to place. Logistics are responsible for supply of goods in order to fulfil the hospitality needs of tourists. Therefore, for the tourism sector to run smoothly, the efficient logistics service is required (Dharmaratne et al., 2023). For tourism logistics, the emphasis is placed on the content, timing and quality of service provided to the client. The logistics also attempt to increase the reliability of order fulfillment as the main goal of logistics. These principles enhance the optimization of decisions. They permit travel companies to strengthen their competitive position in the consumer market (Rakhmatullaeva & Aminova, 2022). The rapid expansion of the tourism sector has led to an increase in supply chain operations that have adverse effects on the environment. In order to reduce negative impacts on environment, companies are must follow a range of environmental regulations. These regulations could be established by regional and international units. This is created to ensure tourism sustainability (Suleiman, 2022). It is suggested that tourism encompasses various activities, it's important to approach its development from diverse perspectives. (Rakhmatullaeva & Aminova, 2022).

GREEN LOGISTICS

The economic expansion that occurred globally in the past century resulted in a significant increase in the consumption of products, and the process of globalization has facilitated the movement of goods across the world. Nevertheless, the production, transportation, storage, and use of these goods have generated significant environmental challenges (Dekker et al., 2011). Green Logistics can be defined as initiatives aimed at assessing and reducing the ecological footprint of logistics operations (Saroha, 2014). This encompasses all processes related to the movement of products, information, and services from their starting point to their destination, including both forward and reverse flows. Green logistics aim to diminish adverse effects by reevaluating procurement, distribution systems, and the handling of reverse logistics to eradicate inefficiencies, avoid unnecessary freight transportation, and minimize waste, including packaging waste. As a result, green logistics is considered a positive initiative for organizations (Realreungrat, 2015).

The instance of green logistics illustrates its connection with environmentally conscious investment choices. The cultivation of a mindset and a willingness to adopt eco-friendly products leads to higher profits for businesses. Enhanced macro-level energy efficiency in enterprises is associated with various eco-friendly factors, such as the selection of environmentally conscious suppliers, sustainable engineering and procurement practices, consumer awareness of green products, efficient product recycling, and innovative green solutions. These factors collectively contribute to the inclination to purchase eco-friendly products and make it easier to embrace and use such products, fostering a positive attitude and intention toward their adoption (Anser et al., 2020).

GREEN TRANSPORTATION

Supply chain is considered as vital part of logistics and transportation is recognized as part of supply chains. Transportation industry is known as fundamental infrastructures. This industry is responsible for the carrier of goods and passengers. It is necessary for economic and industrial growth and development. Most organizations use road transportation because it is the most dependable alternative. Therefore, it can be said that road transportation is popular among organizations. Nevertheless, road transportation creates a big contributor to greenhouse gases and CO 2 emissions in the air, since it is one of the transportation that consumes enormous of petroleum products. It is strongly suggested that this issue should not be neglected and immediate and proper studies. The issue need to be carefully revised and finally lead to the acknowledged of the solutions (Salimifard et al., 2012).

Green Transportation is recognized as a greatly interdisciplinary area. Researchers and scholars of different domain of knowledge, for example, engineers, policy makers, management intellectuals, urban planners, and others, are demanding to decrease CO2 emissions from the sector (Salimifard et al., 2012). Green transportation main purpose is to be a low-carbon and initiates environmental travelling method. It encourages healthy and leisure lifestyle. The benefit of green transportation is also including the energy conservation as it leads to decrease of energy consumption. It reduces exhaust emission for improvement of air quality and reduce carbon emission for decrease of greenhouse effect. The construction of green transportation system is decent for the exhaustive use of road resources for ease of traffic congestion. Overall, green transportation can generate to the construction of livable cities for improvement of citizen health. In addition, in tourism context, green travelling is an ideal means of transportation for short-distance travelling and transfer, as well as an indispensable part of urban comprehensive transportation. The development of urban green transportation is an essential measure for saving energy, reducing carbon and PM2.5 emissions and improving environment (Li, 2016).

TOURISM AND GREEN TRASPORTATION

Transportation can be acknowledged as key component of achievement in tourism industry (J. Ko, 2017). While transportation for tourism is a major contributor of environmental pollutants, it provides an opportunity to examine new mechanisms that motivate behavioral responses to this problem. Recently, researcher suggested ways to preserve environment, for example, eco-labels can be identified as a more common method of providing information to consumers about purchasing decisions. Government sector can also utilize market forces to initiate environmental responsibility among organizations (Mastrangelo et al., 2009). Moreover, while green transportation technology is widely widespread and importance of public transportation is also on the rise, this can be promoted as a solution for travelers who are concerned with environment (J. Ko, 2017). It is believed that tourism, as the largest global industry, can act as a main role in reducing the environmental impacts of travel (Mastrangelo et al., 2009).

The example of green transportation in tourism context can be seen as, for example, bicycle tourism. The research on bicycle tourism focuses on the development and promotion of networks and bicycle trails. It is stated that cycle tourism is not entirely a rural tourism phenomenon. Since, the use of the bicycle as part of the city tourism offer is enjoying, there are several categories of bicycle tourists. Bicycle tourism includes for sports, long distance journeys or for taking multiple excursions. These kinds of bicycle tourists mostly visit rural areas. These bicycle tourism is also the category dominating in the literature as the proper bicycle

tourists. There is also another bicycle tourism category which is holiday cyclists, for whom cycling forms part of the holiday experience. The development of urban bicycle tourism can be recognized as an innovative process based on incremental change in local and regional socio-technological mobility systems (Nilsson, 2019).

In North America, Green Coach Certification is a trial certification project and is currently operating for motor-coach companies. The Green Coach Certification initiative provides a distinctive eco-label to motor coach enterprises, signifying their commitment to environmental stewardship. Within the expansive domain of the tourism industry, an assemblage of over one hundred eco-labels already subsists. Nonetheless, the proliferation of such eco-labels is no unequivocal assurance of their efficaciousness or universal embrace by consumers. Previous studies of tourist responses to eco-labels show that there are very low rates of recognition and awareness of the labels. This evidentiary backdrop underscores the imperative not solely to comprehend the profile of consumers engaging with eco-labeled commodities but also to distinguish the hidden demand for eco-labels within specific market contexts (Mastrangelo et al., 2009).

The effective formation of a railway system, aligned with the preferences of its users, creates success within the travel industry. Specific design guidance of public transit in tourism is essential in order to promote public transportation rather than private cars. Diverse endeavors have been undertaken across various nations, aiming to incorporate aesthetic considerations into the evaluation of transportation modalities, albeit with certain limitations. Since a feeling of beauty is idiosyncratic, it was significant to shape integrated definition and qualified issues. Two complementary definitions were suggested. One is sight-seeing mechanism and the other is vehicle exterior design. Wireless tram got the highest score from travelers. It should be noticed that decision maker should consider all factors integrally depends on the situation. It is recommended that there should be further research which determines appropriate types of trains and railway system (Ko et al., 2017).

ATTITUDE

The notion of attitudes is a theoretical concept established by psychologists to help clarify and understand relevant phenomena. According to dispositional models of attitudes, when consistent attitude reports surface over different time periods, it indicates the existence of a "strong" or "well-established" attitude deeply stored in memory (Converse, 1964). The connection between attitudes and behavior is of great importance in many areas of psychology. This has sparked academic interest that transcends disciplinary boundaries, leading to a significant body of research. Most of the current research argues that the relationship between attitudes and behavior follows a straightforward, linear path. Across various themes, measurement methods, and contexts, the congruence between attitudes and behaviors tends to follow a pattern. Initially, the shift from highly negative to moderately negative attitudes is relatively gradual. Then, as attitudes move from negative to neutral, and subsequently from negative to positive, this transition becomes steeper. Finally, the connection weakens again as attitudes transition from moderately positive to highly positive (Bechler & Tormala, 2021).

Attitude strength relates to the level of lasting impact an attitude has, consistently guiding behavior. (Bechler & Tormala, 2021). Therefore, it is believed that attitude can guide future behavior. Past empirical investigations have established a distinct correlation between attitudes and future behaviors, especially when attitudes are facile to recall and exhibit stability across time. When attitudes are more readily accessible, they become stronger indicators of future behavior, especially when individuals have firsthand experiences with the significant subject of their attitudes and regularly clarify their attitudes. (Glasman & Albarracín, 2007). It is recognized that possessing knowledge, holding a certain attitude, and putting it into practice can result in a specific behavior. (Puspitasari et al., 2020).

PUSH AND PULL THEORY

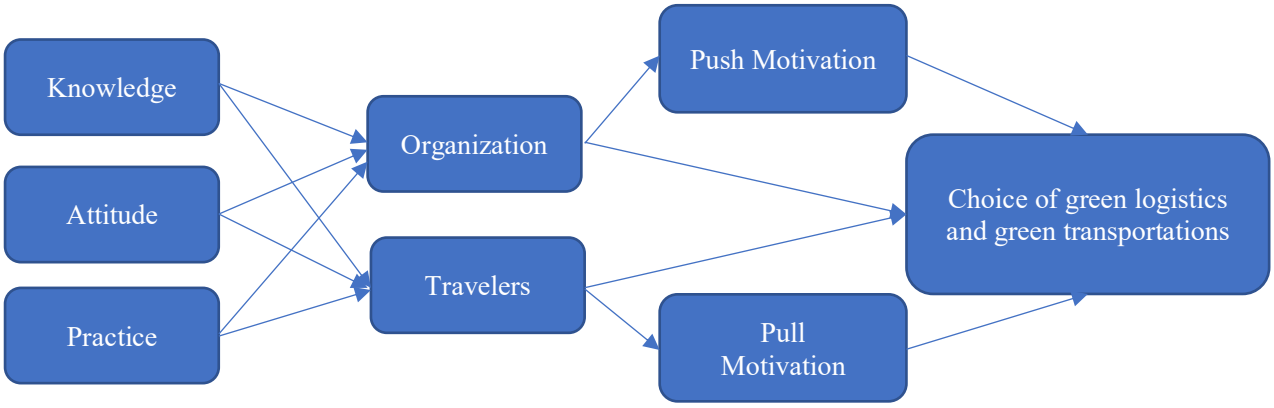
It is believed that there are factors that can explain switching/shifting behavior of human. These factors include push and pull factors. Push factors encourage individuals to leave their current option. Pull factors motivate individuals to embrace the new option. Push factors that thrust individual to shifts to green transportation could be the limitations of commuting by private cars. It is believed that these limitations can generate individual's willingness to shift to green transportation. Pull factors produce the advantages and benefits of shifting to green transportation. For example, green transportation policies and campaign and green transportation system. These policies and campaigns aim to motivate individuals to take green transportation (Wang et al., 2020)

THAILAND CONTEXT

In Thailand, sustainable tourism is promoted through the 7 Greens Concept. They are categorized as "Green Heart, Green Logistics, Green Attraction, Green Community, Green Activity, Green Service and Green Plus". The concept is initiated and launched by Tourism Authority of Thailand. It was identified by Thai tourists that tourism environment in Thailand did not reach their expectation (Nilnoppakun & Ampavat, 2016). Nowadays, it is suggested that travelers can choose eco-friendly ways to travel. It is recommended that tourists can swap taxis and planes for public transport and trains. They may choose tour operator who concerns about environmental issues. For example, visitors should search for companies that run conservation and community initiatives and choose a tour group that doesn't disturb wildlife (Wanderlust Travel Media, 2021).

CONCEPTUAL MODEL

From the review, in order to encourage the usage of green logistic and green transportation, attitude towards green logistics and green transportation need to be investigated.



Picture 1: Conceptual Ideas for Green Logistics and Green Transportation.

CONCLUSION

The objective of this paper is to delve into the intricacies of the notion of green logistics and its interplay with green transportation within the purview of the tourism sector. While the tourism industry offers economic advantages upon nations, encompassing both urban and rural landscapes, it is equally acknowledged that the endeavors associated with tourism can exert adverse ecological impacts. In the pursuit of sustainable tourism, an imperative indicates to integrate environmentally conscientious practices and innovative strategies. The relevance of green logistics emerges as an instrumental facet in addressing the multifaceted challenges embedded within the trajectory of sustainable tourism development. There is a significant joint relationship between tourism and the environment, thus highlighting the pivotal role that green logistics assumes in development the evolution of a sustainable tourism paradigm.

REFERENCES

Abduganiev, O.I. and Makhkamov, E.G., 2022. ECOLOGICAL TOURISM IN PROTECTED NATURAL AREAS. *Journal of Geography and Natural Resources*, *2*(02), pp.25-32.

Ahani, P., Arantes, A. and Melo, S., 2016. A portfolio approach for optimal fleet replacement toward sustainable urban freight transportation. *Transportation Research Part D: Transport and Environment*, *48*, pp.357-368. Murphy, P.R. and Poist, R.F., 2003. Green perspectives and practices: a "comparative logistics" study. *Supply chain management: an international journal*, *8*(2), pp.122-131.

Anser, M.K., Yousaf, Z. and Zaman, K., 2020. Green technology acceptance model and green logistics operations:"to see which way the wind is blowing". *Frontiers in Sustainability*, *1*, p.3.

Bechler, C.J., Tormala, Z.L. and Rucker, D.D., 2021. The attitude–behavior relationship revisited. *Psychological science*, *32*(8), pp.1285-1297.

Ciacci, A., Ivaldi, E., Mangano, S. and Ugolini, G.M., 2023. Environment, logistics and infrastructure: the three dimensions of influence of Italian coastal tourism. *Journal of Sustainable Tourism*, *31*(7), pp.1583-1607.

Converse, P.E., 1963. Attitudes and non-attitudes: Continuation of a dialogue.

Dekker, R., Bloemhof, J. and Mallidis, I., 2012. Operations Research for green logistics–An overview of aspects, issues, contributions and challenges. *European journal of operational research*, *219*(3), pp.671-679.

DeLacy, T. and Jiang, M., 2019, November. Transforming a tourism destination into a green economy: A policy analysis of Wakatobi Islands, Indonesia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 363, No. 1, p. 012004). IOP Publishing.

Dharmaratne, D., Siriwardena, S., Edirisinghe, L. and Silva, D.S., 2023. Interdependence of Logistics and Tourism: Crafting a Novel Logistics Concept in Tourism. *Sustainable Development Research*, *5*(1), pp.p87-p87.

Glasman, L.R. and Albarracín, D., 2006. Forming attitudes that predict future behavior: a meta-analysis of the attitude-behavior relation. *Psychological bulletin*, *132*(5), p.778.

Higgins-Desbiolles, F., 2018. Sustainable tourism: Sustaining tourism or something more?. *Tourism management perspectives*, *25*, pp.157-160.

Ko, J., Kim, E., Jeong, D.W. and Kim, D.K., 2017. Aesthetic Approach to green transportation planning in tourism with design factors. *Journal of Fundamental and Applied Sciences*, *9*(7S), pp.1-14.

Li, H.R., 2016. Study on green transportation system of international metropolises. *Procedia engineering*, *137*, pp.762-771.

Li, X. and Chen, F., 2021. Impact of logistics development on economic growth: An empirical research from guangdong province in China. Complexity, 2021, pp.1-12.

Mastrangelo, C., Anderson, L.E., Chase, L.C. and Kestenbaum, D., 2010. Green Transportation for Tourism: Assessing Demand for Ecolabels. In *Compendium of papers for the Transportation Research Board 89th annual meeting*.

Nilnoppakun, A. and Ampavat, K., 2016. Is pai a sustainable tourism destination?. *Procedia Economics and Finance*, *39*, pp.262-269.

Nilsson, J.H., 2019. Urban bicycle tourism: Path dependencies and innovation in Greater Copenhagen. *Journal of Sustainable Tourism*, *27*(11), pp.1648-1662.

Nugroho, L.D., Melati, S.R., Wahyuliana, I., Pawestri, A. and Kurniawan, L.F., 2023, May. Legal Policy of Implementation Green Economy In the Tourism Sector To Realize Sustainable Tourism And Environment. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1181, No. 1, p. 012018). IOP Publishing.

Patel, H., Shakhreliya, S., Maurya, R., Pandey, V.C., Gohil, N., Bhattacharjee, G., Alzahrani, K.J. and Singh, V., 2022. CRISPR-assisted strategies for futuristic phytoremediation. In *Assisted phytoremediation* (pp. 203-220). Elsevier.

Perkumienė, D., Pranskūnienė, R., Vienažindienė, M. and Grigienė, J., 2020. The right to a clean environment: Considering green logistics and sustainable tourism. *International Journal of Environmental Research and Public Health*, *17*(9), p.3254.

Puspitasari, I.M., Yusuf, L., Sinuraya, R.K., Abdulah, R. and Koyama, H., 2020. Knowledge, attitude, and practice during the COVID-19 pandemic: a review. *Journal of multidisciplinary healthcare*, pp.727-733.
Rakhmatullaeva, F.M. and Aminova, N.B., 2022. Methodological Approaches to the Development of Ecological Tourism Logistics. *European journal of innovation in nonformal education*, *2*(1), pp.207-211.
Realreungrat, P., 2015. Green Logistics for Sustainable Development. FEU Academic Review, 8(2), pp.12-12.
Ren R, Hu W, Dong J et al (2020) A systematic literature review of green and sustainable logistics: bibliometric analysis, research trend and knowledge taxonomy[J]. Int J Environ Res Public Health 17(1):261
Rodrigue, J.P., Slack, B. and Comtois, C., 2017. Green logistics. In *Handbook of logistics and supply-chain management* (Vol. 2, pp. 339-350). Emerald Group Publishing Limited.
Salimifard, K., Shahbandarzadeh, H. and Raeesi, R., 2012, February. Green transportation and the role of operation research. In *Int. Conf. Traffic Transp. Eng.(ICTTE 2012)* (Vol. 26, pp. 74-79). IACSIT Press.
Saroha, R., 2014. Green logistics & its significance in modern day systems. *International Review of Applied Engineering Research*, *4*(1), pp.89-92.
Schwarz, N., 2007. Attitude construction: Evaluation in context. *Social cognition*, *25*(5), pp.638-656.
Suleiman, M.A., 2023. The impact of tourism supply chain on sustainable performance in sub-Saharan Africa: evidence from Tanzania. *Management of Environmental Quality: An International Journal*, *34*(2), pp.492-510.
Tian, G., Lu, W., Zhang, X., Zhan, M., Dulebenets, M.A., Aleksandrov, A., Fathollahi-Fard, A.M. and Ivanov, M., 2023. A survey of multi-criteria decision-making techniques for green logistics and low-carbon transportation systems. *Environmental Science and Pollution Research*, *30*(20), pp.57279-57301.
Thommandru, A., Espinoza-Maguiña, M., Ramirez-Asis, E., Ray, S., Naved, M. and Guzman-Avalos, M., 2023. Role of tourism and hospitality business in economic development. *Materials Today: Proceedings*, *80*, pp.2901-2904.
Ukaogo, P.O., Ewuzie, U. and Onwuka, C.V., 2020. Environmental pollution: causes, effects, and the remedies. In *Microorganisms for sustainable environment and health* (pp. 419-429). Elsevier.
Wanderlust Travel Media, 2021. 8 Easy ways to become a more eco-friendly traveler in Thailand. Available at http://www.responsiblethailand.co.uk/green-tourism/easy-ways-to-reduce-carbon-footprint-in-thailand/

THE KEY DRIVERS AND BARRIERS IN THE ADOPTION OF MEDICATION DISPENSING TECHNOLOGY

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ABSTRACT

Purpose - This research aims to identify the keys driver and barriers that influence the adoption of medication dispensing technology. The study seeks to contribute to inform the seamless integration of healthcare technology into the fabric of modern medical practices.
Design/methodology/approach - This research employs an interview approach. Qualitative data is gathered through semi-structured interviews with healthcare stakeholders.
Findings - The findings reveal a complex interplay of keys driver and barriers influencing medication dispensing technology adoption. Clinical benefits emerge as a primary driver, with healthcare professionals emphasizing improved patient outcomes.
Research limitations/implications - Limitations of this research are potential participant response only conceptual framework of key drivers and barriers of sample size, and generalizability constraints. The research primarily focuses on specific Thai healthcare.
Practical implications - The research findings offer valuable insights for healthcare stakeholders. Organizations can leverage the understanding of influencing factors to develop tailored adoption strategies. Healthcare providers can better navigate the complexities of technology integration and can refine their offerings to align with healthcare needs.
Originality/value - This research contributes to the field by comprehensively analyzing the multifaceted keys driver and barriers that impact medication dispensing technology adoption. It offers a nuanced understanding of stakeholders' complex decision-making processes, contributing to healthcare technology adoption.

Keywords – drivers, barriers, healthcare, medication dispensing, technology

Introduction

Integrating advanced technology into healthcare has revolutionized medical practices, promising enhanced patient care, streamlined processes, and improved outcomes (Akhtar *et al.*, 2023). Technology is a revolutionary concept in the realm of intelligence technology (Islam *et al.*, 2015), offering promising solutions for enhancing healthcare services, particularly within the medication dispensing process. It has the potential to minimize errors and optimize processes for greater efficiency (Nadhira & Dachyar, 2020; Prajapati *et al.*, 2018).

However, successful medication dispensing technology adoption is not solely technological. It is a complex interplay of multifaceted factors determining the extent and pace of implementation (Nadhira & Dachyar, 2020). In addition, the successful implementation of technology in the medication dispensing process

necessitates careful consideration of critical decision factors by both the medication dispensing process and hospital stakeholders (Aamir *et al.*, 2018)

In order to understand these factors becomes paramount as technology continues to reshape the healthcare landscape. This research aims to comprehensively analyze the key drivers and barriers healthcare organizations and providers face when considering integrating new technologies. The adoption of healthcare technology transforms medical practices and improves patient care (Kraus *et al.*, 2021). This research method provides a comprehensive understanding of the complexities surrounding medication dispensing technology used in healthcare by employing qualitative interviews. Shedding light on these factors can gain insights into the challenges and opportunities that arise during the adoption process. An in-depth interview can pave the way for informed the seamless integration of healthcare technology into the fabric of modern medical practices.

This research starts with an introduction to this study. Following that is section two, which encompasses the literature review about the comprehensive importance of medication dispensing technology. The subsequent section focuses on the research methods, describing the methodology and outlining the steps undertaken. Section four is dedicated to presenting the results, and finally, the last section encompasses the conclusion and summarizing the research findings.

The important of medication dispensing technology

Healthcare organizations face increasing regulatory requirements for medication management. Technology solutions can assist in meeting these standards and reduce the risk of error (Astier *et al.*, 2020). This section explains the literature review, which covers the importance of medication dispensing technology. That has been extensively explored in existing research, ensuring adoption and implementation within healthcare services.

Technology in the medication dispensing process can help ensure the proper medication, dosage, and administration time, improving patient safety (Alam *et al.*, 2018). Modern technology enables precise medication dosing and administration, reducing the risk of under-dosing or over-dosing. That is particularly crucial in complex treatment regimens. Technology, such as electronic prescribing (e-prescribing), Internet of Things, sensors, barcode, pick-to-light, dispensing machine, and computerized physician order entry (CPOE) (Ciapponi *et al.*, 2021), significantly reduce medication errors (Kuiper *et al.*, 2007). Automating medication management processes generally leads to time savings for healthcare professionals. This efficiency allows them to focus more on direct patient care, ultimately improving the overall patient experience (Alam *et al.*, 2018).

Technology facilitates accurate and comprehensive record-keeping, enabling healthcare providers to track medication histories, monitor interactions, and assess patient responses more effectively (Haleem *et al.*, 2021, 2022). In addition, access to real-time patient data through electronic health records (EHRs) and other systems supports better decision-making by healthcare professionals during medication administration (Schopf *et al.*, 2019). Technology can aid in monitoring patient adherence to prescribed medications. That is especially important for patients with chronic conditions where medication non-adherence can lead to treatment inefficacy (Chen *et al.*, 2020). Healthcare organizations must adhere to strict regulatory guidelines in medication management. Technology helps ensure compliance and reduces the risk of medication-related errors. While initial costs might be associated with implementing technology, it can lead to long-term cost savings by reducing errors, preventing adverse events, optimizing inventory management, and improving overall operational efficiency (Buer *et al.*, 2021).

As mentioned above, this research aims to thoroughly identify the critical factors that impact the adoption of medication dispensing process technology within healthcare services. Through identifying primary drivers and barriers, this study seeks to offer valuable insights that empower informed decision-making and the

creation of efficient strategies, all aimed at achieving a smooth integration and maximizing the benefits of medication dispensing technology. The following section will describe the research methodology.

Research methodology

The research methodology was used for in-depth interviews on the key drivers and barriers to healthcare technology adoption. That is a systematic framework encompassing data collection, analysis, and interpretation. The primary goal is to comprehensively understand the intricate factors influencing the adoption of medication dispensing technology. Figure 1 presents the research outlines the essential components of this research methodology.

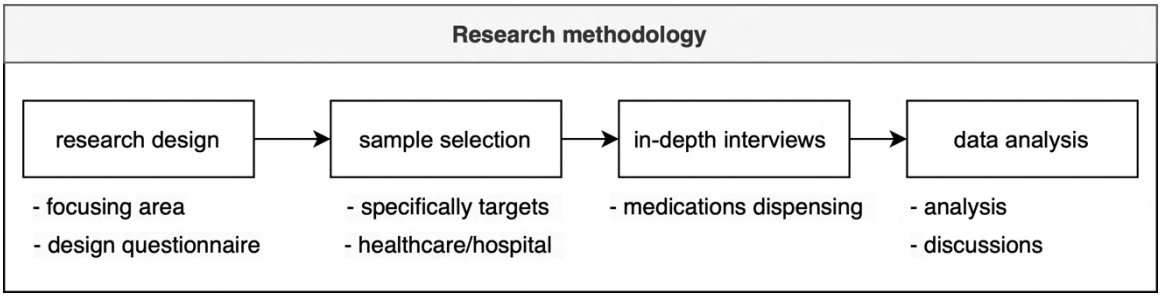

Figure 1: Research methodology

The initial phase is the research design, which on conducting in-depth interviews with healthcare professionals and administrators. These interviews serve as a crucial means to capture nuanced insights and perceptions.

Question 1: What drivers impact adaptation/used medication dispensing technology?
Question 2: What are the limitations or constraints in medication dispensing technology?

Following this, the sample selection, this research specifically targets involved in medication dispensing, including healthcare professionals, administrators, and pharmacists. This research selects the healthcare/hospital, including public and private hospitals.

The subsequent step involves data analysis. This qualitative approach examines interview transcripts and discussions to identify recurring themes and patterns. The insights from this analysis highlight the key drivers and barriers, thus providing valuable guidance for decision-making, technology design, and effective implementation strategies.

Through applying this research methodology, the study aims to shed light on the intricate complexities associated with adopting healthcare technology. The resulting insights offer valuable guidance to stakeholders navigating the ever-evolving landscape of modern healthcare practices.

Research Result

This research delves into the key drivers and barriers shaping medication dispensing technology adoption, exploring the intricate connections between clinical efficacy, regulatory compliance, and user experience.

This research conducted field visits to observe the actual work practices and interview executives' hospital team, administration, and medical staff involved in medication dispensing, both for inpatients and outpatients. This interview is about integrating technology solutions into the medication dispensing process. This study covered six large hospitals in Thailand, categorized into two public hospitals, two private hospitals, and two university hospitals.

Following the interview and observations allowed the researchers to identify significant issues, particularly in the prescription screening and managing a large volume of medications. These issues led to a decrease in the efficiency of medication dispensing, longer waiting times for patients, and a decline in the overall system performance.

Ultimately, it is essential to consider the factors that impact the system's performance to analyze the implementation of IoT for enhancing the efficiency of the medical supply/medication storage system, **"**What drivers impact adaptation/used medication dispensing technology?" and "What are the limitations or constraints in medication dispensing technology?". The researchers found that by summarizing the key factors that affect the system's efficiency, as Table 1

Drivers	**public hospitals**		**private hospitals**		**university hospitals**	
	A1	**A2**	**B1**	**B2**	**C1**	**C2**
falling number of pharmacists	✓	✓	✓	✓	✓	✓
more difficult or complex diseases		✓		✓	✓	✓
increasing number of drugs			✓		✓	
growing number of patients	✓	✓	✓	✓	✓	✓
technology transformation	✓		✓		✓	
Barriers						
unfriendly user interface	✓	✓	✓		✓	
slow robots speed in high demand				✓	✓	✓
limitation throughput technology				✓		✓
modifying machine to a new drug			✓	✓	✓	✓
limited LASA drugs	✓	✓	✓	✓	✓	✓

Table 1: Keys driver and barriers of medication dispensing technology

Drivers impact adaptation/used medication dispensing technology

The falling number of pharmacists is the first driver impacting the adaptation/use of medication dispensing technology. Healthcare is facing a shortage of qualified pharmacists, which can impact the quality of patient care and lead to increased workloads for existing pharmacists. This shortage can be attributed to an aging population, increased demand for healthcare services, and expanding pharmaceutical roles beyond traditional pharmacy settings.

After COVID-19 pandemic situation, diseases are more difficult or complex. The emergence of new diseases or the increasing complexity of existing diseases (e.g., drug-resistant strains) places additional demands on healthcare systems. Addressing these challenges requires continuous medical research, innovative treatments, and effective public health measures. That challenges pharmacists in terms of understanding disease mechanisms and treatment options and managing patient medications effectively.

Following this, diseases will become more complex cause of an increasing number of drugs or medications. The pharmaceutical industry is continually developing new drugs to treat a wide range of conditions. While this expands treatment options, it also necessitates robust regulatory oversight to ensure drug safety and efficacy—which affect the medication dispensing process and treatment.

Due to the aging society, the growing number of patients is one of the main drivers to accept technology in healthcare services. Population growth, aging demographics, and improved healthcare access can lead to a more significant number of patients seeking medical care. That requires healthcare systems to scale their services, manage patient flow efficiently, and address the needs of diverse patient groups.

In addition, the technology transformation. Technological advancements, such as telemedicine, electronic health records, automation and artificial intelligence, and AI-driven diagnostics, are transforming healthcare operations. While these innovations offer opportunities to improve efficiency and patient outcomes, they also require careful implementation and consideration of ethical, legal, and privacy concerns.

Finally, safety standards are critical in healthcare to ensure patient well-being. Healthcare providers must adhere to rigorous safety protocols to minimize patient risks, including hygiene, infection control, and medication management. Ensuring patient safety is paramount in pharmacy practice. Pharmacists must stay vigilant about medication errors, adverse drug reactions, and proper dispensing procedures to maintain high safety standards.

These points highlight the evolving landscape of pharmacy and healthcare, where pharmacists must navigate a range of challenges related to workforce shortages, medical complexities, technological changes, and patient care. Adapting to these changes often requires ongoing education and training to ensure pharmacists can provide their patients with the best possible care.

Barriers, limitations or constraints in medication dispensing technology

The first barrier of using medication dispensing technology from the interview is unfriendly user interface. The user interface of a system, software, or device used in a pharmacy is not user-friendly, it can lead to inefficiencies, errors, and frustration among pharmacy staff. A well-designed interface is crucial to ensure smooth operations and reduce the potential for mistakes.

The second barrier is robots in the peak-time duration. In high demand (high number of prescriptions), pharmacists can work faster than dispensing machine (leading to higher error rates and significantly increased workload). While robots can help reduce errors in medication dispensing, they may work at a slower pace due to the complexity of their processes and the need to follow precise steps programmed from the control system.

Moreover, the "pick to light" technology, which guides workers to specific items using lights, might be efficient but can limit throughput, as only one person can work at a time. It could lead to slower overall operations and workflow, leading to inefficiencies, especially if there is a high demand for medication dispensing.

Introducing new drugs could necessitate changes in automated systems. Adapting a machine to accommodate a different drug involves modifying its software and hardware components to be configured and dispensing the correct medications. Modifying a machine's setup for a new drug requires taking it to the factory, causing delays and interruptions in the medication process.

Lastly, the dispensing machine is still limited to Look Alike Sound Alike (LASA) drugs. LASA refers to drugs that have similar names or appearances, which can potentially lead to medication errors if not properly identified. This is an important safety concern in healthcare, as errors related to LASA drugs can have serious consequences.

Conclusion

This study aims to provide insights to medication dispensing process administrators, outlining essential drivers and barriers that pave the way for the effective integration of technologies into the medication dispensing process setting.

Following a dep-interview in six hospitals in Thailand, the research found that medication dispensing technology can help reduce errors in tasks of medication dispensing. Due to the falling number of pharmacists, more difficult or complex diseases, a growing number of patients, safety standards, and technology transformation. It is essential for medication dispensing operations to adapt technology in service.

Finding the right solutions that minimize errors while optimizing speed and efficiency is a crucial challenge. While automatic machines can deliver medications, there might still be issues with LASA drug conditions and demand time and operate slower due to their programmed steps and several limitations. It is essential to consider a balance between automated processes' speed and error rate to ensure patient safety and satisfaction. That also includes user interfaces, efficiency, and accuracy. Continuous improvement and adaptation to emerging technologies are crucial for providing safe and effective pharmaceutical services.

Limitations of this research are potential participant response only conceptual framework of key drivers and barriers of sample size, and generalizability constraints. The research primarily focuses on specific Thai healthcare.

Future research will develop the technology road mapping for the medication dispensing process. This roadmap aims to guide the strategic implementation of technology within the medication process, leading to notable enhancements in patient efficiency, workload management, and reduced errors across healthcare systems.

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References
Aamir, J., Ali, S. M., Boulos, M. N. K., Anjum, N., and Ishaq, M. (2018), "Enablers and inhibitors: a review of the situation regarding mHealth adoption in low-and middle-income countries". Health Policy and Technology,Vol. 7 No.1,pp. 88-97.

Akhtar, M. N., Haleem, A., and Javaid, M. (2023), "Scope of health care system in rural areas under Medical 4.0 environment". Intelligent Pharmacy.

Alam, S., Osama, M., Iqbal, F., and Sawar, I. (2018), "Reducing pharmacy patient waiting time". International journal of health care quality assurance,Vol. 31 No.7,pp. 834-844.

Astier, A., Carlet, J., Hoppe-Tichy, T., Jacklin, A., Jeanes, A., McManus, S., . . . Fitzpatrick, R. (2020), "What is the role of technology in improving patient safety? A French, German and UK healthcare professional perspective". Journal of Patient Safety and Risk Management,Vol. 25 No.6,pp. 219-224.

Buer, S.-V., Semini, M., Strandhagen, J. O., and Sgarbossa, F. (2021), "The complementary effect of lean manufacturing and digitalisation on operational performance". International Journal of Production Research,Vol. 59 No.7,pp. 1976-1992.

Chen, X., Zhou, X., Li, H., Li, J., and Jiang, H. (2020), "The value of WeChat application in chronic diseases management in China". Computer Methods and Programs in Biomedicine,Vol. 196,pp. 105710.

Ciapponi, A., Fernandez Nievas, S. E., Seijo, M., Rodríguez, M. B., Vietto, V., García-Perdomo, H. A., . . . Garcia-Elorrio, E. (2021), "Reducing medication errors for adults in hospital settings". Cochrane Database Syst Rev,Vol. 11 No.11,pp. Cd009985. doi:10.1002/14651858.CD009985.pub2

Haleem, A., Javaid, M., Singh, R. P., and Suman, R. (2021), "Telemedicine for healthcare: Capabilities, features, barriers, and applications". Sensors international,Vol. 2,pp. 100117.

Haleem, A., Javaid, M., Singh, R. P., and Suman, R. (2022), "Medical 4.0 technologies for healthcare: Features, capabilities, and applications". Internet of Things and Cyber-Physical Systems.

Islam, S. R., Kwak, D., Kabir, M. H., Hossain, M., and Kwak, K.-S. (2015), "The internet of things for health care: a comprehensive survey". IEEE Access,Vol. 3,pp. 678-708.

Kraus, S., Schiavone, F., Pluzhnikova, A., and Invernizzi, A. C. (2021), “Digital transformation in healthcare: Analyzing the current state-of-research”. Journal of Business Research,Vol. 123,pp. 557-567.

Kuiper, S. A., McCreadie, S. R., Mitchell, J. F., and Stevenson, J. G. (2007), “Medication errors in inpatient pharmacy operations and technologies for improvement”. Am J Health Syst Pharm,Vol. 64 No.9,pp. 955-959. doi:10.2146/ajhp060267

Nadhira, A., and Dachyar, M. (2020), “Selection factor analysis for Internet of Things (IoT) implementation using DEMATEL based ANP and COPRAS method at the hospital intensive care unit (ICU)”. Int. J. Adv. Sci. Technol,Vol. 29 No.7,pp. 3614-3622.

Prajapati, B., Parikh, S., and Patel, J. (2018). “An intelligent real time IoT based system (IRTBS) for monitoring ICU patient”. Paper presented at the Information and Communication Technology for Intelligent Systems (ICTIS 2017)-Volume 2 2.

Schopf, T. R., Nedrebø, B., Hufthammer, K. O., Daphu, I. K., and Lærum, H. (2019), “How well is the electronic health record supporting the clinical tasks of hospital physicians? A survey of physicians at three Norwegian hospitals”. BMC health services research,Vol. 19 No.1,pp. 1-9.

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