ICLT 2024

THE 14th INTERNATIONAL CONFERENCE ON LOGISTICS AND TRANSPORT 2024

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SUPPLY CHAIN MANAGEMENT RE-IMAGINED ENABLING CONNECTIVITY WITH PHYSICAL INTERNET

18-22 NOVEMBER 2024 | SEOUL | S.KOREA

THAMMASAT BUSINESS SCHOOL

MIdS Multidisciplinary and Interdisciplinary School CHIANG MAI UNIVERSITY

CAU CHUNG-ANG UNIVERSITY 1916

SCEM Supply Chain and Engineering Management Research Unit Chiang Mai University

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"Supply Chain Management Re-Imagined" Enabling Connectivity with Physical Internet"

Proceeding of International Conference on Logistics and Transport 2024

[MANUSCRIPT]

CONFERENCE LOCATION
SEOUL- SOUTH KOREA
CONFERENCE VENUE
CHUNG-ANG UNIVERSITY

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INTRODUCTION

International Conference on Logistics and Transport This is the 14th international conference organised by the Center of Excellence in Connectivity at Thammasat Business School, Thammasat University, the Multidisciplinary and Interdisciplinary School of Chiang Mai University and the Supply Chain and Engineering Management Research Unit of Chiang Mai University. This is a major event for researcher in transport, logistics, supply chain and value chain management especially in the Asia Pacific region.

This year's event in Seoul (South Korea), 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), 2023 in Helsinki (Finland). This year's event will be held in Seoul, South Korea, during November 18th to 22nd, 2024, hosted by Chung-Ang University, organised by North-East Asia Logistics and Distribution Research Institute (NALDI).

The theme for this year's event is "Supply Chain Management Re-Imagined, Enabling Connectivity with Physical Internet". Discover how this transformative approach empowers businesses to seamlessly connect with the Physical Internet, revolutionalising the way goods and information flow across the global supply chain network. Gain insights from leading experts, engage in stimulating discussions, and unlike the potential for enhanced efficiency, sustainability, and resilience in supply chain operations. The official language of the Conference is English. Join us at the forefront of innovation in supply chain management. We sincerely hope to see all of you at the event.

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WELCOME ADDRESS FROM THE CONFERENCE CHAIRS

On behalf of the ICLT General Chair, it is our great pleasure to welcome you to the **International Conference on Logistics and Transport (ICLT) 2024** here in South Korea. We are delighted to bring together leading minds from across the globe in the fields of logistics, transportation, and supply chain management to share insights, forge new collaborations, and explore innovative solutions to the challenges facing our industry.

The theme of **"Supply Chain Management Re-Imagined: Enabling Connectivity with the Physical Internet"** captures the transformative vision of this year's discussions. As we face increasingly complex global challenges, the concept of the Physical Internet represents a pivotal step towards enhanced connectivity, efficiency, and sustainability across supply chain networks. This conference provides a platform for thought-provoking discussions on how supply chain management can evolve in alignment with this innovative framework to meet the demands of tomorrow.

We are grateful to our distinguished speakers, session chairs, and participants whose expertise and dedication make this event possible. The conference program has been thoughtfully designed to foster meaningful discussions, facilitate networking, and inspire innovative ideas that will undoubtedly drive our field forward. We are confident that these exchanges will not only contribute to the professional growth of each participant but will also provide valuable perspectives on how our field can adapt and thrive in a rapidly changing world.

I would also like to extend our heartfelt thanks to our sponsors, partners, and the local organizing team for their support and hard work in bringing this conference to fruition. Their efforts have been essential in creating an environment conducive to learning, collaboration, and growth.

Once again, welcome to ICLT 2024. We look forward to an engaging and successful conference and to the many exciting contributions that each of you will bring to this gathering.

Warm regards,

Poti Chaopaisarn
ICLT General Chair

WELCOME ADDRESS FROM THE LOCAL CHAIRS

It is with great pride and excitement that I welcome you to the **International Conference on Logistics and Transport (ICLT) 2024** here in South Korea. On behalf of Chung-Ang University and the local organizing committee, we are honored to host this prestigious event in our country and delighted to join such a distinguished gathering of experts in logistics, transportation, and supply chain management.

This year's theme, **"Supply Chain Management Re-Imagined: Enabling Connectivity with the Physical Internet,"** resonates deeply with our shared goal of building a more connected, efficient, and sustainable future. As logistics and supply chain professionals, we stand on the threshold of transformative advancements that promise to reshape our field. This conference provides a valuable platform to exchange knowledge, explore groundbreaking research, and discuss the ways in which the concept of the Physical Internet can redefine connectivity in supply chain networks worldwide.

We are immensely grateful to all the speakers, session chairs, and participants who bring their expertise and passion to this event, as well as to our sponsors and supporters who have contributed to making this conference possible. I also extend a warm welcome to our international and local guests, who enrich our discussions with a diverse range of perspectives and insights.

I hope that your time in South Korea is not only academically rewarding but also culturally enriching. May you take this opportunity to experience the unique heritage and hospitality of our country as you connect with colleagues and fellow researchers.

Once again, welcome to ICLT 2024. I look forward to the inspiring conversations and collaborative spirit that will undoubtedly make this conference a memorable and impactful experience for all.

Warm regards,

Polin Lai
ICLT General Chair

CONTENT

ADAPTING SERVICE BLUEPRINT WITH A TOUR PROGRAMME

Puthipong Julagasigorn, Phornphan Roopklom, Koratach Sukhong, Natnicha Sompornsuksawad, Monsicha Jeennakorn, Pornpimai Thanasarn
Hospitality and Tourism Management Department, International College for Sustainability Studies, Srinakharinwirot University, Bangkok, Thailand 10110

ABSTRACT

Purpose: This study explores the flows and processes of a tour program to identify interactions between tourists, tour operators, and service providers. Additionally, it highlights critical problems and issues encountered during the tour that may decrease tourism performance and tourist satisfaction.
Design/methodology/approach: Participant observation was employed to investigate a one-day trip. Researchers took part in the tour program as both tour operators and tourists, which enhanced data triangulation and ensured consistency in the findings. A service blueprint was adapted to diagram and visualise (1) tourism processes based on the tour itinerary, (2) the main actors involved in the tour program, and (3) four logistics flows: physical, information, tourist, and financial. Problems and issues encountered during the tour were recorded to highlight critical supply chain and logistical concerns that may require improvement.
Findings: The adapted service blueprint proved useful for diagramming the tour program. It outlines the tourist journey and the interactions between tourists, the tour operator, and other service providers. Key touchpoints were identified and found to significantly impact tourist satisfaction. The findings also indicated that both the tour operator and the guide played crucial roles in enhancing tourist satisfaction and influencing overall tour performance. Some issues that arose during the trip, such as delayed public transport, were nearly impossible to eliminate, as they fell outside the tour operator's primary responsibilities and presented challenges that increased costs and extended the duration of the tour. Based on this study, several opportunities for future research in the areas of supply chain and marketing are suggested.
Practical implications: The study demonstrates how to visualise a tour program using the adapted service blueprint.
Originality/value: The study proposes the adapted service blueprint which can effectively map a tour program.
Keywords: tourism supply chain, tourism logistics, service blueprint, touchpoint, tourist experience
Article classification: research paper

Introduction

The tourism sector is one of the largest and fastest-growing economic sectors (UN Tourism, 2023). Its contribution to the economy—and vice versa—arises from the myriad activities and businesses involved (Aratuo and Etienne, 2019). These businesses encompass, but are not limited to, tour operators and agencies, travel and transportation, lodging and accommodation, shopping, recreation and entertainment, and food and beverage (Pizam, 2009; Piboonrungroj, 2012; Aratuo and Etienne, 2019). As a result, the tourism service system is complex and involves various stakeholders and resources (Gao et al., 2022).

From a marketing perspective, scholars generally agree that tourism branding, service quality, tourist satisfaction, and tourist experience are influenced by the different stakeholders involved in tourism (Faerber et al., 2021; Gao et al., 2022; Kim and So, 2022; Kim and So, 2024). These areas of research have garnered significant academic attention. Chen et al. (2021) have called for studies that explore how different tourism service providers affect the tourist experience. Similarly, Gao et al. (2022) have urged investigations into the supply-side aspects of tourism, which are often overlooked in the literature, specifically regarding the interactions and collaborations among stakeholders in the tourism network.

In response to these calls, this study adopts a supply chain approach. Scholars have suggested that understanding the "AS-IS" state of the supply chain—in terms of its network structure, processes, and configurations—is essential for further action (Lambert et al., 1998). Visualisation-aid tools are often employed to reveal this "AS-IS" status (Banomyong et al., 2019). This study adapts the visualisation-aid tool of service blueprinting to uncover the "AS-IS" status and activities of a tour program. The findings indicate that the tool requires adaptation but proves useful in identifying actors, interactions between tourists and service providers, as well as the flows and processes involved in the tour

program. Critical problems and issues encountered during the tours were revealed, indicating potential decreases in tourism performance related to cost, time, and tourist satisfaction.

Moreover, this study identified interactions not only between tourists and service providers (B2C) but also among various service providers (B2B) involved in the tour program, addressing the call for research on B2B collaboration (Gao et al., 2022). Based on the study's findings, further research on the tourism supply chain and logistics, as well as tourism marketing, is encouraged.

Literature review

Tourism supply chain

A tourism supply chain consists of multiple interrelated supply chains due to the involvement of various stakeholders in providing services to tourists. These stakeholders can be categorised as firms at the upstream end (e.g., businesses that supply resources and services) or at the downstream end (e.g., businesses that sell tourism products and services to tourists) (Zang et al., 2009; Piboonrungroj, 2012). Zang et al. (2009) outline a tourism network structure from an upstream-downstream perspective. The downstream end of a tourism supply chain includes tourists, while tour agents act as retailers, gathering and distributing tourism products. At the upstream end, tier-1 suppliers are considered service providers that directly supply tourism services to tourists (e.g., theme parks, shopping malls, restaurants, and hotels), while tier-2 suppliers are other companies that provide tourism-related goods and services to first-tier suppliers.

While Zang et al. (2009) suggested a tourism network structure, Piboonrungroj (2012) classified stakeholders based on their roles. First, input providers (e.g., food supply chains) supply resources and materials for service operations. Second, service providers (e.g., restaurants, hotels, and airlines) are key players that deliver services to tourists and significantly influence tourist satisfaction. Third, tour agents and operators serve as intermediaries and gatekeepers within the tourism supply chain, assembling tourism-related products and services for tourists while managing tourist flows. Fourth, freight transport facilitates the physical movement of goods between input providers and service providers. Fifth, passenger transport is responsible for transporting tourists. Finally, supportive businesses (e.g., souvenir shops and waste management companies) aid in supporting tourism operations.

The flows and processes of the tourism supply chain can be explained in three stages: pre-travel, on-travel, and post-travel (Piboonrungroj, 2012; Gao et al., 2022). These stages are adapted from the concepts of customer journey and customer experience, which originated in consumer research (Faerber et al., 2021; Gao et al., 2022). In the pre-travel stage, tourists engage in activities such as inquiring about information, arranging trips, and processing booking procedures. During the on-travel stage, they travel and receive services from various providers. The post-travel stage encompasses all activities tourists undertake after the trip is completed, including providing feedback.

Performance measures used in the tourism supply chain can be categorised into three groups (Zang et al., 2009). Financial performance measures include revenue, profit, and costs (e.g., distribution, production, and inventory). Operational performance measures focus on response time, lead time, and product quality and availability. Overall supply chain performance measures primarily centre on tourist satisfaction.

Tourist experience and touchpoints

The tourist experience is influenced by various stakeholders and touchpoints (Gao et al., 2022). From a consumer perspective, these touchpoints refer to the interactions between customers, products, services, firms, and other influencers (Kim and So, 2024). Kim and So (2024) further explain that touchpoints are perceived by tourists when services are realised, occurring at the moment service providers and tourists interact within a service scape.

In the tourism literature, Kim and So (2022) note that there is limited knowledge regarding touchpoints and the tourist experience. Specifically, there are questions about how we define and identify touchpoints in tourism, which touchpoints have the most significant impact on the creation of tourist experiences, and how multiple touchpoints integrate within the service delivery process to ensure superior tourist experiences.

Service blueprinting

Many approaches can be used to improve tour performance and enhance the tourist experience (see, for example, Zang et al., 2009; Piboonrungroj, 2012; Gao et al., 2022). One such tool is the service blueprint, pioneered by Shostack (1982), which has been utilised to explore improvements in the tourism service system (Gao et al., 2022). A service blueprint helps visualise activities, steps of service production, and the actors involved, providing a comprehensive overview of the design of tourism products (Gyimóthy, 2000; Gao et al., 2022). It enables organisations to identify and address inefficiencies and weaknesses in the service process (Harris and Van Der Veen, 2020).

Service blueprinting and touchpoints are interrelated concepts. While service blueprinting reflects how a company realises its services for further improvement, touchpoints illustrate the customer's perspective on what occurs during the service experience (Kim and So, 2024). Touchpoint mapping, also known as customer journey mapping, extends beyond the service firm's scope to include customer thoughts and feelings, whereas service blueprinting is limited to services in action (Harris & Van Der Veen, 2020).

Creating a service blueprint involves five components and four steps (Bitner et al., 2008) (Figure 1). First, customer activities are delineated, encompassing all steps that customers take as part of the service delivery process that is performed by the contact employees. These activities can be depicted chronologically. Second, the actions of contact employees are outlined, both onstage and backstage. Onstage activities are separated from customer activities by the line of interaction (i.e., touchpoints). These operational activities are visible to customers and are performed by the contact employees who deliver service to customers. Backstage activities are separated from onstage activities by the line of visibility. These are invisible to customers although they are performed by the contact employees. Third, support processes are separated from backstage activities by the line of internal interaction, which includes all activities performed by the not-contact employees but contribute to producing products and services. These processes also refer to the systems and procedures undertaken by employees in support of service delivery (Pandey and Kulshrestha, 2021). Finally, physical evidence is delineated, encompassing all tangible elements that customers encounter.

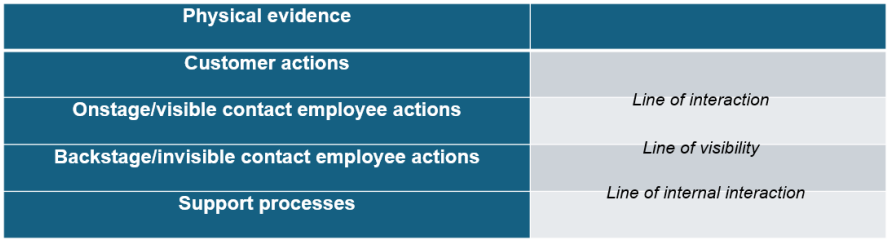

Figure 1: Service blueprinting (adapted from Bitner et al., 2008)

Service blueprinting clearly has limitations and needs to be adapted for investigating the supply-side aspects of tourism. Firstly, onstage and backstage activities are performed not only by tour agents and operators (firms at the downstream end) but also by other service providers, such as restaurants and hotels (tier-1 suppliers). There was only one firm (a hotel) in Bitner et al. (2008) and Pandey and Kulshrestha (2021). However, due to the complex nature of tourism, the contact employees come from different firms. Therefore, both onstage and backstage activities must be expanded to include tier-1 suppliers.

Secondly, support processes are activities performed or the systems and procedures undertaken to support the service delivery. In the tourism context, generally, these support processes can be the systems, procedures, and not-contact employees of service providers and tour operators. The activities should be expended to these entities of companies in various supply chains that provide tourism-related goods and services to tier-1 suppliers and tour operators.

Due to these challenges, this study's scope is limited to tier-1 suppliers and support processes are not considered. Future research should explore tier-2 suppliers and other systems, procedures, and not-contact employees of companies in various supply chains that provide tourism-related goods and services to tier-1 suppliers and tour operators.

Research methodology

Tour programme

The tour program used in this study was a one-day trip offered to both international and Thai students at the International College for Sustainability Studies (SWUIC), Srinakharinwirot University. The tour itinerary was created by the second author, who has over 10 years of experience as a tour planner and has used this itinerary for more than 3 years. The trip was designed as a tailor-made private tour, featuring three destinations: the Grand Palace, Wat Pho, and Wat Arun (Figure 2).

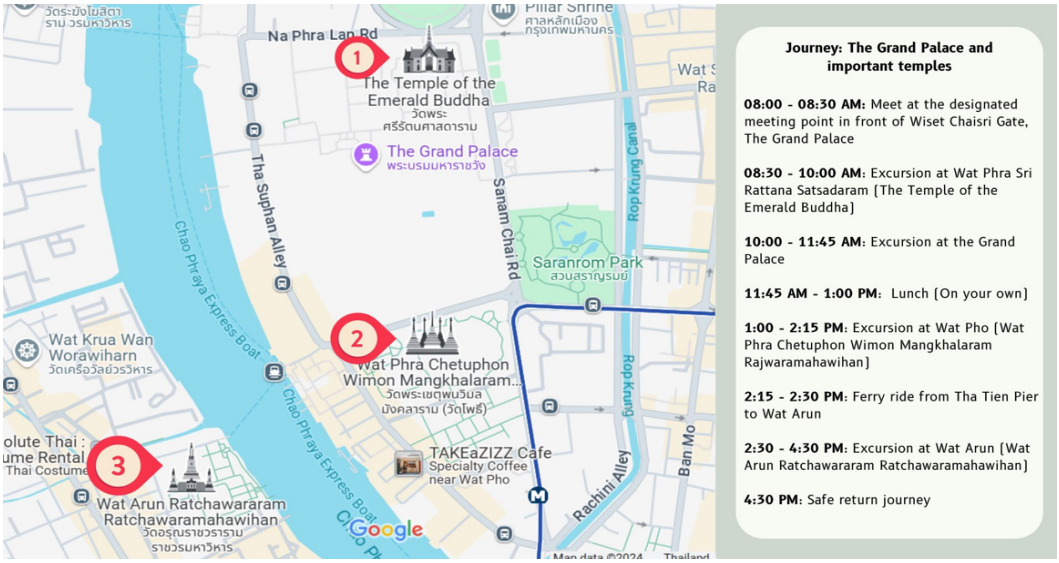

Figure 2: The itinerary for the study (authors)

The investigation for this study was conducted during the trip in March 2024, which included 67 Thai and international students. The second author acted as the tour operator, while a professional tour guide with over 10 years of experience in tour guiding was hired to lead the group.

Participant observation

Participant observation was employed to investigate this tour program. All authors, except the first, participated in the trip, taking on roles as both tour operators and tourists to observe and record all activities that occurred. The second author served both as a tour operator and data collector, while the remaining authors acted solely as data collectors. The main activities focused on the tourists' actions as outlined in the itinerary. During the observation, most tourists' activities aligned with the itinerary; however, some deviations were noted and recorded in field memos. Other activities performed by the tour operator (the second author), the tour guide, and other stakeholders involved in the trip were also documented. The field memos served as the primary data source for generating the blueprint.

After the trip, all data collectors developed their own blueprints separately, using Figure 1 as a guide. This process enhanced the research's trustworthiness through data triangulation. The first author (etic perspective) and the second author (emic perspective) then analysed and integrated all blueprints to create a comprehensive service blueprint for this study. Further adaptations were made as necessary to ensure the blueprint was well-suited to the study's context.

Findings

Adapted service blueprinting

The adaptation of a service blueprint was an iterative process. The chronological stages include pre-travel, on-travel, and post-travel stages (Gao et al., 2022), illustrating the activities in which tourists engage during their trip (Figure 3). The tourism process is defined as encompassing all tourist activities according to the itinerary, as well as other activities performed by service staff involved in tourism. Tourist activities consist of physical evidence—tangible and sensory stimuli to which tourists are exposed—and the activities undertaken by tourists, which may include those specified in the itinerary as well as other spontaneous actions during the trip.

Chronological stages: pre-travel, on-travel, and post-travel					
Tourism process		Activity 1	Activity 2	…	Activity *i*
Tourist activity	Physical evidence for tourists		*Line of interaction*		
	Tourist's activity				
Onstage activity	Tour operator's activity				
	Tour guide's activity				
	Service provider's activity		*Line of visibility*		
Backstage activity	Documents for the operator and service providers				
	Tour operator's activity		*Line of internal interaction*		
	Tour guide's activity				
	Service provider's activity				

Figure 3: The adapted service blueprint (authors)

Onstage activities include tasks performed by the tour operator, the tour guide, and other service providers. In this study, the guide is considered a tier-1 service provider. While tour operators are responsible for planning tours and itineraries, assembling tourism products and services, and coordinating with service providers, tour guides lead, communicate with, and educate tourists, facilitating interactions between them and other service providers (e.g., destinations and hotels) (Cetin and Yarcan, 2017). Thus, a tour guide acts as a representative of the tour operator and is responsible for ensuring the smooth process of the tour itinerary on behalf of the operator (Cetin and Yarcan, 2017). Additionally, in this study, the guide is distinguished from other service providers, as they engage with tourists throughout the entire trip, while service providers, such as destinations, interact with tourists for only a brief period. The activities of other service providers are also considered part of the onstage activity, as they are delivered directly to the tourists (i.e., they are touchpoints).

The backstage activity encompasses tasks performed by the tour operator and tier-1 suppliers. Documents for the operator and service providers are introduced in the blueprint, serving as contracts that outline the commitments regarding the tourism products and services provided to tourists. Activities carried out by the tour operator, the guide, and other service providers are included in this stage. The adapted service blueprint shown in Figure 3 was further used to illustrate the tourism process as illustrated in Figure 4 and 5.

Pre-travel					
Tourism process		Preparing itinerary	Selling itinerary	Booking	Pre-travel preparing
Tourist activity	Physical evidence for tourists	-	• Itinerary • Payment	-	-
	Tourist's activity	-	• Confirmed the itinerary • Processed the payment	-	-
Onstage activity	Tour operator's activity	-	• Explained the itinerary • Received payments	-	-
	Tour guide's activity	-	-	-	-
	Service provider's activity	-	-	-	-
Backstage activity	Documents for the operator and service providers	• Itinerary	-	• Reservation letters • Confirmation letters	• Trip schedule • Job order
	Tour operator's activity	• Created an itinerary	-	• Made the reservations with service providers • Received the confirmation letters	• Created the trip schedule (for the tourists) • Created a job order (for the tour guide)
	Tour guide's activity	-	-		• Received the job order • Prepared the destination's information (for the tourists)
	Service provider's activity	-	-	• The Grand Palace and temples received reservation letters and made the confirmation letters.	
Problems and issues		-	-	-	-
Performance		-	-	-	-
Key success factor		-	-	-	-

Post-travel					
Tourism process		Trip schedule	On-travel preparing	On-travel	Post-travel
Tourist activity	Physical evidence for tourists	• Trip schedule	-	-	-
	Tourist's activity	• Acknowledged the trip schedule	-	-	-
Onstage activity	Tour operator's activity	• Explained the trip schedule	-	-	-
	Tour guide's activity	-	-	-	-
	Service provider's activity	-	-	-	-
Backstage activity	Documents for the operator and service providers	-	-	-	-
	Tour operator's activity	-	-	-	-
	Tour guide's activity	-	• Received the job order • Prepared the destination's information (for the tourists)	-	-
	Service provider's activity	-	-	-	-
Problems and issues		-	-	-	-
Performance		-	-	-	-
Key success factor		-	-	-	-

Physical flow — Information flow — Financial flow

Figure 4: The adapted service blueprint for the pre-travel stage (authors)

On-travel										
Tourism process	Meeting at the Grand Palace	Entering the Grand Palace	Sightseeing in the Grand Palace	Having lunches	Meeting and entering Wat Pho	Sightseeing in Wat Pho	Walking to the pier to take a ferry to Wat Arun	Entering Wat Arun	Sightseeing in Wat Arun	Going homes
Tourist activity – Physical evidence for tourists	• Public transport services	• Tourist Name List • Entrance gate	• Attractions	• Restaurants	• Permit letter	• Attractions	• Wat Pho Pier • Ferry	• Permit letter	• Attractions	• Public transport services
Tourist activity – Tourist's activity	• Travelled to the meeting point at the Grand Palace • Met at the meeting point	• Entered the Grand Palace	• Walked around the Grand Palace	• Had lunch at their convenience	• Entered Wat Pho	• Walked around Wat Pho	• Walked to the pier to get tickets • Took a ferry	• Entered Wat Arun	• Walked around Wat Pho	• Travelled back home
Onstage activity – Tour operator's activity	• Greeted the tourists	• Cooperated with the Grand Palace's staff to lead the tourists to the entrance gate	-	-	-	-	• Accompanied with the tourists to the pier to for a ticket • Took a ferry	-	-	-
Onstage activity – Tour guide's activity	• Greeted the tourists	• Gathered tourists and affirmed the Tourist Name List	• Provided the information about the Grand Palace	-	• Gathered tourists and affirmed Tourist Name List	• Provided the information about Wat Pho	• Accompanied with the tourists to the pier to get a ticket • Took a ferry	• Gathered tourists and affirmed Tourist Name List	• Provided the information about Wat Pho	-
Onstage activity – Service provider's activity	• Public transport services operated without an action from the tour operator.	• The destination's staff cooperated the tour operator to lead the tourists.	• The destination's staff handled safety and security and ensured that the sightseeing experience ran smoothly.	• Restaurants, located around the destinations, served foods and beverages.	• Wat Pho's staff at the gate checked the permit letter.	• The destination's staff handled safety and security and ensured that the sightseeing experience ran smoothly.	• Public ferry operator sold tickets to tourists and the tour operators individually. • Ferry carried the tourists.	• Wat Arun's staff at the gate checked the permit letter.	• The destination's staff handled safety and security and ensured that the sightseeing experience ran smoothly.	• Public transport services operated without intervention from tour operators.
Backstage activity – Documents for the operator and service providers	-	• Confirmation letter • Tickets	-	-	• Permit letter	-	-	• Permit letter	-	• Working time sheet
Backstage activity – Tour operator's activity	-	• Confirmed the reservation with the Grand Palace's staff	-	-	• Obtained the permit letter from the staff at the office and presented it to the gate staff	-	-	• Obtained the permit letter from the staff at the office and presented it to the gate staff	-	• Paid reimbursements to the tour guides
Backstage activity – Tour guide's activity	-	-	-	-	-	-	-	-	-	• Signed a working time sheet and earned reimbursements
Backstage activity – Service provider's activity	-	• The Grand Palace received the confirmation letter and processed tickets within their operations.	-	• Restaurants prepared foods and beverages.	• Wat Pho's office staff handed the permit letter to the tour operator; the gate staff received it from the tour operator	-	-	• Wat Arun's office staff handed the permit letter to the tour operator; the gate staff received it from the tour operator	-	-
Problems and issues	A tourist flow issue: Some tourists did not sure how to go from a public transport station to the meeting point while some others had arrived and waited for a half hour.	A service provider issue: The Grand Palace offered free tickets to all tourists, as they were students. However, their internal operations were complex. Some staff at the gate were unsure whether they should charge a fee to the foreign students, which resulted in delays at the entrance and complaints from the tourists about the tour operator.	A tourist flow issue: Some tourists lost interest and felt bored with the scenes at the destination and were also annoyed by the hot weather.	A tourist flow issue: Some tourists had lunch at distant restaurants, resulting long distance travelling and delays.	A service provider issue: Obtaining the permit letter from one staff and delivering it to another should be an internal operation but this required the tour operator to do this task.	A tourist flow issue: This is similar to the Grand Palace.	A service provider issue: The public operator received cash only while the tourists paid individually, resulting long queues. One ferry had limit capacity to carry all tourists, separating the tourists to smaller groups.	A service provider issue: Obtaining the permit letter from one staff and delivering it to another should be an internal operation but this required the tour operator to do this task.	Issue from the tourists: Some tourists lost interest and felt bored with the scenes at the destination and were also annoyed by the hot weather.	-
Performance	• The tour was delayed. • Waiting tourists felt dissatisfied. • Delayed tourists paid more transport costs.	• The tour was delayed. • Tourists complained about the delay, the destination, and the tour operator. • Tourists felt dissatisfied.	• Some tourists felt dissatisfied as they were bored of the destination.	• Waiting tourists felt dissatisfied.	• Non-value-added and unnecessary activity of the tour operator	• Some tourists felt dissatisfied as they were bored of the destination.	• The tour was delayed. • Some tourists felt dissatisfied	• Non-value-added and unnecessary activity of the tour operator	• Some tourists felt dissatisfied as they were bored of the destination.	-
Key success factor	The tour operator informed and managed the lost tourists to the meeting point by using tracking and sharing online locations of social media applications.	The tour operator took an instant action to help coordinate between the destination's office staff and their gate staff.	The tour operator had some flexibilities to adjust the schedule by managing the time and locations at the destination to meet the tourist's needs.	Ensuring time management by notifying tourists of the arrival time.	No solution as it was the destination's requirement.	The tour operator had some flexibilities to adjust the schedule by managing the time and locations at the destination to meet the tourist's needs.	No solution as the ferry was not allowed for advance booking.	No solution as it was the destination's requirement.	The tour operator had some flexibilities to adjust the schedule by managing the time and locations at the destination to meet the tourist's needs.	-

Physical flow — Information flow — Financial flow

Figure 5: The adapted service blueprint for the on-travel stage (authors)

Adapted service blueprinting across all three stages
Figures 4 and 5 illustrate the adapted service blueprints for the pre-travel and on-travel stages. The post-travel stage could not be developed in this study, as it was a one-day trip, and most activities between service providers and the tour operator were completed on the same day. Future research should explore the interactions and collaborations among these B2B firms involved in the post-travel stage.

Additionally, each blueprint includes three flows: physical, information, and financial. For example, in Figure 4, the itinerary and trip schedule were delivered to the students as an online document, resulting in both information and physical flows, while the payments made represent the financial flow. In all figures, the tourist flows are depicted horizontally within the tourism process. Problems and issues encountered during the tours are highlighted as critical supply chain and logistical concerns that may require improvement.

Discussions

The findings indicated that the adapted service blueprint can be used to map the tour program, identify actors and their activities, and reveal operational problems and weaknesses in the tourism chain. Several lessons learned from the study are as follows.

First, the tour operator played a crucial role in addressing problems that arose during the trip. This operator was essential because the trip was neither commercial nor routine. The tour operator and guide could collaborate in real time to operate the tour efficiently. In commercial contexts, a tour guide, rather than an operator, typically approaches to problems. Because tour operators conduct pilot trips to inspect all destinations, activities, and potential issues before the actual tours, tour guides are generally encounter and solve most problems easily.

Secondly, onstage and backstage activities often occur simultaneously. In some trips, multiple tour operators are needed to manage challenges effectively. For instance, at our case study locations (Wat Pho and Wat Arun), the tour operator was required to present a permit letter from the destination's office at the gate, even though the letter was supposed to be delivered internally. This necessitated at least two staff members: one to care for the tourists and another to handle backstage operations. However, this issue fell outside the tour operator's primary responsibilities and posed challenges that increased costs and extra time for the operator. Additionally, public transport also impacted tour performance, adding extra tasks for the operator. These problems were nearly impossible to eliminate.

Several opportunities for future research emerge from this study. From a supply chain perspective, the service blueprint serves as a basis for visualising a tour program. Since this study focused on a domestic trip, examining an international trip may show more complex and would be worthwhile to investigate to make the blueprint robust. Further studies should integrate support processes in the adapted service blueprint. Other visualisation tools, such as swim lane mapping, should also be employed to reveal decision-making processes in the pre-travel stage, where various information flows and decisions across multiple parties exist.

From a marketing perspective, several touchpoints were identified and found to have significant impact on tourist satisfaction. The service performance of staff at destinations also affected the tour's performance and, consequently, overall tourist satisfaction. The tour operator and guide played an important role in enhancing tourist satisfaction and influencing overall tour success. Interestingly, allowing tourists to exercise free will—wandering and choosing their meals at their convenience—enhanced their satisfaction but also introduced new challenges (e.g., delays). Future studies should explore the relationships between tourist activities and those performed by individual service staff, as these interactions can significantly affect both tourist satisfaction and tour costs.

Conclusion

In this study, a service blueprint was adapted to diagram and visualise the main actors involved in a tour program. Tourism processes were revealed according to a tour itinerary, while four logistics flows were identified: physical, information, tourist, and financial. Problems and issues encountered during the tours were highlighted as critical supply chain and logistical concerns that need improvement.

The primary contribution of the study is the adapted service blueprint that can be applied to the tourism context. An application of the adapted tool was demonstrated through a case study of a student field trip. Breaking down the tour programs using the concepts of logistics and supply chain can provide insights into problems and issues, as well as key success factors for tour programs. The study suggests further research opportunities in the supply chain and marketing areas.

The adapted service blueprint offers practical implications. The study demonstrates how to employ such tool to diagram and visualise tour programs as well as to identify problems and improvement opportunities. Understanding current tour operations should guide practitioners in better addressing problems and challenges, and in developing their tours to be more efficient and beneficial.

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ANALYSIS OF FACTORS AFFECTING CONSUMER'S PURCHASE DECISION IN PERFUME BUSINESS IN CHIANG MAI PROVICE

Kotchanan Sae-ear[1], Poti Chaopaisarn[2]
[1] Master' Degree Program in Industrial Engineering, Faculty of Engineering, Chaing Mai University, Chiang Mai' Thailand
[2] Supply Chain Engineering Management Research Unit, Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand. Tel: (+66) 53-944125, E-mail: poti@eng.cmu.ac.th

Abstract

Purpose: To understand the factors influencing consumer purchase decisions for perfumes.
Design/ methodology/ approach: a questionnaire to study perfume purchase decisions using Structural Equation Modeling (SEM)
Findings: To analyze the factors that affect consumers' purchasing decisions in the perfume business in Chiang Mai.
Originality/value: To analyze the factors that affect consumers' purchasing decisions in the perfume business in Chiang Mai.
Keywords: Purchase Decision, Information Quality, Service Quality, Trust, Luxury, Perfume

Introduction

(Perspectives on retail and consumer goods, Number 8, 2020) mention that currently, people spent more time at home and turned to online shopping. Many store retailers have been compelled to shut down or reduce physical stores due to the rise of online shopping. The shift from offline stores to online stores and e-commerce has been driven by technology. Nevertheless, some retailers have been able to adapt to the digital age by integrating online and offline channels, offering services such as click-and-collect and in-store pickup to cater to changing consumer preferences. Furthermore, as mentioned by Paulyn (2021) The global health crisis has caused an increase in stress and anxiety levels among people worldwide. To counteract the overwhelming effects of isolation and negative news, people try to find things that make them relaxed and comfortable at home. Recent studies have shown that 85 percent of fragrance users have incorporated scented items such as candles, home fragrances into their living spaces over the past year. Fragrances have proven to be effective in promoting a sense of calm and tranquility, transforming living environments, and providing comfort during the pandemic.

Perfume plays an important role in our daily routines and has the potential to shape our style and identity. Businesses need to understand what motivates consumers to make a purchase. Therefore, this study aims to identify factors in consumers' purchase decisions for perfume in Chiang Mai province. The researcher does believe that perfume businesses can develop effective marketing strategies and improve their products to meet consumers' preferences and needs by finding the factors of purchase decisions. According to a report by Fragrances in Thailand (2021), the perfume market in Thailand has been growing steadily in recent years, driven by increasing consumer demand for luxury and premium fragrances. The value sales of fragrances in Thailand reached 10.6 billion baht (approximately united states dollar 335 million) in 2020, with a compound annual growth rate of 4 percent from 2015 to 2020.

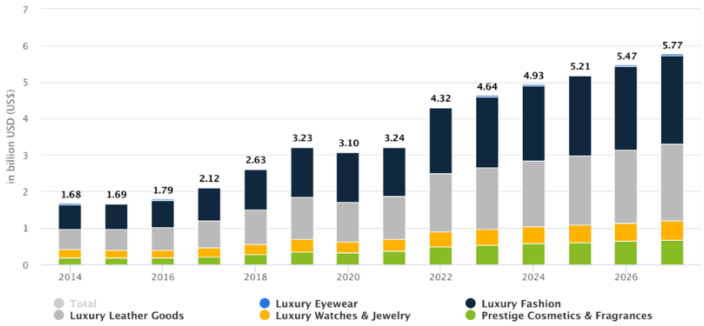

Figure 1: Sales statistics on the luxury goods industry in Thailand
Source: Adapted from Statista (2022)

From Figure 1, Statista (2022) presented the luxury goods industry is expected to generate revenue of united states dollar 460 billion by 2023, with a compound annual growth rate of 5.6 percent (2023-2028). The segment with the highest market volume is Luxury Fashion, predicted to reach United States dollar 194 billion in 2023. The United States is the top revenue-generating country in this industry, with an estimated revenue of United States dollar 75.69 billion in 2023. On average, each person is assumed to generate united states dollar 221.83 in revenue in 2023. Additionally, online sales are expected to reach 12 percent of the total revenue in the luxury goods market by 2023.

Therefore, this study aims to analyze the factors that affect consumers' purchasing decisions in the perfume business in Chiang Mai. Chiang Mai, a well-known tourist spot in Thailand, boasts a flourishing perfume market that appeals to both natives and tourists. This market provides an extensive range of scents, comprising conventional Thai fragrances as well as globally recognized brands.

Purchase Decision

A purchase decision is the process by which a consumer decides whether to buy a product or service based on previous actions.

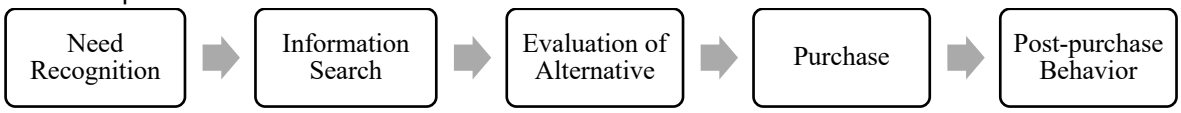

Figure 2: Consumer Purchase Decision Process
Source : Adapted from Kotler and Armstrong (1972)

The stage model presented by Kotler and Armstrong (1972) in Figure 2 outlines the five typical stages consumers undergo when making a purchase: recognizing the problem, searching for information, evaluating alternatives, deciding to purchase, and post-purchase behavior. The buying process begins well before the actual purchase and can have enduring effects. Some consumers may make decisions based on unsolicited information, highlighting the necessity for marketers to develop strategies that address all stages of the decision-making process. Kotler (2000) indicated that the purchasing process commences when a buyer becomes aware of a problem or need, triggered by internal or external factors. Marketers must identify these triggers by collecting information from numerous consumers, particularly for non-essential purchases like luxury goods, where they need to stimulate consumer interest and motivation. Consumers engage in various levels of search behavior, from heightened attention to active information seeking. Marketers must understand the types of information consumers seek at different times and places, including personal, commercial, public, and experiential sources. During the evaluation stage, consumers assess each attribute based on its perceived importance in delivering desired benefits. They then evaluate each brand on these attributes, forming an overall attitude toward the brand. This evaluation process is intricate

Previous Research

Salem (2018) explored on perfume purchases, emphasizing that the decision-making process guides a consumer from identifying a need to choosing a specific product and brand. This process encompasses several choices before the actual purchase, such as determining where to buy, which brand and model to select, when to make the purchase, how much to spend, and which payment method to use. Packaging plays an important role in influencing these decisions. Factors impacting consumer choices include external influences (such as culture, social class, and family), internal influences (including perception, attitude, and personality), and marketing factors (like product attributes, packaging, and promotions). Marketers analyze consumer buying patterns to understand the where, what, and why of consumer purchases. However, pinpointing the exact reasons behind a purchase remains complex.

The Conceptual Framework of Hypothesis

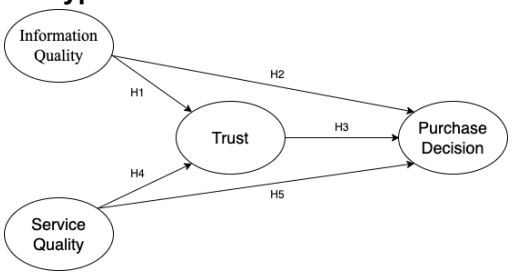

Figure 3 : The Conceptual Framework of Hypothesis

H1: Information quality has a positive impact on trust.

Chen et al. (2011) highlights the importance of trust in strategic alliances, defining it as the willingness to rely on a partner without fear of opportunistic behavior. Trust reduces risks and promotes information sharing and is strongly linked to the quality of information provided. High-quality information that is accurate, timely, reliable, and easy to use builds trust, while poor information increases costs and uncertainty.

H2: Information quality has a positive impact on purchase decision.

Information quality refers to the degree to which information meets the needs of its users in terms of accuracy, timeliness, relevance, completeness, precision, and reliability. It is a critical factor in decision-making and system success, particularly within information systems, where high-quality information enhances user satisfaction and facilitates system utilization (DeLone and McLean, 1992). In online commerce, information quality plays a pivotal role in shaping consumer behavior. Accurate, relevant, and personalized information helps reduce uncertainty and enables customers to make informed purchasing decisions, leading to higher satisfaction and increased trust in the system (Saefurahman and Hadi, 2020) In the context of e-commerce, information quality includes aspects such as detailed product descriptions, accurate labeling, and timely updates, which are essential for enhancing consumer trust and purchase confidence (Kim et al., 2013; Mbete and Tanamal, 2020). Ultimately, high-quality information serves as a marketing tool, driving better decision-making and contributing to system success and business profitability (Hung and Cant, 2017; (Rachmawati et al., 2020). Suryani and Syafarudin (2021) ; Akbar, Sularso and Indraningrat (2020). These studies show that high-quality, accurate, and relevant information significantly influences consumers' purchasing decisions, enabling them to make better choices. Alshikhi and Abdullah (2018) They examine the relationship between information quality and decision-making, highlighting that the effectiveness of decision-making depends on the quality of data presented. High-quality information is essential for organizational success, as it guides better decision-making and actions.

H3: Trust has a positive impact on purchase decision.

Trust is defined as confidence in the reliability, integrity, and competence of a partner or system, playing a key role in building and maintaining relationships despite risks and uncertainties (Wilson, 1995). It is particularly important in marketing, where it influences consumer behavior,

enhances satisfaction, and promotes long-term commitment (Mbete and Tanamal, 2020; Rachmawati et al., 2020). In the digital and e-commerce context, trust is important due to the lack of direct interaction, with factors such as secure payment systems and credible seller information impacting trust and online purchasing behavior (Mukherjee and Nath, 2007). High trust leads to positive behaviors, reduced transaction costs, and better information sharing, while low trust increases hesitancy and the need for additional safeguards (Chen et al., 2011).

Research by Fadhilah and Affifatusholihah (2021) demonstrates that higher consumer trust significantly enhances purchase decisions, particularly in online marketplaces, where trust in seller benevolence is critical for both initial and repeat purchases. Similarly, Mahliza (2020) highlights that trust in a seller's reliability, competence, and integrity motivates consumers to engage in online shopping, with higher levels of trust resulting in more consistent purchasing behaviors, repeat transactions, and overall satisfaction.

H4: Service quality has a positive impact on trust.

Rasheed and Abadi (2014) found a strong correlation between service quality and trust, demonstrating that 40.9% of the variance in trust is explained by service quality. Their study indicates that higher service quality enhances customer trust and perceived value, which in turn strengthens customer loyalty. This is especially important in sectors like the Malaysian service industry, where customer loyalty directly impacts revenue. Wijaya (2020) supports these findings, showing that improvements in service quality boost customer satisfaction and trust. Rivaldo and Amang (2022) noted that service quality plays a important role in consumer trust, highlighting that product excellence and high service quality are essential for influencing purchasing decisions.

H5: Service quality has a positive impact purchase decision.

Service quality is a critical factor that shapes consumer perceptions and purchasing decisions, with research across various sectors consistently highlighting its significance. Parasuraman et al., (1988) laid the foundation for understanding service quality by identifying five key dimensions: reliability, responsiveness, assurance, empathy, and tangibles. These dimensions form the basis of the widely used SERVQUAL model, which assesses service quality across industries. In the context of e-services, additional factors such as website design, ease of use, and security become crucial for delivering high-quality service (Zeithaml et al., 2002). Grönroos (1984) emphasized that both technical and functional aspects of service quality influence consumer perceptions, with both the outcome of the service and how it is delivered playing a role in shaping customer satisfaction.

Poor service quality, on the other hand, acts as a deterrent, diminishing consumer interest and lowering purchase rates (Hoque et al., 2023). Research by Prianggoro and Sitio (2020) supports these findings, showing that services exceeding consumer expectations are perceived as high-quality, leading to higher purchase rates, while services that fall short of expectations are deemed poor. Anggita and Ali (2017) further confirmed a strong relationship between service quality and purchasing decisions, noting that responsiveness to customer complaints, personalized attention, and understanding of customer needs play a vital role in positively influencing consumer behavior.

Pranoto et al., (2022) highlighted that improvements in service quality directly enhance consumer confidence, leading to more frequent purchase decisions. The findings across these studies consistently show that service quality, particularly when it exceeds consumer expectations, driving higher purchase rates, and ultimately shaping consumer behavior across different industries.

Methodology

This study will primarily focus on understanding the significance of luxury products, especially perfumes, and identifying the reasons why consumers choose to buy them. By analyzing consumer attitudes toward trust, service quality, and information quality, the research aims to provide insights into the driving factors behind perfume purchases. This will help brands and marketers in Chiang Mai better understand their target audience and tailor their strategies accordingly.

The primary goal of this study is to analyze the factors that significantly influence the purchasing decisions of perfume consumers in Chiang Mai. Specifically, this research aims to test a hypothesis using a Structural Equation Model (SEM), focusing on three key factors: trust, service quality, and information quality. These factors play an important role in shaping consumer purchasing behavior. The Structural Equation Model (SEM) approach will provide a framework to confirm the relationships between these variables and their impact on purchasing decisions. This study uses random sampling method to ensure that the sample accurately represents the broader population of Chiang Mai, with a focus on diversity in age groups, genders, and income levels. The target population includes individuals who have purchased perfume within the last year and reside in Chiang

Mai. Those who have not purchased perfume recently or who do not live in Chiang Mai will be excluded from the study.

Sample

A total sample size of 200 respondents will be selected to ensure both the reliability and validity of the results. This sample size is recommended by Kline (2011) for studies using Structural Equation Model (SEM), enabling the detection of significant relationships between the variables.

Data Collection

Data will be collected through a structured questionnaire, distributed via Google Forms on social media platforms like Facebook to specifically target perfume consumers in Chiang Mai. The questionnaire will consist of multiple sections, designed to gather comprehensive information about:

1.Demographic Information: General data about the respondents, such as age, gender, and income level.

2.Purchasing Behaviors: Specific details regarding the frequency and types of perfumes purchased.

3.Factors affecting Purchase Decisions: This section will focus on measuring the affecting of trust, service quality, and information quality on purchase decisions.

To minimize response bias, a four-point Likert scale for the questions related to trust, service quality, and information quality. Respondents will rate their agreement with various statements, ranging from 1 = strongly disagree to 4 = strongly agree. This scale is selected based on the work of Mbete and Tanamal (2020)

Data Analysis

Once the data is collected, it will be analyzed using SPSS (AMOS). The analysis will follow steps:

1.Demographic Description: The respondent demographics will be described using descriptive statistics to provide an overview of the sample characteristics.

2.Structural Equation Modeling as Confirmatory Factor Analysis: Close-ended questions will be analyzed to assess the relationships between the independent variables (trust, service quality, and information quality) and the dependent variable (purchase decision). The results will be used to validate or reject the hypothesis through.

Reliability and Validity

The questionnaire's reliability will be evaluated using Cronbach's Alpha coefficient to ensure consistency and stability over time. The reliability (Cronbach's Alpha coefficient) has value of 0 to 1. If Reliability coefficients that are equal to or above 0.80, are considered high reliability. Reliability coefficients which are between 0.60 to 0.79, are considered moderate reliability. And reliability coefficients that are below 0.60, will be considered low or poor reliability. According to Fornell and Larcker (1981) Composite Reliability (CR) will also be used to assess reliability and validity. The values of composite reliability between 0.6 to 0.7 are acceptable.

Results

The results of this study are expected to provide insight into how information quality, trust, and service quality influence consumer purchasing decisions in the perfume business in Chiang Mai.

Information Quality: based on the literature framework, information quality is hypothesized to positively impact both trust and purchase decisions (H1, H2). This factor encompasses the accuracy, timeliness, and relevance of information provided by perfume brands and retailers. It is anticipated that higher-quality information will increase consumer trust and positively influence purchase decisions. Preliminary responses from similar studies suggest that consumers prioritize detailed product descriptions, especially for perfumes, where fragrance profiles are important to the buying process.

Trust: trust is expected to be a significant factor influencing purchase decisions (H3). Literature shows that trust reduces the perceived risks associated with purchases, particularly in luxury goods like perfumes. Trust in both the brand and retailer is hypothesized to increase the likelihood of purchase. According to previous studies, consumers who trust a brand are more likely to engage in repeat purchases, particularly when they perceive the brand as reliable and honest.

Service Quality: the service quality provided by retailers is expected to have a positive impact on both trust (H4) and purchase decisions (H5). High service quality, characterized by

responsiveness, personalized service, and after-sales support, is likely to foster greater trust in the retailer and lead to higher customer satisfaction, thereby increasing the likelihood of a purchase.

Discussion

Information Quality: the findings, if consistent with the hypotheses, would demonstrate that information quality significantly influences both trust and purchase decisions. The studies by Akbar et al., (2020) and Rachmawati and Hidayatullah (2020) found that high-quality information helps reduce uncertainty and improves consumer decision-making. For the perfume industry, accurate descriptions of fragrances, ingredients, and usage recommendations would be ensuring consumers feel confident about their choices.

Trust: trust is predicted to emerge as one of the strongest factors influencing consumer purchase decisions. As indicated by Fadhilah et al., (2021), higher trust levels lead to more consistent buying behaviors. This is particularly relevant for perfume businesses, as consumers are often more hesitant to buy luxury products without prior experience or strong brand reputation.

Service Quality: high service quality is expected to not only improve customer satisfaction but also foster trust in the brand, ultimately driving purchase decisions. As supported by Hasibuan et al., (2022) and Pranoto et al., (2022), personalized customer service, quick responses, and after-sales care significantly contribute to consumer satisfaction and positive purchase behavior.

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BLOCKCHAIN FOR CERTIFICATION OF LOCAL FOOD PRODUCTS

Aicha Ferjani[a,*], Claude Duvallet[a] and Cyrille Bertelle[a]
[a]LITIS (UR4108), Université Le Havre Normandie, 76600, Le Havre, France

Abstract

Purpose:

In Europe, and particularly in France, there is growing interest in short food circuits, particularly local food systems (Augère-Granier, 2016). These systems involve the distribution of food products in a very restricted geographical area (Paciarotti and Torregiani, 2021). This interest is reinforced by new regulations aimed at promoting the consumption of local products to stimulate the local economy and reduce carbon emissions. Large-scale distribution sector is actively engaged in this movement by seeking ways to certify and promote products from these local systems. In this context, our study aims to propose a blockchain-based solution to ensure traceability, real-time monitoring and certification of products from these local food systems.

Methodology

Our study focuses on local food systems, where we recognize the retailer as the sole intermediary between producers and consumers. We impose a maximum distance threshold between these actors to qualify as a local food system (in our case, we assume that it must not exceed 80 km). To guarantee the origin of the product sold in supermarkets and allow traceability and tracking of orders in real time, we have developed a front-end application with two user interfaces: one for producers and retailers, and another for consumers.

On the one hand, our application allows producers and retailers to enter order details and track their progress in real time. When registering, they must provide their SIRET ("Directory Establishment Identification System") numbers and the addresses of their operational sites to calculate the distance between them. This information is crucial to verify if the product comes from a local food system. On the other hand, consumers can scan the QR code present on the product packaging to access its details.

Order data from producers and retailers is automatically stored in a database. To protect against data falsification, we propose securing them with blockchain technology. This technology, recognized for its transparency, traceability and security, has effectively responded to the traceability challenges in agri-food chains. Its integration into our solution improves security and transparency (Sunny *et al*., 2020).

For this, we have opted for the Ethereum blockchain, a public platform widely adopted by researchers and industrials (Buterin, 2014). A smart contract was developed to automate the anchoring of orders in the blockchain, ensuring that all data from producers to consumers is recorded securely and immutably. After each transaction, the smart contract sends the transaction hash and TX data back to our front-end application, serving as proof of transaction completion in the blockchain for transparency and traceability.

Using a public blockchain platform allows consumers to verify transaction execution by accessing transaction hashes. Additionally, we provide the Application Binary Interface (ABI) generated during smart contract deployment, allowing consumers to verify the accuracy of the data retrieved by our front-end application against the data anchored in the blockchain.

Finding

We have developed a proof of concept (PoC) to certify products from local food systems. This PoC includes a common application for producers, retailers and consumers, with user-friendly interfaces accessible to all. The application is connected to the public Ethereum blockchain and we have implemented a smart contract to securely and immutably store product data. This improves transparency and visibility within our solution.

Originality

Our study stands out for its originality in the field of traceability and certification of products from local food systems through the use of blockchain technology. Although existing scientific literature explores

blockchain-based solutions for traceability in food supply chains (Wang *et al.*, 2019; Bumblauskas *et al.*, 2020; Ferdousi, Gruenbacher and Scoglio, 2020), to our knowledge none have specifically addressed the certification of local food systems using this technology. Additionally, our research reveals that there is limited exploration of traceability using smart contracts, often with insufficient technical details and IT implementation information (Burgess *et al.*, 2022).

Our contribution aims to fill this gap by providing a practical demonstration of how blockchain can certify food products from local food systems. In collaboration with Grandis, a subsidiary of Carrefour, we have developed a concrete application which presents the implementation of our blockchain-based solution in a real context.

Introduction

In recent times, short food supply chains and local markets, where farmers sell their products directly to consumers or with a minimum of intermediaries, have flourished in all European Union (EU) countries. Therefore, since 2014, the EU rural development policy have placed an increased importance to short food supply chains and tried to define them.

According to the research report of the European Parliamentary Research Service of September 2016, there was no common definition of short food supply chains (SFSC) at EU level (Augère-Granier, 2016). A first common European definition is given in (Reg.1305/13), where short supply chain is defined as: “a supply chain involving a limited number of economic operators, committed to cooperation, local economic development, and close geographical and social relations between producers, processors and consumers”. This definition is then complemented by (Reg.807/2014), which stipulates that “Support for the establishment and development of short supply chains ... shall cover only supply chains involving no more than one intermediary between farmer and consumer”. In France, SFSC have been officially defined by the French Ministry of Agriculture as a marketing mode involving either the direct sale of products from the producer to the consumer, or the indirect sale with no more than one intermediary (Augère-Granier, 2016).

Regarding the definition of local SFSC, known also as local food system, it seems to be more complex because the notion of “local” food is subjective and depends on the context (population, accessibility, etc.). However, the term “local” refers usually to the distance between the point of production and the point of sale. That is why, the Joint Research Centre (JRC) 2013 scientific and policy report on short food supply chains and local food systems defines local SFSC as: a food system in which foods are produced, processed and retailed within a defined geographical area' (depending on the sources, within a 20 to 100 km radius approximately).

Producers wishing to participate in local food systems can benefit from various measures jointly financed by the European Agricultural Fund for Rural Development. In France, this mode of distribution is now favored, to the point that a law has been introduced to promote short local supply chain: the EGALIM law (JORF n°0253, 2018). This law requires that meals served in collective restaurants contain at least 80% of products meeting the requirements of short circuits. This is why large-scale distribution sector is more interested in products from this type of channel and seeks to promote and label them on the supermarkets. To do this, it is necessary to have solutions allowing the certification of food products coming from a SFSC, in order to strengthen customer confidence and reassure them about the origin of their products.

This study falls within the project “Blockalchaine”, which represents a collaboration between the University of Le Havre Normandy, the company 2SN, and Grandis, which is a subsidiary of the famous Carrefour supermarket group. This multidisciplinary collaboration between the academy, industry and the distribution sector aims to respond to current challenges in the traceability of food products and to promote more responsible practices in the field of logistics. The aim of this partnership is to develop a solution based on blockchain to make the supply chain more transparent and sustainable by favoring local food system.

The remainder of this paper is structured as follows. Section 2 recalls related research on traceability with blockchain in food supply chains and explains the novelty of our study with respect to the existing literature. Section 3 is devoted to the presentation of the studied supply chain and the description of

the proposed approach. The final section draws the conclusions and some suggestions for future research are pointed out.

Related Research

Blockchain technology is known as a Distributed Ledger Technology that provides a single, immutable ledger of transactions across the network, which are time-stamped and stored in “blocks” (Chandra *et al.*, 2019; Taherdoost, 2023). That is because tampering with a block makes it impossible to connect to other blocks. This ensures the integrity and security of the recorded data. Thanks to this immutability aspect, the blockchain is reliable, secure and resistant to hacking attempts.

This technology is increasingly used today in various domains (e.g. healthcare, supply chain and banking) and offers innovative solutions to improve business integration, specially within food supply chains. Its characteristics of transparency, traceability and resistance to falsification make it a valuable tool for solving a multitude of problems encountered in these chains (Li *et al.*, 2023).

The lack of traceability is one of the major problems encountered in food supply chains. According to Awan *et al*., (2021), the biggest reason for foodborne disease is contamination which is hard to track in the conventional food supply chain. Furthermore, consumers are increasingly wondering about the nature of the food products they purchase and the sources of the product they buy (Hasan *et al*., 2023). In order to address this issue, an emphasis is put on the blockchain, which could provide a relevant solution and offer significant advantages. Galvez *et al*., (2018) and Feng *et al.*, (2020) have studied the potential of blockchain in order to ensure the traceability and authenticity of products. According to Dasaklis *et al*., (2022), blockchain seems to be the most promising technology for offering traceability services in supply chain networks. Indeed, the data exchanged between the different actors in the agri-food chain are recorded in a common register, in an unmodifiable manner thanks to the block security mechanism, which helps to limit fraud (Laforet, 2023).

In (Awan *et al*., 2021), the authors believe that the combination of IoT with a blockchain system could be interesting to handle the problem of traceability in food supply chain. However, the authors have only focused on issues related to sensor installation and routing rather than the questions about the data that should be registered in the blockchain and the anchoring mechanism. On the other hand, we find that several researchers have focused on the technical aspects of blockchain. They have mainly used smart contracts to address the traceability issues. For instance, the authors in (Ferdousi *et al.*, 2020) have proposed a smart contract based framework for beef traceability. Cocco *et al.*, (2021) have developed a smart contract to ensure the safety, quality and traceability of batches of bread. In addition to their smart contract enabling the traceability of products, the authors in (Wang *et al*., 2019) have proposed an event response mechanism in order to verify the identities of both parties of a transaction in the blockchain.

It is worth to note that there exist other traceability approaches, which cover various food products such as eggs, fish, wheat, cereals and dairy products (Bumblauskas *et al.*, 2020; Sunny *et al.*, 2020; Cocco *et al*., 2021). However, despite this large number of studies and based on the authors' findings in (Dasaklis *et al*., 2022), it remains uncommon to find publications offering a detailed analysis of the technical aspects of their blockchain solutions.

Despite the significant number of studies on traceability with blockchain in food supply chains, it should be noted that we identified only one article using the blockchain technology for SFSC. In (Burgess *et al.*, 2022), the authors highlight the lack of research on this topic and propose a blockchain-based architecture for quality management in SFSC. However, their study remains theoretical and does not delve into the practical implementation of the proposed architecture. For example, the authors did not discuss which specific blockchain platform to use. Although they mentioned smart contracts, no details or specifications were provided on the structure of these contracts or the interaction between the different components of their proposed framework. Furthermore, the authors have focused on SFSC in general, without addressing the specific requirements of local food systems, mainly the proximity aspect, that requires verifying the distance between producers and consumers and certifying the origin of the product. In our study, we propose to solve this problem through a solution based on blockchain. While the scientific literature already

proposes blockchain-based solutions for traceability in food supply chains, to our knowledge, none have specifically addressed the certification of local food system using this technology. In addition, our research reveals that work on traceability using smart contracts is infrequent and often lacks details on the technical aspects and IT implementation.

Blockchain Solution for Certifying Local Food Systems

In this section, we present a practical demonstration with a proof of concept (PoC) of the use of blockchain for the certification of food products from local food system. In collaboration with Grandis, a Carrefour subsidiary, we have developed a concrete application which illustrates the application of our blockchain-based-solution in a real context.

Presentation of the studied supply chain

As depicted in figure 1, we focus on local food systems with a single intermediary between the producer/supplier and consumer, which is the retailer, in our particular case, it is the supermarket. We consider that the distance between these stakeholders shouldn't exceed 80km (Paciarotti and Torregiani, 2021).

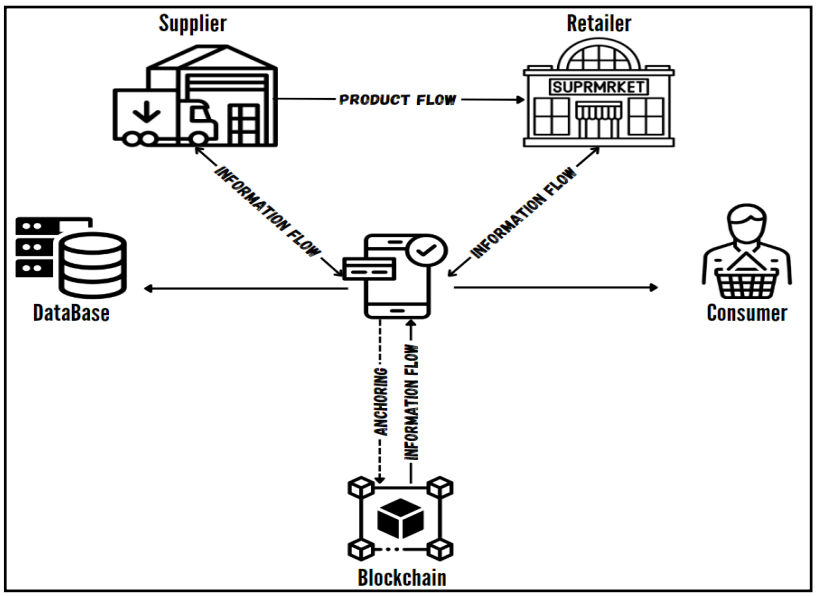

Figure 1: Overview on the Blockchain solution.

Product flow moves directly from suppliers to retailers. However, we have different types of information flow that passes through the mobile application implemented to track orders status in real time. It is to note that this application serves as a common tool between our stakeholders and helps to guarantee traceability and real-time visibility of orders. We have developed two user interfaces: the first one is dedicated to producers and retailers, while the second is intended for consumers.

On one side, our application allows suppliers and retailers to enter order related information and track its progress in real time. On the other side, it offers consumers the possibility to access details about the product they want to purchase by scanning the QR code found on the product's packaging. It is important to note that, during registration, suppliers and retailers must provide their SIRET numbers and the addresses of their operational sites to calculate the distance between them. The SIRET number is unique to each site, and any change in address requires a new SIRET number. This information is essential to accurately identify the company and, more importantly, to determine the distance between the supplier and the supermarket, ensuring the product originates from a local food system.

Blockchain-based solution

The data collected about orders from suppliers and retailers is automatically saved in an external database. However, in order to prevent any alteration or manipulation of this data, we propose to secure it using blockchain technology, which is recognized for its transparency, traceability and security (Wang *et al.*, 2019). In addition, blockchain has been widely used to resolve traceability

problems in agri-food chains. That is why, we have opted for the Ethereum blockchain, a permissionless public platform widely adopted by researchers and industrials. This allows our stakeholders, namely suppliers and retailers, to create a node through our mobile app and join the network, as well as access the data stored within it. This is part of our transparency strategy towards consumers. Our platform enables suppliers and retailers to provide product information via the mobile app. This data can then be verified by consulting the public Ethereum blockchain to retrieve all relevant product details and the transaction hash that confirms its anchoring in the blockchain.

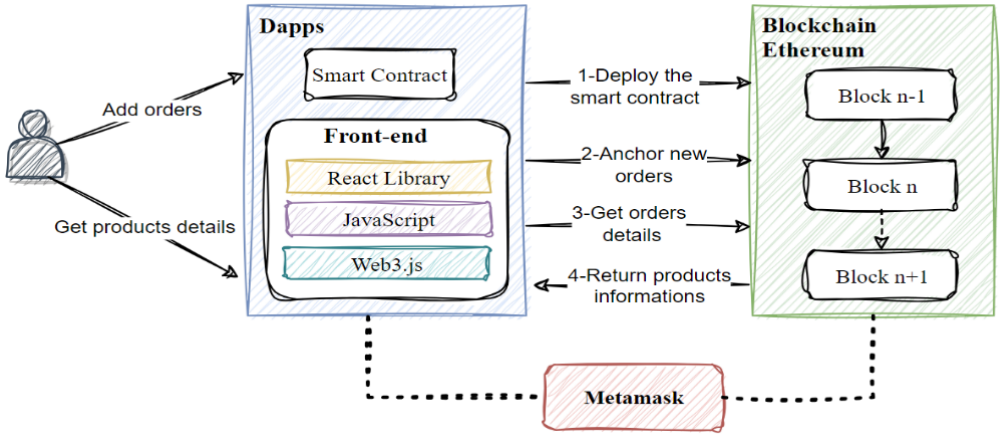

Figure 2: Architecture of the blockchain-based solution.

Figure 2 depicts the interactions among the different components of our PoC, as well as the steps involved in order registration and blockchain querying. A smart contract, written in Ethereum's Solidity language, was developed to automate the registration and anchoring of orders in the blockchain. It consists of a set of data structures designed to record the details of the orders submitted.

Thus, the data collected about the origin of the product and the addresses of the supplier and retailer is recorded securely and immutably in the blockchain (cf. Figure 3). After each order anchor transaction, the smart contract returns the hash and TX Data of the transaction/block to our mobile application. This data is then recorded in the database and serves as proof of the completion of transactions in the blockchain, ensuring transparency and traceability for consumers.

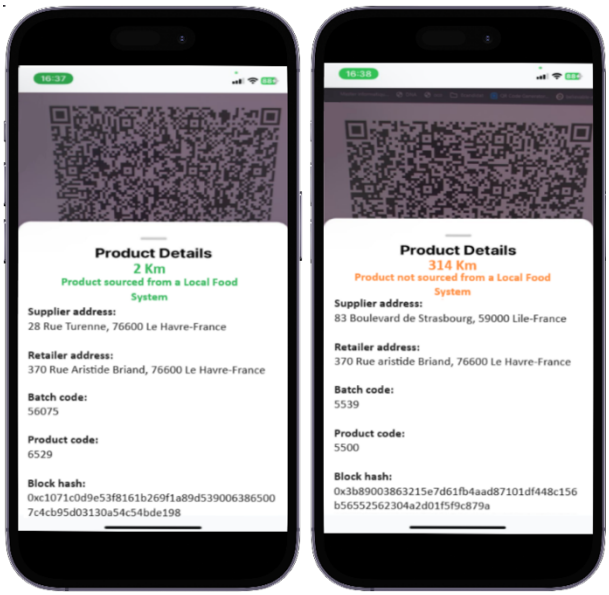

Figure 3: Examples of blockchain query results when consumers scan products' QR codes.

Since we use a public blockchain platform, the consumer has the possibility to copy the hash of the transaction to verify its execution directly on the Ethereum blockchain via Etherscan[1]. In addition, we provide the ABI generated during the deployment of the smart contract, thus allowing the consumer to verify the accuracy of the data retrieved by our mobile application by comparing with those anchored in the blockchain. This is can be done transparently thanks to decoder libraries[2], which are popular open-source libraries developed by the Ethereum developer community and that provide Ethereum input data decoder functionality.

Conclusions and Perspectives

We have addressed, in this study, the problem of certification of products coming from local food systems. For that, we have developed a PoC that includes a common application for suppliers, retailers and consumers, but with different friendly user interfaces This application, which enables real-time tracking of order processing, is also integrated with the public Ethereum blockchain. This is achieved through a smart contract that automates the process of recording order details in the blockchain. This process enables the secure and immutable storage of product data, thereby providing more transparency and visibility to our solution.

The blockchain-based solution proposed in this study is designed for certifying local food systems. However, it can be easily adapted to handle other certification needs, such as halal or organic/bio food products. The key adaptation lies in the type of information recorded on the blockchain. For instance, halal certification would require specific criteria related to religious guidelines, while organic certification would involve criteria related to agricultural practices.

However, it's crucial to optimize the amount of information recorded in the blockchain because it directly impacts transaction costs. Therefore, studying the costs associated with blockchain implementation is essential for understanding both the economic and environmental implications. A future research could explore how blockchain technology affects costs and sustainability, and propose optimization strategies to mitigate these impacts.

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COLLABORATIVE LEARNING FOR DEMAND FORECASTING IN URBAN LOGISTICS

Maharshi Dhada[1], Matteo Giaretti, Duncan McFarlane[1]
[1]Institute for Manufacturing, Department of Engineering, University of Cambridge, Cambridge, CB3 0FS, UK.

Abstract

Purpose: This paper presents a probabilistic hierarchical statistical model for tackling the often encountered cold-start problem in urban logistics sector. Companies face the cold-start problems when they start their operations in a new city and therefore don't have sufficient data to accurately forecast the demand for that city. Using real-world industrial data, authors propose a hierarchical autoregression model that enables a logistics company to forecast customer orders in a new city, given the historical orders in other cities.
Design/ methodology/ approach: Using a statistical hierarchical model enables the user to systematically model the operations of an urban logistics company across multiple cities. Each city is associated with an individual autoregression model, whose parameters are sampled from a common higher level distribution that represents the general behaviour of other similar cities. Operations in a new cities are therefore enhanced using systematically evaluated prior knowledge, enabling reliable forecasts in the early time-steps. Similarities across the cities are modelled using factors such as population density, geography, cultural influences, etc.
Findings: Using a statistical hierarchical model enables the user to systematically model the operations of an urban logistics company across multiple cities. Each city is associated with an individual autoregression model, whose parameters are sampled from a common higher level distribution that represents the general behaviour of other similar cities. Operations in a new cities are therefore enhanced using systematically evaluated prior knowledge, enabling reliable forecasts in the early time-steps. Similarities across the cities are modelled using factors such as population density, geography, cultural influences, etc.
Originality/ value: This is the first application of statistical hierarchical modelling for forecasting customer demand in urban logistics sector. Such a cold-start problem addressed in this paper is critical for several urban logistics companies, and the results shown in this paper are evaluated using real-world industrial dataset which justify the applicability of the technique.

Keywords: Machine Learning, Logistics, Collaborative Learning, Statistics, Hierarchical Modelling

Introduction

Urban logistics sector aims at meeting consumer expectations summarised in Carlos Moreno's idea of a '15-minute city', where essential goods and services are accessible within 15 minutes of a resident's home in an efficient and environmentally sustainable manner (Moreno et al., 2021) The rise in the quick e-commerce segment, where the customers expect rapid and free deliveries, has been further accelerated by the Covid-19 pandemic. The lockdowns in particular restricted the public movement, meaning many products and services could only be availed online. As such, high prevalence of delivery vans, HGVs, motorcycles, or bicycles, delivering goods or food from one part to the other can be seen on the streets of major cities today (ARUP, 2023; Statista Research Department, 2023).

A recent ARUP report highlights this boom in urban logistics sector through the current decade. The report presents that 66% of millennials routinely look for one- hour delivery options, with the 'Amazon effect' leading to more consumers expecting free deliveries. The same-day or instant delivery service is expected to grow by 20-25% (ARUP, 2023). And consequently, the number of delivery vehicles on the roads of the 100 most significant global cities is expected to increase by 36% from 2019 to 2030 (World Economic Forum, 2020).

This paper discusses a particularly interesting problem faced by a technology company Glovoapp23 SA, popularly known as Glovo, which serves as a platform to bring together couriers, individuals, and organisations in urban areas. Glovo offers their customers an exclusive home delivery service, not just for food but delivering anything you could possibly need, from pharmacy products and gifts to flowers, contact lenses, and much more (Glovoapp23 SA, 2021).

A key driver of Glovo's operations is their forecasting engine that predicts the number of customer orders, enabling Glovo to ensure optimal availability of the couriers. However, forecasting customer orders is challenging for the cities where sufficient data does not exist for training the forecasting algorithms, often these cities are where Glovo operations have newly commenced. Such a cold-start problem can also be seen for events which are not strictly seasonal, presence of a new competitor in the market, or reasons that have a long lasting effect on the demand such as Covid-19.

This paper discusses and shows, with an example of a hierarchical auto-regressor model, that there exist opportunities for the cold-start problem to be solved by selectively learning from other cities where Glovo operates. The initial results show that an isolated forecasting model for a particular city with insufficient data is associated with a high variance, whereas a forecasting model common to all the cities is associated with a high bias. A hierarchical forecasting model, where the parameters of isolated forecasting models are sampled from a single overlying distribution common to the cities with similar behaviour, systematically enables cross learning via combined inference using the data obtained from the cities. More generally, this provides for an industrial strategy where the lack of local information can be alleviated via collaborative learning within the system.

The following paper is as follows: Section 2 Discusses the existing industrial applications of hierarchical modelling and collaborative prognosis technique, for example industrial collaborative prognosis. Section 3 provides a brief introduction to Glovo's forecasting problem for cities with insufficient data. A hierarchical auto-regressor model that was implemented for cross-learning at Glovo is discussed in Section 4. The results are discussed in Section 5.

Hierarchical Models for Cross-Learning

The term knowledge transfer is used in the probabilistic machine learning literature to refer to methods that learn from multiple related datasets. While the multi-task approach also assumes the predictors (i.e. tasks) are correlated over the fleet, the parameters across domains are learnt at the same time with equal importance. Hierarchical Statistical Modelling offers a multi-task framework, where a model is built with a 'hierarchy' of parameters, whereby domain-specific tasks are correlated via shared latent variables (Bull et al., 2022)

For the industries, statistical hierarchical models enable combined inference from the asset fleet data by learning a set of correlated models via shared higher level distributions. The shared higher level distributions ensure that the behaviour observed across other similar assets in the fleet is incorporated when the assets have sparse data. The parameters of the overall model are learnt using hierarchical Bayesian inference and provide robust variance reductions compared to the independent models inferred for the as- sets with sparse data. Hierarchical models therefore automatically incorporate collaborative learning across similar assets or sub-fleets, such that the assets with sparse data borrow statistical strength from those that are data-rich. Comprehensive information about statistical hierarchical modelling can be found in (Gelman et al., 1995)

One of the earliest applications use hierarchical models for inferring the Bernoulli parameters for reliability estimation of emergency diesel generators in separate nuclear power plants. They show that the hierarchical Bernoulli model was more accurate for modelling the collective "composite" and individual reliabilities of the generators, compared to the prevalent approach of analysing data from all generators as a single dataset. (Di Francesco et al., 2021) use hierarchical models to build corrosion models given the data from multiple sources. An interesting application can also be found in (Johnson et al., 2005) where hierarchical modelling was used for reliability estimation of new space crafts, which had only experienced few failures or in some cases no failures.

Glovo's Forecasting Problem

Forecasting lies at the core of Glovo's data science to optimise its operations, along with two other fundamental engines which are matching and routing. Glovo's end-to-end operations include the following steps:

1. **Forecast** the number of orders in a city for a given time. This is to open vacancy for the optimal number of couriers in the city
2. **Match** the orders with the optimal courier out of the ones available at that instance

3. **Route** the courier journey so that it can optimally pick up the parcel and deliver it to the customer

This paper focuses on the forecasting step where the problem is to forecast the number of orders, given the past orders. Glovo operates in hundreds of cities from which the past orders training data can be obtained. An example of the daily orders across a subset of cities is shown in Figure 1, where each city is indicated with a different colour. It is apparent from the figure the cyclic pattern which peaks at dinner and lunch times.

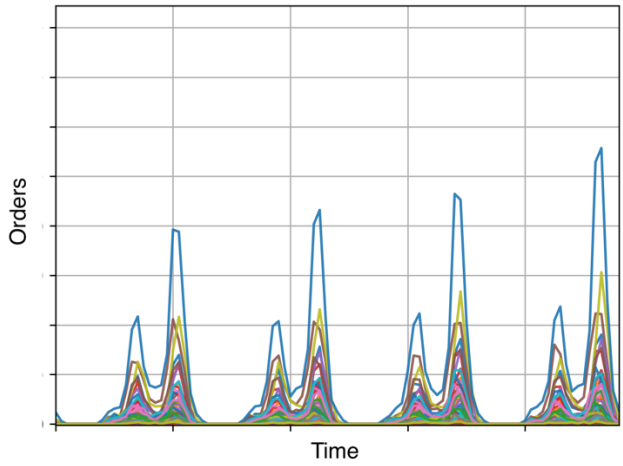

Figure 1: Example of daily orders from a subset of cities

Upon analysing the partial auto-correlation function (PACF) values, an auto-regressor with lag 2 (represented henceforth as AR(2)) is deemed suitable model for forecasting and for the purpose of this paper. The mathematical representation of this model is shown in (1), where the customer orders forecast for city i, at the current timestep t, is linearly correlated with the two previous timesteps and a noise coefficient ε.

$$X_{i,t} = \alpha_{i,1} X_{i,t-1} + \alpha_{i,2} X_{i,t-2} + \varepsilon \quad (1)$$

An example of this forecasting model, showing true vs. predicted customer order numbers for a city is presented in Figure 2, giving a MAPE score of 16.3% across all cities. This shows that the AR(2) model is sufficient for forecasting with acceptable accuracy, if sufficient training data is available.

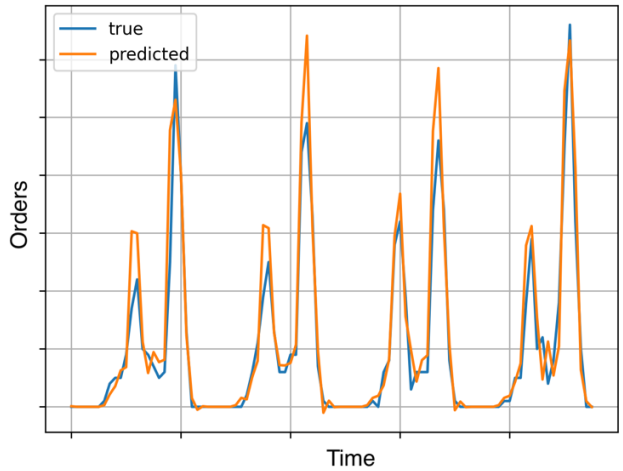

Figure 2: True vs. predicted order numbers using AR(2)

However, the auto-regressor ceases to be reliable when the training data is insufficient. A probabilistic AR(2) was used to highlight this drawback, where the model coefficients were sampled using Monte Carlo Markov Chain (MCMC) sampling technique and the probabilistic programming language Stan (Carpenter et al., 2017). Time- series of a randomly selected city was truncated to simulate insufficient training data, and gradually increased. The probabilistic estimates of the AR(2) model coefficients were recorded as distributions as the timeseries data was increased, to study the effect of training data on the predictive accuracy and confidence. The accuracy was compared evaluated AR(2) coefficient values trained using the same timeseries but with a large enough training dataset to achieve stable values, and the confidence was evaluated based on the variance (or spread) of the inferred distributions of the AR(2) coefficients.

The results of this exercise are shown in Figure 3. It is evident from this figure that when there is lack of training data, the estimates are (1) inaccurate and (2) associated with high variance. Here the thick vertical line in the plots correspond to their true values.

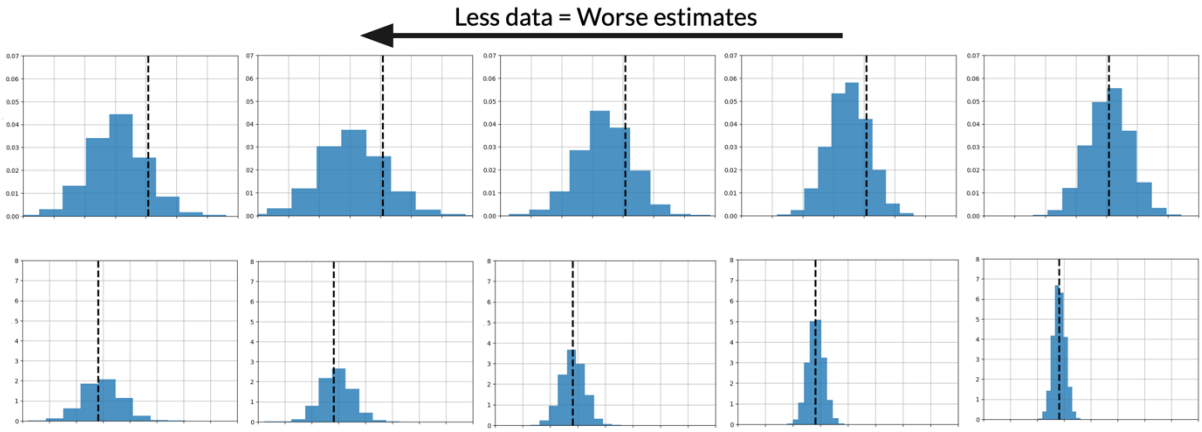

Figure 3: Low data resulting in inaccurate inference of the AR(2) coefficients, with high variance

Hierarchical Model for Glovo Forecasting

In this section, the methodology to experiment with a hierarchical AR(2) model is described. The aim of this experiment was to establish whether a hierarchical model is better suited for forecasting when a given city does not have sufficient training data.

Hierarchical Model

In the hierarchical model for forecasting, for the problem at hand, clusters of cities that show similar trends shall share higher level distributions from which the city-specific AR(2) slope coefficients are sampled. For this case only α parameters shared higher level distributions as the noise variable is treated as random, and in case of a hierarchical model it should ideally be shared across all cities similarly. Concretely, the α are sampled from higher level Gaussians, with noninformative priors having high corresponding variances. This is represented in mathematical terms in (3), where the i^{th} alpha coefficient is sampled from the corresponding Gaussian N_k shared by the cluster k comprising of cities showing a similar behaviour.

$$\alpha_{i,j} \sim N_k(\mu_j, \sigma_j) \quad (2)$$

$$X_{i,t} \sim N\left(\alpha_{i,1} X_{i,t-1} + \alpha_{i,2} X_{i,t-2}\right) + \epsilon \quad (3)$$

Design of the Experiment

In an ideal setting, the clusters of cities with similar trends should be identified using meta data such as the geography, weather, presence of other competitors, population density, etc. But the focus of this paper is to show that a hierarchical model improves the prediction for a city with insufficient data, in the presence of other similar cities with higher information. The clustering is not the focus, but it can nonetheless be coupled in the inference steps via algorithms such as expectation-maximisation.

The same subset of cities shown in Figure 1 are used for the experiment discussed here. There exists sufficient data for each of these cities to train an AR(2). To identify the clusters of similar cities, standard k-means algorithm was implemented using the coefficients of the AR(2) models trained for each city using the complete training dataset. The city clusters identified through this procedure are shown in Figure 4, where the city clusters are shown in various colours.

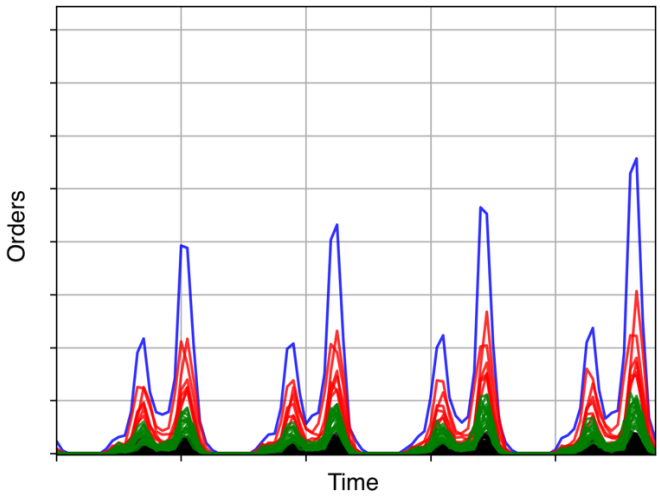

Figure 4: City clusters identified and shown in difference colours

Once the clusters are identified, the same city selected for plotting the values in Figure 3 was used to experiment with the hierarchical AR(2) model. The data was increased in the same quantities and iterations as Figure 3, with the only difference being this time the AR(2) model coefficients of this city were sampled from a distribution shared among other cities in its cluster which had more training data. The distributions obtained after inferring both the slope coefficients of the hierarchical AR(2) model are shown in Figure 5.

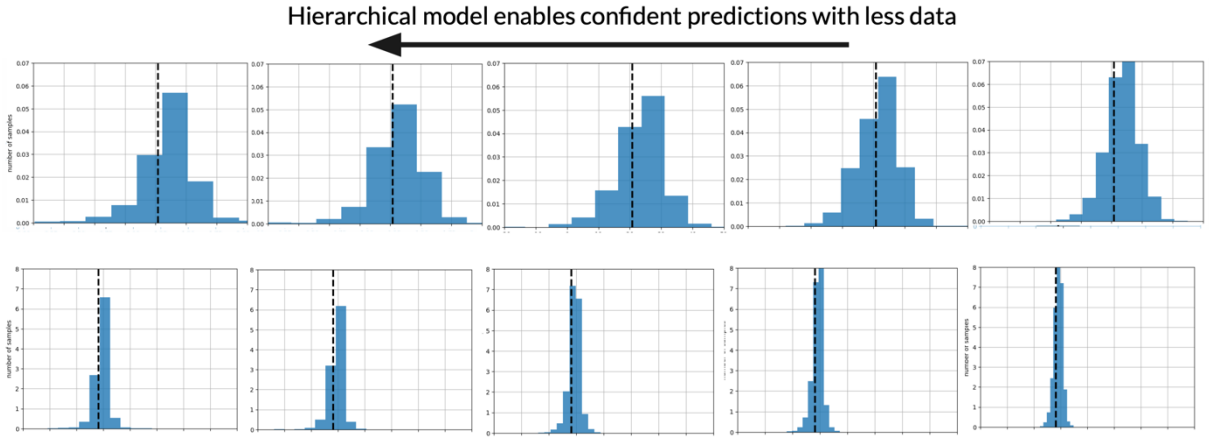

Figure 5: Hierarchical AR(2) model enables confident inferences of the slope coefficients, despite insufficient training data

Discussion and Results

The initial results presented in this paper show that, for the case of Glovo, an isolated AR(2) model for cities with less data is associated with a high variance. In theory, an AR(2) common to all cities in the Glovo operations shall be associated with a high bias, given the range of customer order values. The results in the Figure 5 show that a hierarchical AR(2) balances the above by systematically incorporating prior knowledge from other cities showing similar trends.

The future research comprises of identifying the meta data and a systematic algorithm for identifying the clusters of cities showing similar trends, and also a forecasting model that incorporates seasonal long-term variations in the consumer orders.

Acknowledgements

This research was supported by the SF Express Research Fellowship in Logistics. This research was also made possible by Glovoapp23 SA, based in Barcelona.

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CRUCIAL FACTORS AFFECTING SAME-DAY DELIVERY LOGISTICS IN VIETNAM

Thanh Thi My Truong
Department of Urban Transport Planning, Faculty of Civil Engineering,
University of Transport Technology, Vietnam

ABSTRACT
Research purpose: The study aims to investigate the crucial barriers and enablers in the application of same-day delivery logistics in Hanoi, Vietnam – a city with very high-speed e-commerce development.
Methodology: From the literature review, factors that affect same-day delivery were identified. Then, a survey was distributed among e-retailers and customers including pre-defined factors and questionnaires. From the service-demand side, the questionnaires are designed to report (yes/no) specific barriers and enablers that customers might have encountered, such as delivery time constraints, delivery costs, or geographical limitations. From the service-supply side, the e-retailers were asked to rank the factors that affected their decision to provide same-day delivery services. The e-retailers rated the enablers and barriers according to their relative importance out of five, where five represents the highest importance and one the lowest. Then the results were analyzed using the Pareto chart to identify the most important factors.
Findings: The survey findings revealed that the most important factors that affect same-day delivery substantially are infrastructure, traffic congestion, weather conditions, high logistics costs, limited payment options, and limited customer awareness. The study results confirm that while same-day delivery offers a competitive advantage for e-commerce businesses, it also presents significant logistical and financial challenges in Vietnam.
Value: Findings from the study facilitate the recommendations for e-commerce and logistics service providers on requiring careful planning and coordination of various logistics processes, including order processing, inventory management, and last-mile delivery. The results also provide practical evidence to transport authorities to provide a possible reduction of logistics costs in the long term.

Keywords: Same-day Delivery; Urban Transport; City Logistics; Last-Mile Delivery; E-Commerce.

Introduction

Vietnam's e-commerce market has grown rapidly in recent years, with total e-commerce revenue expected to reach over $52 billion by 2025, according to a report by The White Book on Vietnamese E-Business (Vietnam E-Commerce and Digital Economy Agency, 2022). This represents a significant increase from the estimated $14 billion in revenue in 2019. Furthermore, Vietnam has a mobile-first population, with more than 70% of internet users accessing the internet through their mobile devices (Vietnam E-Commerce and Digital Economy Agency, 2022). This has led to the development of mobile commerce (m-commerce), which has become a significant driver of e-commerce growth in the country. Despite the growth of e-commerce, Vietnam's logistics infrastructure is still developing, with challenges such as traffic congestion and limited last-mile delivery options. This has led to the emergence of third-party logistics providers and innovative solutions such as on-demand delivery services.

Same-day delivery logistics refers to the processes and operations involved in delivering goods or packages to customers on the same day that an order is placed (Taniguchi et al., 2004). It is a time-sensitive service that aims to provide fast and convenient delivery options, allowing customers to receive their purchases within a few hours of ordering. The logistics behind same-day delivery involves a series of coordinated activities, including order processing, inventory management, transport, and last-mile delivery. Various studies have been conducted to understand the advanced technology, optimize logistics operations, improve delivery speed, and enhance the overall customer experience on same-day delivery services. However, the factors affecting same-day delivery logistics in the Vietnamese e-commerce market, where same-day delivery services have been applied in a very early stage, are still unknown.

The study aims to investigate the crucial barriers and enablers on the application of same-day delivery logistics in Hanoi under the perception of customers and e-retailers who are the main actors of same-day delivery services. The paper begins with a literature review of factors affecting same-day

delivery logistics, followed by a discussion of methodology and data collection. The outcomes of data analysis, as well as a summary of the findings, are then discussed. The conclusions are given in the last section.

Factors Affecting Same-Day Delivery Logistics

Barriers and enablers play a crucial role in the successful implementation and operation of same-day delivery logistics. They can significantly impact the feasibility, efficiency, and customer experience associated with same-day delivery services (Dolati Neghabadi et al., 2019). Here are some common barriers and enablers in this context:

Barriers

Same-day delivery requires fast order processing, inventory management, and transport, which can be challenging for e-retailers who are not equipped with efficient processes and systems (Klapp et al., 2020). Furthermore, offering same-day delivery can be cost-intensive due to the need for additional resources, such as vehicles, drivers, and operational infrastructure. High delivery costs may hinder widespread adoption or result in increased product prices for customers. In many studies, it was revealed that inadequate transport infrastructure, such as poor roads, traffic congestion, or limited transport options, can pose significant challenges to timely and efficient same-day deliveries (Banerjee et al., 2023; Chen et al., 2023; Lin et al., 2018)]. Moreover, remote or hard-to-reach areas might have limited coverage for same-day delivery due to longer transport distances (Truong et al., 2021; Truong, 2023a), limited logistics infrastructure (Truong, 2023a; Truong and Derrible, 2021), or higher costs associated with serving these regions. Considering the economic aspects, scaling up same-day delivery operations can be challenging if a company lacks the necessary capacity (Truong, 2023b), such as warehousing space, delivery vehicles, and a sufficient workforce, to meet increasing customer demand. On the other hand, the complexity of managing multiple orders, coordinating logistics operations, and optimizing delivery routes in real time can be a barrier for companies implementing same-day delivery logistics. The summary of barrier factors is shown in Table 1.

Barrier Factors	Details	Sources
Time Constraints	Requires fast order processing, good inventory management and transport	(Banerjee *et al.*, 2023; Verma *et al.*, 2023)
Cost	Requires cost-intensive due to the need for additional resources, such as vehicles, drivers, and operational infrastructure	(Chen *et al.*, 2023; Dayarian *et al.*, 2020)
Infrastructure Limitations	Challenges from inadequate transport infrastructure, such as poor roads, traffic congestion, or limited transport options	(Lin *et al.*, 2018; Taniguchi *et al.*, 2004)
Geographical Constraints	Remote or hard-to-reach areas	(Irawan and Belgiawan, 2022; Savelsbergh and Van Woensel, 2016)
Scalability and Capacity	Ability to scale up same-day delivery operations	(Dolati Neghabadi *et al.*, 2019; Irawan and Belgiawan, 2022)
Operational Complexity	The complexity of managing multiple orders, coordinating logistics operations, and optimizing delivery routes in real-time	(Irawan and Belgiawan, 2022; Savelsbergh and Van Woensel, 2016)

Table 1: Summary of barriers

Enablers

Despite numerous barriers restraining the expansion of same-day delivery service, several enabling factors appeared in recent years. Firstly, the changing work patterns and lifestyles enable the expansion of same-day delivery in many cities (İmre *et al.*, 2021; Irawan and Belgiawan, 2022). Secondly, the advancements in logistics technology, including route optimization software, real-time tracking systems, inventory management tools, and automated order processing systems, enable more efficient and streamlined same-day delivery operations. Additionally, collaborating with logistics providers, fulfilment centers, or third-party delivery services can help expand the delivery network and

leverage existing capabilities to offer same-day delivery services (Lin *et al.*, 2018; Taniguchi *et al.*, 2004).

The advancement of technology can help optimize operations, forecast demand, and make data-driven decisions to improve the efficiency and accuracy of same-day deliveries (Lin *et al.*, 2018). Furthermore, the real-time visibility of inventory levels across multiple locations allows retailers to ensure the availability of products for immediate dispatch, reducing order fulfilment time and enhancing same-day delivery capabilities. In research by Lin et. al., it has been presented that offering flexible delivery options, such as specific time slots, evening deliveries, or pick-up points, can provide customers with convenience and increase the likelihood of successful same-day deliveries (Banerjee *et al.*, 2023; Lin *et al.*, 2018).

Considering the implementing strategies from logistics companies, they investigated the strategic location of distribution centers (Dolati Neghabadi *et al.*, 2019; Savelsbergh and Van Woensel, 2016). Strategically located distribution centers and fulfilment centers near target customer bases can minimize transport distances and enable faster same-day deliveries. Moreover, retailers consider that having a trained and skilled workforce, including delivery drivers, warehouse staff, and customer service representatives, is crucial for efficient same-day delivery operations (Klapp *et al.*, 2020; Taniguchi and Van Der Heijden, 2000). By addressing the barriers and leveraging the enablers, companies can overcome challenges and optimize their same-day delivery logistics, offering fast and reliable services to meet customer demands.

Enablers	**Details**	**Sources**
Advanced Technology	Route optimization software, real-time tracking systems, inventory management tools, and automated order processing systems	(Banerjee *et al.*, 2023; Chen *et al.*, 2023; Xi *et al.*, 2021)
Collaboration and Partnerships	Collaborating with logistics providers, fulfilment centers, or third-party delivery services	(Dolati Neghabadi *et al.*, 2019; Savelsbergh and Van Woensel, 2016)
Data Analytics and Predictive Modeling	Analyzing historical data and using predictive modelling techniques	(İmre *et al.*, 2021; Irawan and Belgiawan, 2022)
Inventory Visibility and Management	Real-time visibility of inventory levels across multiple locations	(Irawan and Belgiawan, 2022; Klapp *et al.*, 2020)
Flexible Delivery Options	Offering specific time slots, evening deliveries, or pick-up points	(İmre *et al.*, 2021; Irawan and Belgiawan, 2022; Xi *et al.*, 2021)
Strategic Location of Distribution Centers	Locating distribution centers and fulfillment centers near target customer	(Dolati Neghabadi *et al.*, 2019; Savelsbergh and Van Woensel, 2016)
Skilled Workforce	Having a trained and skilled workforce, including delivery drivers, warehouse staff, and customer service representatives	(Dolati Neghabadi *et al.*, 2019; Savelsbergh and Van Woensel, 2016; Taniguchi *et al.*, 2004)

Table 2: Summary of enablers

Methodology and Data Collection

From the literature review, factors that affect the same-day delivery were identified. Then, a survey was distributed among e-retailers and customers including pre-defined factors and questionnaires. From the service-demand side, the questionnaires are designed to report (Yes/No) for specific barriers and enablers that customers might have encountered, such as delivery time constraints, delivery costs, or geographical limitations. The questions also encouraged respondents to provide detailed explanations and examples, allowing for a deeper understanding of their perceptions. The survey sample included a diverse group of customers (Table 3) who had either used or considered using same-day delivery services. The customer survey was conducted from October 7th to October 15th, 2023. The face-to-face interview survey was implemented with the involvement of 400 respondents. The interviewees were randomly selected at the commercial areas and office buildings

by the survey team. After scanning the respondent-filled questionnaires, the missing data sheets were omitted. Finally, 382 respondents were selected for the analysis.

From the service-supply side, the survey targeted professionals involved in logistics and operations within retail organizations. The questionnaire consisted of a series of questions designed to assess the retailers' experiences and perceptions of same-day delivery. The questions covered various aspects, including operational challenges, cost considerations, infrastructure limitations, and technological capabilities. Finally, the e-retailers were asked to rank the factors that affected their decision to provide same-day delivery services. The e-retailers rated the enablers and barriers according to their relative importance out of five, where five represents the highest importance and one the lowest. Then the results were analyzed using the Pareto chart to identify the most important factors.

Characteristics	**Description**
Gender	Male (45%); Female (55%)
Age	18-25 (22%), 25-40 (41%); 40-60 (35%); Above 60 (2%)
Education	College/associates (33%); Undergraduate (56%); Graduate (11%)
Monthly household income	Less than 3 million VND/month (1%); 3 ~ < 6 million VND/month (8%); 6 ~ < 10 million VND/month (11%); 10 ~ <20 million VND/month (35%); 20 ~ 40 million VND/month (28%); Above 40 million VND/month (17%)
Experience in purchasing products via E-commerce	Less than 1 year (3%), 1-3 years (62%); 3-5 years (21%); More than 5 years (14%)
Average number of orders per month	Seldomly using e-commerce: Less than 3 orders (8%); Moderately using e-commerce: 5-10 orders (42%); 10-20 orders (38%); Frequently using e-commerce group: More than 20 orders (12%)
Top three products purchased via e-commerce	Books (45%); Electronics (38%); Home and Kitchen (21%)

Table 3: Characteristics of customer respondents (N=382)

The survey sought to identify the specific barriers retailers cope with in implementing and managing same-day delivery services. Additionally, it aimed to uncover enablers that contribute to successful same-day delivery, such as strategic partnerships, advanced logistics technology, or optimized processes. The e-commerce retailers were selected through the 3-step process. In the first step, the shops offering same-day-delivery services in such e-commerce websites as Tiki (Tiki-Now), Lazada (24h-Delivery), and Shopee (Shopee Express Delivery). In the second step, the e-commerce retailers were contacted by sending direct messages through the website, to be introduced the aim of the survey and the possibility to share the survey results. Next, direct calls were conducted to the accepted retailers who agreed to be involved in the survey in the previous step. Finally, 128 e-commerce retailers were included in the analysis with a diverse range and encompassing different industries and sizes (Table 4).

Characteristics	**Descriptions**	**(%)**
Product Categories of E-retailers	Electronics	14,1
	Fashion and Apparel	13,3
	Home and Kitchen	15,6
	Beauty and Personal Care	18,8
	Sports and Fitness	10,2
	Books, Movies, and Music	14,8
	Health and Wellness	13,3
Number of Orders per Day of E-retailers	0-500 orders	73,4
	500-1000 orders	14,8
	1000- 3000 orders	8,6
	Above 3000 orders	3,1

Table 4: Characteristics of e-commerce retailers (N=128)

Results and Discussion

Results

Based on the survey results, time constraints, operating complexity, cost, and infrastructure constraints account for around 80% of the significant variables (barriers) affecting the willingness to expand same-day delivery logistics from an e-retailer's perspective (Table 5). Meanwhile, the strategic location of distribution centers, inventory visibility and management, data analytics and predictive modelling, and advanced technology are the most important factors (enablers) that accounted for almost 70% of the significance as rated by the e-retailers (Table 6). With the development of advanced technology, many problem issues in the past, such as inventory management or the location selection of distribution center have been transformed into enablers in the current implementation of e-retailers.

Barriers	Average weight	Percentage	Cumulative %	Rank
Time Constraints	5.4	22.46%	22.46%	1
Operational Complexity	5.2	21.02%	43.48%	2
Cost	4.7	18.52%	62.00%	3
Infrastructure Limitations	3.9	16.56%	78.56%	4
Geographical Constraints	2.5	13.01%	91.57%	5
Scalability and Capacity	2.2	8.43%	100%	6

Table 5: Barriers to expand same-day delivery logistics from the e-retailer's perspective

Enabler category	Average weight	Percentage	Cumulative (%)	Rank
Strategic Location of Distribution Centers	7.1	19.58%	19.58%	1
Inventory Visibility and Management	6.8	19.01%	38.59%	2
Data Analytics and Predictive Modeling	5.7	15.46%	54.05%	3
Advanced Technology	5.2	14.12%	68.17%	4
Changing Work Patterns and Lifestyles	3.8	10.52%	78.69%	5
Collaboration and Partnerships	3.1	8.56%	87.25%	6
Flexible Delivery Options	2.5	7.01%	94.26%	7
Skilled Workforce	2.2	5.74%	100%	8

Table 6. Enablers to expand same-day delivery logistics from the e-retailer's perspective

Considering the customer's side, the study aims to analyze the customer's perspective on barriers and enablers to encourage them to use same-day delivery service. First, the customers are categorized into three groups based on their online purchasing frequency (as the average number of orders per month). Then, customers were asked to report (yes/no) on the pre-defined questionnaires on the specific barriers and enablers to use same-day delivery service. The results show that barriers to using same-day delivery customers reported most frequently included paying higher costs compared to standard delivery options (54%), concern about the return policies and return process (35%), and same-day delivery not available in some locations (35%) (Table 7). Of those participants who reported these as barriers, a higher proportion reported concerns about the cost of paying for same-day delivery service. Small proportions of participants (6%) reported factors including being available to receive the package during the delivery window and being hesitant to rely on same-day delivery during periods of adverse weather.

The most highly reported enablers of using same-day delivery included receiving purchases quickly (52%), being able to have real-time tracking and receiving accurate estimated arrival times (42%) and having purchases for the urgency of need (35%) (Table 7). Of the 13% of participants that reported same-day delivery services are more reliable than standard delivery options due to a consistent track record that would enable them to use this service.

Factors	Frequently	Moderately	Seldomly	p-value*

	use group N = 30	use group N = 306	use group N = 46	
Barriers				
I have to pay higher costs compared to standard delivery options	60.2%	52.1%	62.8%	<0.001
Same-day delivery is not available in my location	16.4%	35.4%	41.7%	<0.001
Many products do not apply to same-day delivery service	16.2%	18.1%	18.9%	0.01
This service requires me to be available to receive the package during the delivery window	8.3%	11.5%	12.6%	<0.001
I have concerns about the return policies and return process	24.8%	36.1%	34.9%	0.07
I am hesitant to rely on same-day delivery during periods of adverse weather	3.2%	6.1%	8.3%	0.03
Enablers				
Same-day delivery provides me with the ability to receive my purchases quickly	55.6%	51.8%	48.4%	0.02
I can have my purchases for the urgency of need	36.9%	36.8%	25.5%	<0.001
This service allows me to choose a time slot that suits my schedule	12.1%	10.4%	9.3%	0.04
I have real-time tracking and receive accurate estimated arrival times	46.6%	42.8%	32.7%	0.55
Same-day delivery services are more reliable than standard delivery options due to a consistent track record	15.5%	12.7%	11.5%	<0.001

*Chi-square test for significance across all groups.

Table 7: Barriers and enablers to use same-day delivery from the customer's perspective

Discussion

Based on the study's results, it is important to realize that major goal conflicts between the service-demand side (customers) and the service-supply side (retailers) on same-day delivery logistics can arise due to differing priorities and expectations. Firstly, customers often hesitate to adopt same-day delivery due to the high cost. They desire fast delivery at minimal or no additional cost. However, for retailers, providing same-day delivery involves significant operational expenses, including transport, personnel, and infrastructure. These results are consistent with the previous studies which have been conducted in Malaysia (Siali *et al.*, 2018), Indonesia (Irawan and Belgiawan, 2022), and China (Xi *et al.*, 2021). It should be noted that, at the early stage of e-commerce development in Vietnam, the customers buy commodities at the e-commerce websites because of their low-cost attraction. To fascinating new customers, e-commerce websites often run promotions and discount programs that result in the lower price of goods compared with the selling prices at the traditional market. Therefore, the customs expect low-cost products and free-delivery service for each purchase, even with high-end services such as same-day delivery.

Secondly, customers have specific time constraints or preferences regarding the delivery time window. They may expect deliveries during a specific timeframe, such as after work hours or on weekends. Retailers, on the other hand, must optimize their delivery routes and schedules to ensure efficient operations, which may not always align with customers' desired time frames. A study in Indonesia (Irawan and Belgiawan, 2022) has a contradicting result with this finding, where the authors found that food and grocery retailers could optimize their delivery roots perfectly to adapt to the demands of the customers. Based on their study, the same-day delivery cost and time could be optimized through the application of a ride-hailing app that the e-commerce retailers in urban areas in Vietnam could reference as a lesson learned.

In addition, e-commerce customers expect clear and transparent communication regarding the status of their same-day delivery orders. They want to be notified of any delays or changes in delivery

schedules promptly. Therefore, e-commerce retailers need to establish efficient communication channels and provide real-time updates to meet these expectations. Failure to do so can result in customer dissatisfaction and conflicts related to communication. International studies from China (Xi *et al.*, 2021) and Malaysia (Siali *et al.*, 2018) also revealed the same findings. Although online shopping may reshape the social interactions among neighbours in Chinese research (Xi *et al.*, 2021), research on online shopping from Malaysian customers indicated that efficient and real-time tracking of parcels contributes significantly to customer satisfaction since they notice the reliability of delivery services.

Finally, same-day delivery logistics may have an impact on return and refund policies. Based on the research findings, customers have to pay for a high cost of express delivery, they expect the same level of convenience and speed in returns and refunds for same-day delivery orders. This result is consistent with a study from Finland (Hjort and Lantz, 2016) which revealed that returning policies had a substantial impact on the shopping behaviour of customers, especially in the fashion industry since they are fascinated with the convenient shopping experience. However, retailers must balance efficient return processes with the need to manage inventory, verify returns, and process refunds, which may involve different timeframes and processes. As mentioned in the results of research from Sweden (Saarijärvi *et al.*, 2017), free-of-charge return policies harm the long-term profit of e-commerce retailers. Therefore, same-day delivery could provide a high level of service for consumers, the returning and refunding policies should be designed at a proper level.

In summary, balancing these conflicting goals requires effective communication, transparency, and proactive management of customer expectations. Retailers must carefully consider customer preferences while also ensuring the sustainability and feasibility of their same-day delivery logistics operations.

Conclusions

With the rise of e-commerce and online shopping in Vietnam, customers increasingly expect faster delivery times. Same-day delivery meets these expectations by providing quick turnaround times, enhancing customer satisfaction, and increasing loyalty to businesses. Therefore, there has been an increasing adoption of same-day delivery logistics services in recent years in Hanoi. The study has presented the most important barriers and enablers in the perception of customers and e-retailers. From an e-retailer's viewpoint, time constraints, operational complexity, and cost are the biggest barriers to implementing same-day delivery services. However, they also noticed potential positive factors enabling their expansion, such as the strategic location of distribution centers, inventory visibility and management. Considering the opposite side of customers, they appreciate receiving purchases quickly and being able to have real-time tracking to receive accurate estimated arrival times. However, many customers hesitate to adopt same-day delivery since they have to pay higher costs compared to standard delivery options and are concerned about the return policies and return process.

The study findings facilitate the recommendations for e-commerce service providers on requiring careful planning and coordination of various logistics processes. However, the research comes with some limitations. Firstly, the effectiveness of the structured questionnaire interview survey method heavily relies on the expertise and diversity of the interviewed members. Although the study has communicated with the involved retailers, however, not all of the invited ones agreed to be involved in the survey. Therefore, there could be a lack of diversity in perspectives, and the results may be limited in their applicability. Secondly, the survey area was conducted in Hanoi, Vietnam, where the purchasing attitude and selling services could not be generalized for all areas in the Asia region. Therefore, further research could be extended in a wider region, then, the results could be compared and unique characteristics of same-day delivery service could be compared.

Acknowledgement

This research was supported, in part, by Dong-A Corporation Joint Stock Company. Any opinions and findings are those of the authors and do not necessarily reflect the views of Dong-A Corporation Joint Stock Company. Thanks are due to my students who supported conducting the surveys, as well as to my colleagues at the University of Transport Technology who provided comments on the whole article and the methodology section. The authors also like to thank the interviewees for their contribution.

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DIGITAL TRANSFORMATION & SUSTAINABLE SUPPLY CHAINS: EXPLORING INDUSTRY 4.0 FOR ENHANCED PERFORMANCE

Asterios Stroumpoulis, Evangelia Kopanaki
Department of Business Administration, University of Piraeus, Greece

Abstract

Purpose

This paper aims to explore the relationship between sustainable supply chain management and digital transformation. It also aims to develop a conceptual framework, which clarifies under which circumstances the above combination could lead not only to increased business performance, but also to the development of specific sustainable strategies.

Design/Methodology/Approach

The research follows a mixed methodology, involving a combination of a quantitative and qualitative approach. The quantitative research was based on a survey conducted in 3PL (third party logistics) companies. The collected data enabled the testing and verification of specific hypotheses and led to conclusions that were further explored through qualitative research. The qualitative research was based on the analysis of three case studies leading to an in-depth understanding of the research questions and findings.

Findings

The main findings of this paper demonstrate that digital transformation plays a critical role for companies, as integrating various technologies with business resources can lead to the development of key supply chain capabilities that enhance both sustainability impact and business performance. Furthermore, the results underscore the potential for companies to further advance their sustainability strategies through digital transformation.

Originality/Value

This paper contributes to the literature by addressing a gap in the exploration of all three pillars of sustainability within supply chains, particularly in relation to the impact of information systems and new technologies. It also addresses the lack of mixed research methodologies in this field by developing a theoretical conceptual framework that underpinned the empirical work. The research findings emphasize the importance of digital transformation in fostering sustainable supply chain practices and offer a foundation for further investigation in different industries and company types.

Research limitations/implications

The quantitative research was conducted only in 3PL companies, while the qualitative research was conducted in three companies with different roles (manufacturer, 3PL and retailer) in the supply chain. Therefore, to attain more detailed conclusions, the paper proposes the expansion of this research to include more companies and industries.

Keywords

Digital Transformation, Sustainable Development, Supply Chain Management, Industry 4.0, Business Performance

Introduction

In recent years, the adoption of new information technologies has significantly contributed to the digital transformation (DT) of companies, enhancing and optimizing their operations. Verhoef et al. (2021) note that companies embracing digital transformation have outperformed many traditional businesses. Despite the evident impact of DT on improving business performance, academic attention has been limited, with research into digitization and digital transformation only beginning to rise a few years ago.

Modern companies, which are part of large supply chains need to use new technologies or information systems (IS) to optimize their operations and improve collaboration with trading partners (Rinaldi *et al.*, 2021). DT has the potential to convert traditional supply chains into efficient and intelligent supply chains by connecting all functions and processes, such as product design and production, procurement, logistics, product distribution and customers' services (Brettel *et al.*, 2014).

In addition to the emergence of new technologies and the digitalization of supply chains, sustainability has become a focal objective for many companies. This shift is driven by the growing emphasis placed by organizations like the United Nations and the European Union not only on environmental issues, but also on societal well-being. As a result, companies need to prioritize the development of socially and economically sustainable supply chains, considering the interests of all stakeholders in

their operational environment. Integrating digitalization with sustainable practices within digital supply chains will benefit every participant involved (Farahani et al., 2017).
To address the above issues, this paper examines related research, identifies research gaps in the literature and develops a conceptual framework to explain the relationship between digital transformation and sustainable development. The results of this study, based on a mixed research methodology (qualitative and quantitative), are consistent with the findings of previous research (Stroumpoulis *et al.*, 2021) and show how the combination of sustainable policies with IT and SCM resources can lead to increased business performance and sustainable impact.

Theoretical Development

Researchers, academics, practitioners and business associations are highly interested in understanding the impact of digital transformation (DT) on societal processes, products, and business models (Al-Emran and Griffy-Brown, 2023). It is suggested that without the effective development and implementation of information technology (IT), the business world and society will struggle to achieve the sustainability goals set for 2030.
According to the literature, IT is the most critical factor enabling companies to undergo digital transformation (DT) (Andriole et al., 2017). Therefore, DT is closely linked to the application of IT within companies, with the potential to increase productivity and reduce operating costs (Yin, 2023). While it is commonly believed that digitization refers to the adoption of new digital technologies (Fitzgerald et al., 2014), this research supports the concept of DT as the use of IT resources to enhance a firm's business capabilities.
IT also plays an important role in supply chain management (SCM), as it is imperative for the development of an effective supply chain (de Camargo Fiorini and Jabbour, 2017). According to Kagermann et al. (2013), IT can fully unlock the value and efficient operation of a supply chain if all partners and their customers are able to cooperate and exchange information effectively. Therefore, achieving alignment among all trading partners is crucial when adopting new technologies to foster effective collaboration (Moeuf et al., 2018). The development and alignment of the IT infrastructure are equally important for the operational efficiency of the supply chain members. However, aligning IT among partners is challenging and requires a commitment of resources and coordination at all stages of the chain. Despite these challenges, IT alignment is essential, as digitizing supply chains can lead to automated processes within companies, saving time and resources, redistributing roles, and ultimately increasing performance and productivity (Schallmo et al., 2017).
Also, IT is a very important factor in achieving environmental sustainability (Wang *et al.* 2015). While IT affects the financial, operational, and environmental performance of companies, it remains unclear how its use in sustainable supply chain management (SSCM) might affect the resulting social performance (Fiorini and Jabbour, 2017).
Finally, according to Shee *et al.* (2018), when IT has a positive impact on supply chain performance, it can also improve the sustainable performance of the member companies.

Research gaps

This research aims to address the gaps identified in the literature by developing a conceptual framework and analysing the three pillars of sustainability. The literature review revealed certain research limitations. Firstly, although sustainable SCM is aligned with the three pillars of sustainable development, not all pillars are adequately addressed or framed in existing literature review. Mani *et al.* (2016) highlight that the social dimension of sustainable SCM receives the least attention, yet its integration is crucial for companies to achieve true sustainability. Similarly, Birkel and Muller (2021) point out that Triple Bottom Line (TBL) approaches and the application of information technologies in supply chains are predominantly focused on financial outcomes, neglecting the environmental and social pillars. The literature review indicates that a few studies analyse the integration of all three dimensions. Regarding new technologies of DT, such as blockchain technology (BT), could support supply chains by serving as a decision-making tool. It could help managers enhance their social pillar by aligning with partners and reducing fraud, while also contributing to the environmental pillar by managing and reducing waste in specific industries, such as tourism. However, there is a lack of studies in the literature that explore its impact on sustainability practices within supply chains (Saberi *et al.*, 2019). The same gap exists concerning the use of the Internet of Things (IoT) in supply chains. The implications of IoT are still in the early stages within the supply chain industry (Manavalan and Jayakrishna, 2019), and only a limited number of studies suggest that IoT could improve sustainable SCM and enhance supply chain performance (Manavalan and Jayakrishna, 2019).
After reviewing the relevant papers, none has developed a comprehensive, conceptual framework that addresses the gaps in TBL and digital technologies, nor have they examined the new

technologies of Industry 4.0 and their contributions to supply chains (Stroumpoulis and Kopanaki, 2022).

Conceptual Framework

The literature review identified key factors related to the topic of study and demonstrated that integrating sustainable development and DT with supply chain management (SCM) and IT resources, along with specific IT-based capabilities, can affect both a company's business performance and sustainable impact.

To better understand and explain this sustainable impact, particularly the economic, environmental, and social impact, theories such as the "natural resource-based view," "stakeholder theory," "legitimacy theory," and "transaction cost theory" were identified and served as the foundation for developing the conceptual framework that underpins this study. The application of the N-RBV theory in SCM offers a comprehensive approach to understanding how firms can use natural resources strategically to gain competitive advantages while addressing environmental concerns. This theory highlights the importance of integrating sustainable practices into SCM strategies, which is essential for assessing the environmental impacts of these activities (Joshi & Li, 2016). Stakeholder and Legitimacy theories, when integrated into SCM, provide a robust framework for understanding and managing the social impacts of supply chain activities. These theories emphasize the importance of considering stakeholder perspectives and ensuring that business practices are perceived as legitimate by various stakeholders, including employees, communities, and consumers (Ali & Rizwan, 2013; Deegan, 2019). The Transaction Cost Theory (TCT) offers a powerful framework for analysing the economic aspects of SCM. This theory focuses on the economic factors that influence relationships between business partners within supply chains, such as the costs associated with contracting, managing, and coordinating these relationships. By applying TCT, the research can assess the economic impact of various SCM practices, including contract management and market trend analysis. TCT also helps identify opportunities for cost reduction, risk mitigation, and value creation (Mahapatra *et al.*, 2010).

Moreover, based on the literature review, specific hypotheses have been developed.

- *H1: The company's focus on Digital Transformation (V02) and the orientation towards Sustainable Development (V06) positively influence the development of Capabilities (V05).*
- *H2: The level of Information Technology (V04) together with the skills of the Human Factor (V03) positively influence the development of Capabilities (V05).*
- *H3: The Supply Chain Processes (V01) together with the focus on Digital Transformation (V02) positively influence the development of Capabilities (V05).*
- *H4: The capabilities (V05) that have emerged from the supply chain environment improve the sustainable impact (V11) that have resulted from the adoption of sustainable practices.*
- *H5: The capabilities (V05) that have arisen from the use of Information Technology lead to an increase in Business Performance (V07).*
- *H6: The sustainable impact that has resulted from the use of Information Technology (V11) leads to Excellence in Sustainable Development (V08) within the industry.*
- *H7: The sustainable impact derived from the use of Information Technology (V11) leads to Digital Transformation Excellence (V09) within the industry.*
- *H8: The resulting Business Performance (V07), Excellence in Sustainable Development (V08) and Digital Transformation (V09) lead to the development of Sustainable Strategies (V10).*

The conceptual framework, depicted in Figure 1, demonstrates how companies can leverage sustainable policies and IT resources to improve process effectiveness and efficiency, addressing the above hypotheses. By integrating IT and SCM resources with an emphasis on sustainable development and DT, companies can achieve IT-related business capabilities that lead to improved business performance and sustainable outcomes, promoting excellence in these areas. Ultimately, these capabilities enable companies to further develop sustainability strategies, thereby improving their position in the market. As a result, the integration of digital technologies with sustainability objectives contributes to creating a more responsible and resilient business environment (Gupta *et al.*, 2020).

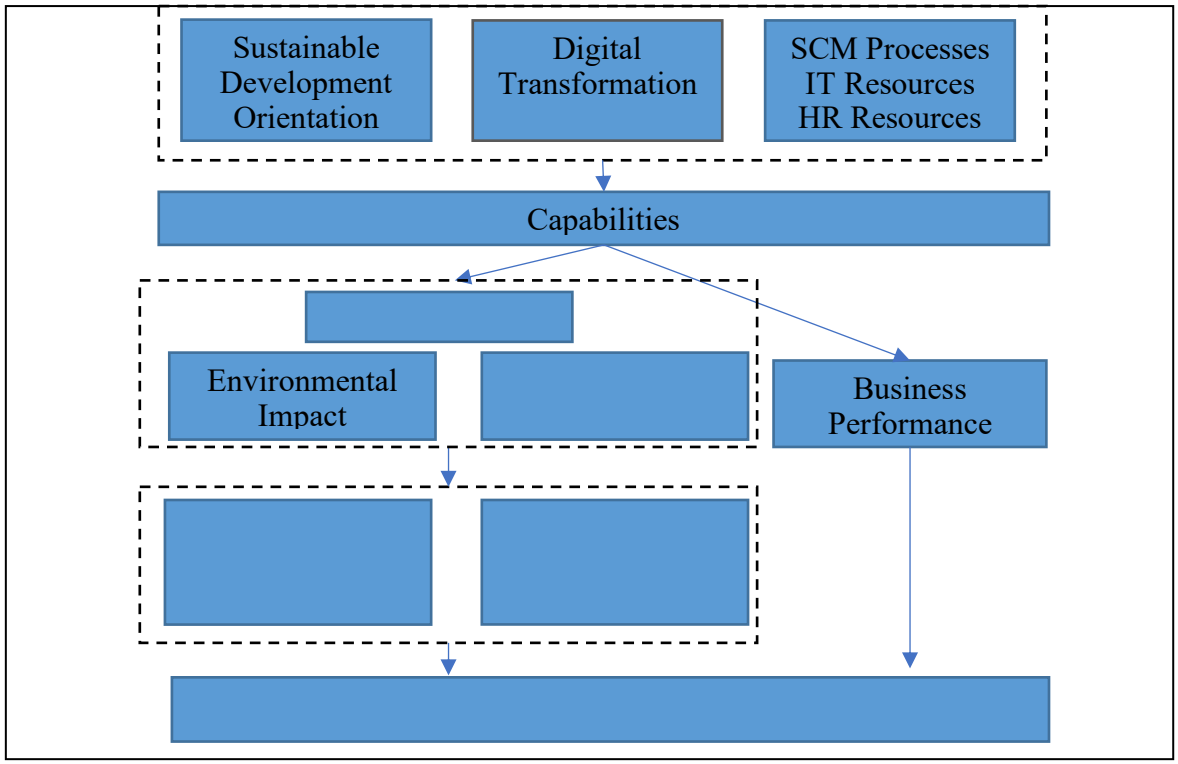

Figure 1: Conceptual Framework
Source: Stroumpoulis *et al.*, 2024

Research Methodology

In this research, a mixed research methodology was used in order to understand and address appropriately its purpose and objectives. Initially, quantitative methodology was carried out by using and designing a survey questionnaire. Finally, qualitative research through case study analysis was conducted with the use of semi-structured interviews. The combination of all the above was carried out to draw more reliable conclusions.

Quantitative Methodology

To reach safe conclusions, the authors used and tested the above conceptual framework through empirical work. To achieve this, they first employed a quantitative methodology, which investigates phenomena by collecting quantifiable data in numerical form and applying mathematical models and statistical techniques to analyze the data (Creswell and Poth, 2016). Questionnaires play a crucial role in quantitative methodology as a data collection tool (Caputi and Balnaves, 2001).

The questionnaire was formulated in accordance with the above theoretical framework, but also with the research hypotheses developed to better understand the framework. For the realization of the research, it was deemed necessary to involve the participation of the "3PL" companies that exist and operate in Greece. The industry of 3PL companies was chosen as these companies can contribute significantly not only to the economic, social and operational performance, but also to the environmental performance of their supply chain.

Following a search conducted both through the search engine "Google" and a sectoral study, a total of 251 companies were recorded, of which 111 are located in the Attica Region. In the specific research that was conducted, a total of 67 companies participated. Therefore, the response ratio of the survey is approximately 27%, which is acceptable, because according to Leslie (1972, p. 332), when the sample is homogeneous then "…surveying issues directly related to homogeneous groups should not be overly concerned about the percentage of questionnaire returns.". Moreover, the survey which was conducted by Sheekan *et al.* (2001) revealed that there is a huge decline in the response rate through email from a mean response rate of 61.5% to 24.0% in 2000. The above statement is confirmed by the survey of Wu *et al.* (2022), which observed that surveys with a smaller sample size (i.e., less than 500) require response rates of 20% to 25% to generate reasonably confident estimates.

The variables that emerged from the questionnaire were too many, so it was necessary to group them together in order to better study the research hypotheses. In order to reduce the number of variables, factor analysis was carried out using the statistical software SPSS (IBM) (Field, 2009). The above method describes the analysis of variability among correlated variables, while reducing their number

to a group of factors, also known as factors (Tharenou *et al.*, 2007). Specifically, Factor Analysis is a multivariate technique, which is undertaken to reduce the observed variables (Yong and Pearce, 2013). A Kolmogorov-Smirnov analysis was also necessary to examine whether the variables could follow the normal distribution. The KS test is widely regarded as one of the most well-known normality tests. It is mainly used to determine whether a sample originates from a population with a completely specified continuous distribution. (Drezner *et al.*, 2010). According to Sainani (2012), if the dependent variable follows the normal distribution, then the statistic test of linear regression is appropriate in order to test the hypotheses. Therefore, the linear and multiple regression analysis took place and confirmed that all the hypotheses of this research were supported.

Hypothesis	Findings	Formula
H1	Accepted	(V05) = 0,875(V02) +0,760(V06)
H2	Accepted	(V05) = 0,793(V03) +0,684(V04)
H3	Accepted	(V05) = 0,694(V01) + 0,822(V02)
H4	Accepted	(V11) = 4,036(V05) + 21,574
H5	Accepted	(V07) = 0,408(V05) + 2,048
H6	Accepted	(V08) = 0,027(V11) + 2,972
H7	Accepted	(V09) = 0,027(V11) + 3,105
H8	Accepted	(V10) = 0,524(V07) + 0,515(V08) + 0,462(V09)

Table 1: Quantitative analysis results

Qualitative Methodology

For the qualitative research, a case study methodology was selected. The research aimed to examine whether integrating sustainability orientation with IT and SCM resources in specific business contexts could improve sustainable impact and strategy formulation within the supply chain. To thoroughly explore this phenomenon and contribute to theoretical advancements, a multiple case design approach was employed. The cases were chosen using a non-random sampling strategy (Saunders *et al.*, 2019) and included a 3PL company, a retailer and a producer of building materials. In this way, the supply chain was examined from different perspectives allowing a better understanding of the issues under consideration. To ensure effective data collection, the study adopted an approach combining documentation analysis, semi-structured interviews, and participant observations. This comprehensive method was designed to gather data from various sources, enabling data triangulation (Shih, 1998). The results obtained from the empirical data collection are summarized in the following table:

Codes	3PL	Retailer	Producer
Sustainable Development Orientation	•Photovoltaic unit installation • Electric vehicles • Specialised staff • Continuous staff training • Close collaboration with business partners • Energy neutrality investments	•Recycling •Environmental campaigns •Circular economy •Packaging improvement •Social contribution •Staff education and awareness raising •Close collaboration with business partners •Energy neutrality investments	•Circular economy •Reduction of CO2 emissions •Reduction of production resources' consumption •Marine biodiversity protection •Social contribution •Health & safety of employees and partners •Continuous training •Close collaboration with business partners • Resilience to Economic challenges
IT & Digital Transformation	•Warehouse Management System •Process automation using Barcode	•Internet of Things •Warehouse Management System •Telematics •Transportation Management System	•ERP (Financial Supply Chain Management; Logistics Execution) •Internet of Things •Big Data Analytics
SCM Resources/ Processes	•Warehouse management •Picking & packing	•Fleet management •Mapping Systems for route optimization	•Fleet management •Electric vehicles for products' transportation

	•New facilities in northern Greece	•Warehouse layout •Cameras and sensors •Distribution infrastructure	•Location and traffic assessment for distribution centers •Upgrading and modernization of facilities
Capabilities	•Efficient warehouse management •Automation •Customer satisfaction and "Loyalty"	•Productivity increase •Reduction of operating costs •Consumer value	•Process automation •Efficient management of distribution centres •Consumer value
Environmental Impact	•Reducing the environmental footprint •Reverse Logistics •Traceability	•Environmental footprint reduction •Paperless processes •Reverse logistics •Traceability	• Environmental footprint reduction •Responsible resource management •Waste reduction
Social Impact	•Alignment with business partners •Transparency •Equal opportunities	•Transparency •Corporate Social Responsibility	•Transparency •Safety •Corporate Social Responsibility
Economic Results	•Financial resources saving	•Financial resources saving •Research funding	•Cost savings Access to green finance
Sustainable Development Excellence			√
DT Excellence		√	
Business Performance	√	√	√
Sustainable Strategies	•Strategy for the development of sustainable competences and skills •Sustainability strategy based on economic incentives	•Strategy for the development of sustainable competences and skills •Sustainability strategy based on economic incentives	•Networking strategy •Marketing and promotion strategy for sustainable products •Sustainable technological development strategy

Table 2: Overview of findings across different companies
Source: Stroumpoulis *et al.*, 2024

Conclusions and Limitations

The mixed methodology used in this study provides a comprehensive and insightful understanding of the intersection between IS, DT and Sustainability in SCM. The quantitative analysis confirms all the research hypotheses developed, aligns with previous literature and highlights the significant potential of DT to enhance sustainability in supply chains. This quantitative perspective reinforces the critical role of IS in improving business processes and fostering sustainability-oriented practices. Moreover, it highlights the connection of the three pillars of sustainable development - economic, environmental and social - demonstrating that investments in IT and human capital can lead to the development of Capabilities. Also, the sustainable impact developed will lead to excellence in DT, Sustainable Development and, combined with increased Business Performance through Capabilities, will lead to new sustainable strategies.

The qualitative findings from the case studies complement the quantitative analysis, revealing a common thread among companies that prioritize sustainability in their core activities. These companies, regardless of size or industry, recognize the necessary role of IS and DT in enabling and supporting their sustainable strategies. They have adopted an integrated approach that takes into account the economic, environmental and social dimensions of sustainability, thus creating value on multiple fronts. Through innovation and investment in DT, these companies have reduced their environmental footprint, improved operational efficiency and enhanced social impact. Importantly,

these sustainability efforts have not only contributed to environmental and social improvements, but have also yielded economic benefits, highlighting a long-term commitment to sustainable growth over short-term profits. In essence, these companies are well positioned for excellence in their industries, highlighting the importance of IT and sustainability strategies in shaping the future of SCM.
There are also some important limitations, which will have to be addressed in a subsequent study in order to obtain generalized and reliable conclusions. First, the questionnaire could be sent to other supply chain sectors in order to collect more data. In addition to the additional sectors, a survey could also be conducted in other countries. In addition, the qualitative research could include more case studies in each of the sectors. Again, companies from different countries with similar characteristics could be included. Finally, in addition to the range of companies and industries, a future survey could focus on the study of new technologies that are constantly emerging.

Acknowledgement
This work has been partly supported by the University of Piraeus Research Center.

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ESG ENHANCING MECHANISM THROUGH THE LENS OF SUPPLY CHAIN POWER: A THEORETICAL FRAMEWORK

Jeong Hugh HAN[1], Saeyeon Roh[2], Hyunmi Jang[3]
[1] International Business & Trade, Kyung Hee University, Seoul, Republic of Korea,
[2]Plymouth Business School, University of Plymouth, Plymouth, United Kingdom
[3]Department of International Logistics and Port Management, Graduate School of International Studies, Pusan National University, Busan, Republic of Korea

ABSTRACT

Purpose: This study proposes a theoretical framework that explores how mediative and non-mediative supply chain power can enhance ESG integration into supply chain practices and improve sustainable supply chain performance.
Design/methodology/approach: A critical literature review interprets ESG activities within supply chain practices. The combination of supply chain power and stakeholder theory forms the basis for the research model. The appropriate methodological approach is discussed based on the research question and key variables.
Findings: This study establishes a conceptual framework that integrates ESG activities within supply chain practices. We introduce a new theoretical approach to ESG and supply chain integration by combining Stakeholder Theory and Supply Chain Power Theory. This approach offers insights into the underlying mechanisms for effective ESG implementation in supply chain management.
Originality/value: The originality of this study lies in its 1) interpretation of ESG activities within supply chain practices and 2) innovative application of supply chain power concepts to ESG implementation.

Keywords: ESG, SCM, Supply chain power, Sustainable performance, Integration

Introduction

The recent introduction and expansion of Environmental, Social and Governance (ESG) regulations have prompted companies to enhance their ESG practices. ESG seeks to monitor a company's comprehensive activities, aiming to create long term value not only for shareholders but for all stakeholders. The necessity managing the entire supply chain – from the sourcing of materials to final delivery to customers - aligns ESG practices with contemporary supply chain management (SCM) principles. These principles emphasises not only on logistical and technological integration but also environmentally responsible production and long-term sustainability (Truant *et al.*, 2024). This implies that managing and supply chain operations is essential for effective ESG implementation.

Within the domain of SCM, ESG practices are recognized as crucial for several reasons: 1) mitigating ethical risks (Klassen and Vereecke, 2012) 2) enhancing brand reputation and value (Hartmann and Moeller, 2014)3) securing investment opportunities (Eccles *et al.*, 2014), and 4) achieving sustainable performance (Kumar *et al.*, 2012). However, much of the existing research focuses predominantly on external regulations or the factors driving supply chain participant to engage in ESG initiatives. This highlights a notable gap in understanding the internal mechanisms that reinforce ESG practices in supply chain context.

This conceptual paper addresses these gaps by proposing a theoretical framework that extends the concept of supply chain power to ESG practices, encompassing both mediative power (e.g., regulatory pressure) and non-mediative power (e.g., digital influence). Specifically, this paper seeks to: 1) interpret ESG components within SCM practices to establish a conceptual foundation for ESG in the SCM context, 2) provide a rationale for leveraging supply chain power to improve ESG implementation, 3) explore appropriate organizational theories to justify the research model, and 4) outline a methodology to examine the relationship between supply chain power dynamics and ESG practices. This research contributes a robust theoretical framework that guide future empirical studies in the effective integration of ESG.

Conceptual basis

Environment Social and Governance: Achieving ESG through SCM

"Environmental, Social, and Governance (ESG)" is a comprehensive framework designed to assess the sustainability and ethical implications of an organization's operations. Drawing on the work of Whitelock (2015) and the integrated ESG-SCM approach, we define ESG as “a set of activities or processes associated that reflect an organization’s relationship with its ecological surroundings, its interactions with human populations, and its internal systems of governance, all aimed at serving the interests of stockholders and other stakeholders.”

Recent literature emphasizes the growing significance of ESG. This is because stakeholders increasingly demand transparency and responsible corporate behavior. The environmental aspect of ESG focuses on the integration sustainable practices into supply chain management (Carter and Rogers, 2008). This integration may cover both product life cycle and longer-term commitment to green activities (Dang and Chang, 2023). The environmental (E) component is related to sustainable sourcing practices. This prioritises suppliers with low carbon footprints and use of renewable resources (Carter and Easton, 2011). Green logistics also plays a vital role. Firms adopt energy-efficient transportation methods and strategies to reduce emissions throughout the supply chain (Abbasi and Nilsson, 2016). 3PL consumers shown increasing interests to eco-friendly packaging and recyclable materials (Lieb and Lieb, 2010). The social (S) dimension addresses an organization’s relationships with employees, customers, suppliers, and communities. Social factors cover supplier-buyer legitimacy (Ahmed and Shafiq, 2022), and corporate social responsibility (CSR) with labor practices and health/safety standards (Cheng *et al.*, 2014). Ethical supplier relationships and long-term partnerships are also vital (Klassen and Vereecke, 2012). Firms make investment for supplier development through training and knowledge-sharing (Grimm *et al.*, 2016). These practices reflect SCM's commitment to achieve the social objectives. Moreover, such social contribution can build employee loyalty and enhance brand reputation (Fatemi *et al.*, 2018). The governance (G) dimension pertains to the policies and practices that ensure a company's accountability. In the realm of SCM, governance is essential for advancing ESG objectives. Supplier evaluation and compliance with industry standards are governance related examples (Gimenez and Tachizawa, 2012). Moreover, risk management in governance frameworks allows companies to proactively address potential disruptions (Foerstl *et al.*, 2010) This highlights the role of supply chain governance as a critical enabler of ESG success.

We argue that the relationship between ESG and SCM can be characterized with complementary, overlapping, and integrated dimensions. Sustainable sourcing is aligned with ESG objectives like environmental and social impacts. Overlaps occur when ESG principles intersect with supply chain practices, particularly in areas like responsible sourcing, waste reduction. Integration refers to the event when companies integrate ESG to their supply chain strategies to create value. Such relationships highlight the importance of supply chain practices in achieving ESG objectives. This also positions supply chain management as a key mechanism for ESG achievement.

However, the multifaceted and dynamic nature of ESG presents challenges in implementing these practices across the supply chain. The interconnectedness of environmental, social, and governance factors requires coordination with multiple stakeholders beyond internal operations (Dai *et al.*, 2024). Moreover, incorporating ESG goals into supply chain operations requires a balanced approach between long-term and short-term performance (Dang and Chang, 2023). Although an integrative ESG framework offers a clear path toward building more sustainable supply chains, its practical implementation may face significant obstacles in terms of control and coordination of complex supply chain networks.

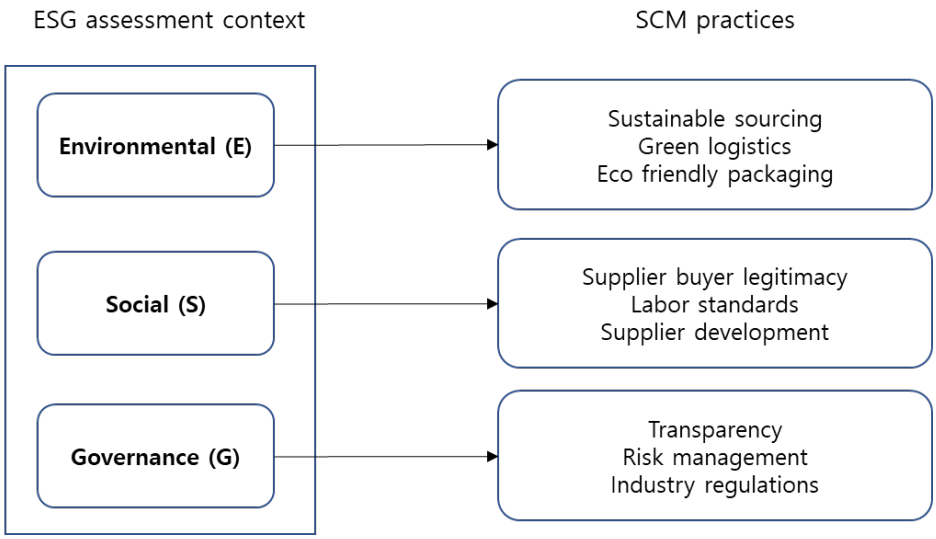

Figure 1: ESG context related to supply chain management practices

The role of supply chain power

Given these challenges, the role of power dynamics within the supply chain becomes crucial in driving the integration of ESG practices. We argue that companies with substantial supply chain power are better positioned to drive the adoption and implementation of ESG standards. Two forms of supply chain power are particularly relevant: mediated and non-mediated power (Reimann and Ketchen, 2017) (Zhang *et al.*, 2020). We interpret that mediated power, which includes regulatory authority and contract-oriented pressure, enables companies to compel suppliers to adhere ESG requirements through formal mechanisms. In contrast, non-mediated power is created by the perception of firms so encompasses firms intention to information and knowledge sharing, capacity-building initiatives that results in voluntary adoption of sustainable practices. Therefore, firms with both mediated and non-mediated forms of power can effectively coordinate their supply chain practices in alignment with ESG objectives. This dual approach – combining formal enforcement with voluntary collaboration – constitutes the theoretical foundation of this research, providing a framework for understanding how supply chain power dynamics can facilitate ESG integration.

Research model development and theoretical background

To provide a rationale for achieving ESG through supply chain management practices, this study employs a combination of organizational theories. In doing so, we explore several organizational theories. Dynamic Capabilities (DC) provides insights into a firm's ability to adapt and reconfigure resources (Teece, 2018). However, its focus on flexible capability in changing environment can overlook the importance of stable and long-term strategies in supply chain relationships. Relational View emphasizes resources sharing for relational rent so often assumes mutual benefit (Dyer and Singh, 1998). This can ignore power imbalances in supply chain relationships. Institutional Theory explains how external pressures, such as regulations and social norms (Liu *et al.*, 2010). However, it focuses on compliance so may overlook internal resource management for ESG implementation. Contingency Theory considers how market conditions affect firm outcomes (Claycomb and Frankwick, 2004), but its context-specific focus may limit supply chain wide applicable strategies.

This study combines Stakeholder Theory (Parmar et al., 2010) and Supply Chain Power Theory (Reimann and Ketchen, 2017) for the research model. Stakeholder Theory can outlines the structure of the supply chain entities as it adds a socio-political layer to discuss a firm's corporate social responsibility. Supply Chain Power Theory can offer a mechanism for controlling stakeholders, particularly those impacted by others in the network.

The model emphasizes ESG integration within the supply chain rather than focusing on specific practices. So, the model has strategic and process integration ESG goals into supply chain practices. Moreover, digital integration is important, as firms use digital tools to monitor and report ESG

practices throughout the network. In sum, our research model proposes that the interplay between supply chain power—both mediated and non-mediated—and ESG supply chain integration leads to improved sustainable performance (Figure 2). It provides a conceptual basis for understanding how ESG objectives can be embedded into supply chain practices. This perspective highlights the importance of leveraging supply chain power and strategic integration to create a coordinated, transparent, and sustainable supply chain performance.

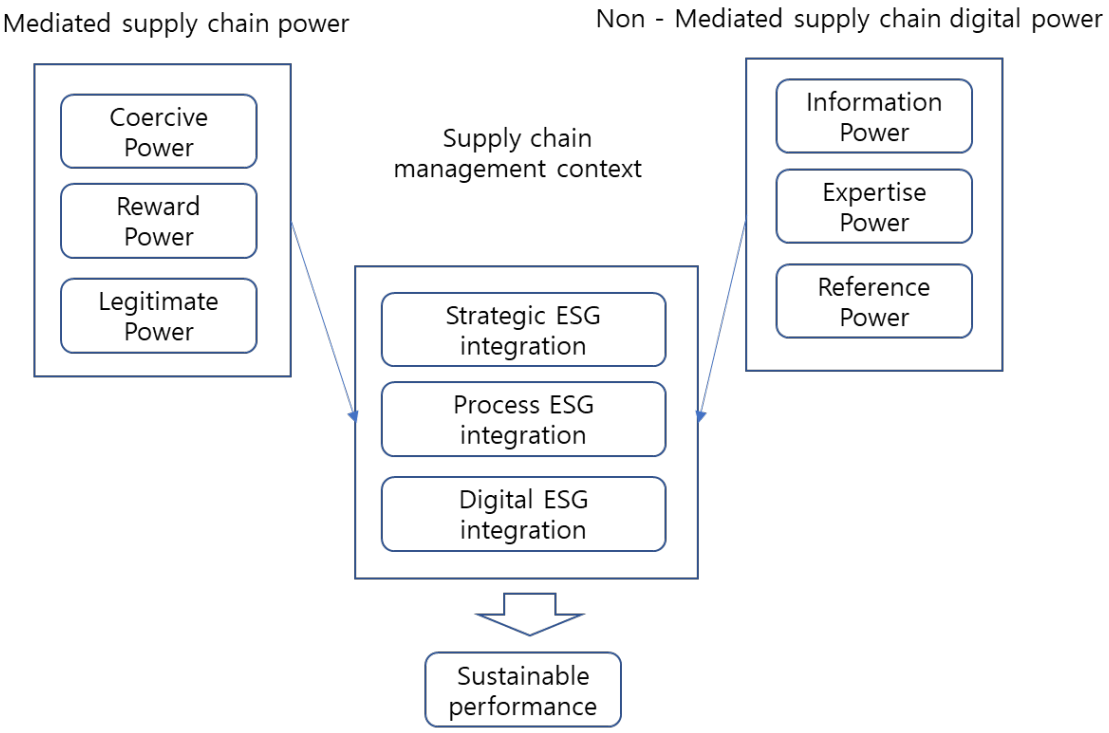

Figure 2: research model

Methodological approach: SEM vs. fsQCA

As this paper is conceptual, it lays the foundation for future empirical research on ESG integration in supply chain management. Based on the research gap to fill, we consider two methods. They are Structural Equation Modelling (SEM) and Fuzzy Set Qualitative Comparative Analysis (fsQCA). SEM is suitable for testing interactions between supply chain powers and ESG integration to supply chain practices. Its statistical approach assesses the strength and direction of the relationships between key variables (Gefen *et al.*, 2011)so offers insights of how supply chain powers contribute to ESG goals. However, it relies on predefined pathways may limit possible findings on impact of supply chain powers to ESG integration to supply chain management.

On the other hand, fsQCA offers a configurational approach that may accommodate complex causal relationships among key variables (Jang *et al.*, 2023)so able to capture multiple combinations of factors that may affect successful ESG outcomes in different scenarios. In sum, while SEM offers a structured framework to test the relationships among variables proposed in our model, fsQCA provides the flexibility to identify multiple combinations of variables for ESG success.

Criteria	SEM	fsQCA
Fit for Testing Hypotheses	Good. It is suitable for predefined hypotheses testing in the model	Less suited for hypothesis testing. It explores configurations of power types influencing ESG success
Captures Complex Interactions	Limited. It assumes linear relationships so potentially miss the non-linear relationships within the model	Effective. It accommodates diverse combinations of powers and other supply cahin practices

Flexibility In Pathways	Less flexible. It focuses on linear pathways for ESG implementation	Flexible. It identifies various configurations leading to successful ESG integration to supply chain management
Measures Strength & Direction	Good. It measures direct and indirect effects of power on ESG integration to supply chain management	Limited. It captures key combinations not exact influence or impact

Table 1: Comparison of SEM and fsQCA for the research question

Conclusion and suggestions for future research

This study establishes a conceptual basis for how supply chain power affect ESG adoption in supply chain management. It interprets ESG components into supply chain practices, examining how environmental, social, and governance factors can be integrated within the supply chain context. By combining Stakeholder Theory and Supply Chain Power Theory, it proposes a model that theorizes the mechanisms promoting ESG implementation in the supply chain network. This approach suggests how different forms of power—mediated and non-mediated—interact with ESG integration in supply chain management to promote sustainable performance.

Future empirical research is required to validate this conceptual model. The empirical research needs to explore the diverse pathways through which supply chain power influence ESG integration to supply chain practices. Researchers should consider different method such as SEM or fsQCA to offer a comprehensive understanding of these interactions. Then researchers are allowed to test the proposed relationships and examine different configurations of power across supply chain networks. Furthermore, studies should consider various industry contexts and regional factors to offer tailored guidance to enhance their firms ESG initiatives. This approach may not only deepen theoretical insights but also propose actionable strategies for sustainable supply chain management.

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EXAMINING ATTITUDES AND PERCEPTIONS TOWARDS WAREHOUSE SAFETY BEHAVIOUR

Yan Weng Tan[1], Shalini Turiahdassu[1], Victor Seah[2], Maria Cecilia Rojas Lopez[1], Qitong Zhao[1],
[1]School of Business, Singapore University of Social Sciences
[2] Behavioural Insights Centre of Excellence, Singapore University of Social Sciences

ABSTRACT

Purpose: Workplace accidents can have severe consequences ranging from the loss of life, permanent disability, legal liabilities, and work stoppages. Workers' attitudes and perceptions are key to preventing workplace accidents. This study examined how the attitudes and perceptions of warehouse personnel in Singapore affect their intention to practice safety at work.
Design/methodology/approach: The study applied the Theory of Planned Behaviour (TPB) as the framework to model safety behaviour in warehouses. The TPB model's constructs – attitudes, subjective norms, and perceived behavioural control – were measured using a set of survey items. To test the model framework against real data, data was collected in two phases: (1) pilot (or elicitation) survey and (2) main survey. Data was collected through a combination of qualitative and quantitative methods, including online and in-person interviews.
Findings: The TPB model accounted for 62% of the variability in workers' intention to practice safety in the warehouse. Attitudes and subjective norms on practising safety significantly influenced the intention to practice safety, while perceived behavioural control did not. Workers from different cultural backgrounds may respond differently to safety practice and social norms.
Research limitations: Future research should expand the sample size and recruit workers from different countries to study cross-national differences and assess the generalisability of the findings.
Practical implications: Internationally, most organisations are cognisant of the importance of Workplace Safety and Health (WSH). This has led to the provision of adequate training and resources for WSH; broadly, workers have the resources to work safely. Our findings indicate that to further enhance WSH performance, organisations need to focus on worker attitudes and subjective norms as well as understand cultural differences.
Originality/value: Few studies have applied the TPB framework to study safety behaviour in the logistics sector in Singapore. Even fewer have focused specifically on warehouse safety behaviour. Our findings highlight the significance of attitudinal and normative factors over perceived control in shaping safety intentions, providing valuable insights for WSH improvements in warehouses internationally.

Keywords: Workplace Safety and Health, Warehouse Sector, Theory of Planned Behaviour, Attitudes, Perceptions

Introduction

Singapore serves as the regional or global headquarters for 25 of the world's largest logistics players (EDB, 2024) and is ranked by the World Bank (2024) among the top 10 global logistics hubs over 2007-2023. In 2023, the Transportation and Storage sector contributed to 6.8% of Singapore's GDP and employed 9.1% of the resident workforce (Singapore Department of Statistics, 2024). Despite its economic importance, the sector poses significant workplace safety challenges.

The Transportation and Storage sector is one of three high-risk sectors that have contributed to the share of total workplace fatal (second highest) and major (third highest) injuries in Singapore. According to the Workplace Safety and Health Report 2023 (Ministry of Manpower, 2023):

- Of the 36 fatal injuries in 2023, the Construction sector was the highest contributor accounting for 18 fatal injuries (50.0%), followed by Transportation and Storage with 8 (22.2%), and Manufacturing with 5 (13.9%).
- Of the 590 major injuries in 2023, the top contributing sector was Manufacturing with 150 major injuries (25.4%), followed closely by Construction with 149 (25.3%), and Transportation and Storage with 47 (8.0%).

The warehouse environment poses significant safety and health risks (Workplace Safety and Health Advisory Committee, 2008). Handling of goods (e.g. lifting, pushing or pulling) carried out repetitively

and over a prolonged period can cause musculoskeletal injuries. Retrieving and putting away goods on high storage racks can expose workers to hazards such as "*falls from height*" and "*struck by falling object*". Working with forklifts and conveyor systems can expose workers to hazards such as "*struck by moving object*" and "*caught in between objects*".

While logistics is crucial to Singapore's economy, few studies have explored workplace safety from the perspective of warehouse workers. This study examines how attitudes and perceptions of warehouse workers affect their intention to practice safety at work. Two research questions were developed to guide this study:

RQ1: What behavioural model can be applied to explain safety behaviour in warehouses?
RQ2: What factors affect can safety behaviour in the warehouse setting?

Literature Review

This literature review examines several approaches to understanding workplace safety behaviour, their main findings, limitations, and the gaps in knowledge that remain.

Health Belief Model

The Health Belief Model (HBM) is a psychological framework to investigate why people take or do not take preventive health actions (Rosenstock, 1966). The HBM has the following constructs: perceived susceptibility, perceived severity, perceived benefits, perceived barriers, self-efficacy and cues to action. Ndep et al. (2020) applied HBM to explore factors influencing safety practices among workers in medium and large-sized factories in Nigeria. They found high levels of perceived susceptibility (95%) to workplace injuries, perceived severity (94%) to injuries, and awareness (98%) that such injuries were preventable. Yet, there was low self-efficacy (22%) in the use of personal protective equipment, indicating a disconnect between perceptions and actual safety practice.

The limitation of the HBM is that it focuses on individual perceptions and overlooks the role of social norms and peer influences as well as workplace culture that may affect safety behaviour. Ndep et al. (2020) focused on factory workers and did not explore how the HBM can apply to the warehouse setting where different safety risks and behaviour may be present.

Safety Climate and Safety Behaviour

Griffin and Neal (2000) developed a framework that linked safety climate (i.e. how safety culture is perceived by employees at a given moment) to safety performance (i.e. actual behaviour that workers perform at work) in several manufacturing and mining organisations in Australia. The study found that safety climate had a direct impact on safety behaviour. Using structural equation modelling (SEM), they found that positive safety climate led to higher safety compliance (i.e. adhering to safety rules) and increased safety participation (i.e. engagement in voluntary safety activities). The framework highlighted that workers' knowledge, skill, and motivation mediated the relationship between safety climate and behaviour.

However, Griffin and Neal (2000) did not delve into how safety climate impacts safety behaviour in warehouse environments. In addition, the framework focused on organisational factors such as policies and practices, with less attention given to individual attitudes and social norms, which may play a role in shaping safety behaviour in the workplace.

Leadership and Safety

de Vries et al. (2016) investigated the factors that contributed to a safer warehouse environment among warehouse employees and managers in small, medium-sized and large warehouses across 11 industries in The Netherlands. The study found that safety-specific transformational leadership (SSTL) played an important role in reducing warehouse accidents. Managers with a prevention-focused mindset positively related to SSTL as a leadership style. SSTL positively affected safety outcomes without negatively affecting productivity or quality, suggesting that focusing on safety did not compromise other performance metrics.

de Vries et al. (2016) reported some limitations of their study. As the study used cross-sectional data, there was a possibility that previous managers' policies influenced current accident rates, limiting the ability to establish causality between SSTL and safety outcomes. Only a small number of warehouses participated in the study which may affect the generalisation of the findings. The non-response bias

may have skewed the results towards safer warehouses; unsafe warehouses with poor safety records were less likely to participate.

Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB; Arjen, 1991, 2006) is a widely used psychological framework for understanding and predicting human behaviour. TPB posits that whether a person intends to do something depends on how positively or negatively the person feels about doing it ("*attitudes*"), how much social pressure the person feels to do it ("*subjective norms*"), and whether the person feels in control over the situation ("*perceived behavioural control*"). See Figure 1. Several studies have applied the TPB to explain safety behaviour in various contexts.

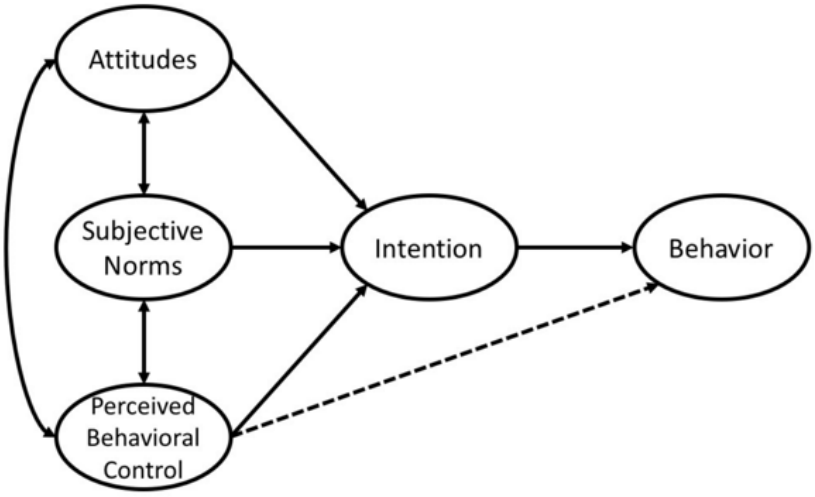

Figure 1: Theory of Planned Behaviour (Source: Ajzen, 1991)

For instance, Fogarty and Shaw (2010) applied the TPB to investigate safety violations of aircraft maintenance personnel in the Australian Defence Force. They found that attitudes, group norms, and intentions accounted for about 50% of the variance in self-reported violations. They noted the importance of management attitudes and group norms in shaping behaviour.

More recently, Cheng et al (2021) applied the TPB to study traffic violation behaviour of e-bike couriers in China. Their results showed that attitudes, descriptive norms, and perceived behavioural control explained about 56% of the variance in intention to engage in traffic violation behaviour. They also noted that intentions together with perceived behavioural control accounted for about 29% of the variance in self-reported violation behaviour.

Previous research has contributed to the understanding of safety behaviour in various settings by applying frameworks such as the Health Belief Model (HBM), safety climate, and safety-specific transformational leadership. However, these studies have mainly focused on individual, managerial or organisational factors. Few studies have explored safety behaviour in warehouses, especially considering social and peer influences. While the TPB has been effective in other contexts, its use in warehouse environments remains limited.

This study addresses this gap by applying the TPB to examine the behavioural factors influencing safety intentions in warehouses. The findings can offer organisations valuable insights into key areas for improving workplace safety and health.

Methodology

This study used the Theory of Planned Behaviour (TPB) as the theoretical framework to explore safety intentions among warehouse workers. Both qualitative and quantitative data were collected to test the TPB model. Data collection occurred in two phases: (1) a pilot survey; followed by (2) a main survey.

Phase 1: Pilot Survey
The pilot (or elicitation) survey sought to identify the salient beliefs that warehouse workers hold towards practising safety in the warehouse. This survey used a semi-structured, qualitative approach centred around the three constructs of the TPB: (1) attitudes, (2) subjective norms, and (3) perceived behavioural control. Respondents were asked open-ended questions related to the perceived advantages, disadvantages, social approval, and barriers to practising safety in the warehouse.

The pilot survey was conducted in March 2023 using Google Forms through online and in-person interviews. The call to participate online was sent out to personal contacts in the logistics sector via social media to reach out to warehouse workers. In-person interviews were carried out near an industrial estate in a conversational format to elicit workers' views on safety behaviour. Each interview took about 10 to 15 minutes to complete.

A total of 15 warehouse workers responded, of which 10 responded online and 5 in-person. The most frequently cited responses to the open-ended questions were analysed to develop the structured questions for the main survey.

Phase 2: Main Survey
The main survey for warehouse workers used a structured approach to collect mainly quantitative data. The survey questionnaire consisted of two sections:

Section 1: Respondent information (7 questions)

Section 2: Attitudes and perceptions on safety behaviour (total 17 questions)
- Attitudes on practising safety (5 questions)
- Subjective norms on practising safety (4 questions)
- Perceived behavioural control on practising safety (5 questions)
- Intention to practise safety (3 questions)

The attitude and perception questions were constructed in plain, easy-to-understand English and used a 7-point Likert scale, ranging from 1 ("strongly agree") to 7 ("strongly disagree") to measure responses to the TPB constructs. The survey questionnaire was administered using Google Forms and the order of questions was randomised.

The main survey was conducted in April and July 2023. In-person interviews were carried out by visiting areas where many warehouse workers congregate during weekends for social gatherings and during weekday evenings at the end of their shift. The interviewer asked the questions in an unobtrusive and relaxed manner, entered the inputs on the participants' behalf, and ensured no questions were skipped or left unanswered.

A total of 121 warehouse workers participated in the surveys. Each survey took about 15 minutes to complete. Most migrant workers from India required clarification in their native language.

Results and Discussion
To enhance the quality of data, respondents who gave uniform, non-differentiating responses (i.e. flatlining) for items on attitudes and perceptions were excluded from the analysis as they were not likely to be meaningfully engaged with the survey or rushed through it. As a result of the exclusion criteria, ten responses were removed: 9 respondents rated "1" for every item (i.e. socially desirable answer); 1 respondent rated "4" (i.e. neutral) for every item.

Respondent Profiles
Figure 2 shows the profiles of the warehouse workers analysed (N = 111) after the exclusion criteria was applied. Most respondents (70.3%) indicated they had at least 5 years of work experience, with a mean of 5.8 years. Most respondents reported they worked between 40 to 50 hours per week. The vast majority (88.3%) indicated they worked in warehouses with a size of between 10 to 50 workers.

The most common age group of respondents was 25-30 years old, followed by those aged 30-35 and 35-40 years old. The mean age of respondents was 34.0 years old. Two-thirds of the warehouse workers surveyed were male while one-third were female. With regards to nationality, most

respondents (44.1%) indicated they came from India, followed by Singapore (27.9%), Malaysia (25.2%) and Bangladesh (2.7%).

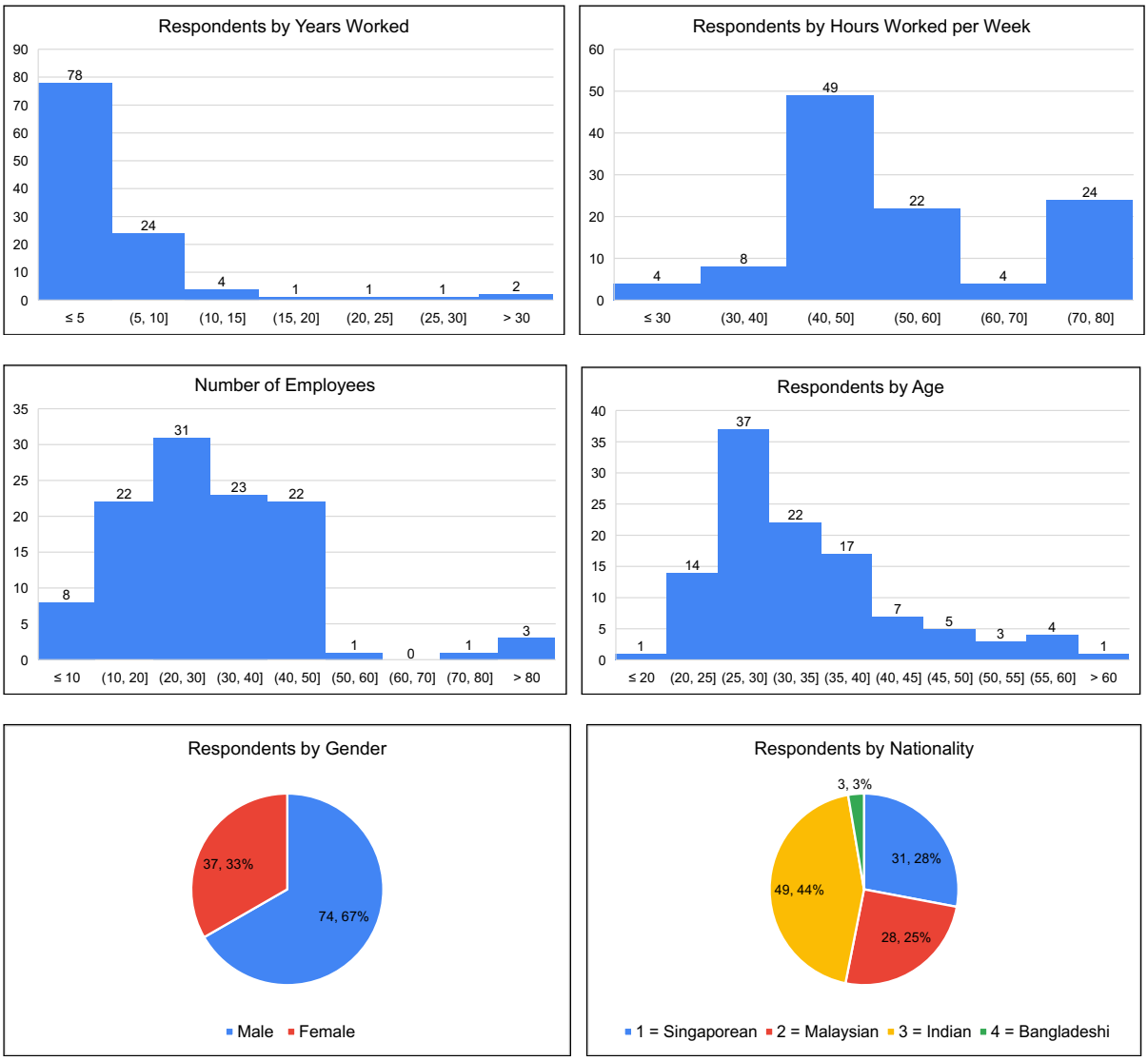

Figure 2: Respondent profiles

Ratings on Attitudes and Perceptions

Table 1 summarises the means and standard deviations of ratings for the TPB items measured in the main survey. For attitudes represented by ATT1-ATT5, respondents agreed that practising safety in the warehouse would result in a safer workplace (mean score = 1.47), better health (1.62) and good staff morale (1.74). Interestingly, respondents were closer to neutral when it came to time (3.53) and convenience (3.02).

Regarding subjective norms (SN1-SN4), respondents strongly agreed that family/spouse (1.29) played an important role in influencing their intention to practise safety in the warehouse, followed by their supervisor (1.94) and colleagues (1.95). Respondents agreed that knowing their colleagues were likely to practise safety (2.51) would influence their intention to practise safety.

For perceived behavioural control (PBC1-PBC5), respondents agreed they had the safety culture (2.01), safety training (2.29), safety equipment (2.33), and proper signs and floor markings (2.41) to practise safety. Respondents somewhat agreed that they had sufficient time to practise safety (3.15).

Regarding intention (INT1-INT3), respondents strongly agreed that they expected to (1.33), will practice (1.34) and intended to practice (1.35) safety in the warehouse.

Constructs	Items	Content	Mean	SD
Attitudes	ATT1	Practising safety in the warehouse would result in a safer workplace.	1.47	0.63
	ATT2	Practising safety in the warehouse would result in better health.	1.62	0.89
	ATT3	Practising safety in the warehouse would be good for staff morale.	1.74	0.92
	ATT4	Practising safety in the warehouse does not take up too much time.	3.53	1.70
	ATT5	Practising safety in the warehouse is convenient.	3.02	1.55
Subjective Norms	SN1	My supervisor thinks that I should practise safety in the warehouse.	1.94	1.01
	SN2	My family/spouse think that I should practise safety in the warehouse.	1.29	0.94
	SN3	My colleagues think that I should practise safety in the warehouse.	1.95	1.09
	SN4	My colleagues are likely to practise safety in the warehouse.	2.51	1.23
Perceived Behavioural Control	PBC1	I have the safety equipment needed to practise safety in the warehouse.	2.33	0.99
	PBC2	I have the necessary safety training needed to practise safety in the warehouse.	2.29	1.12
	PBC3	My warehouse has the proper signs and floor markings needed for me to practise safety.	2.41	1.01
	PBC4	I have the time needed to practise safety in the warehouse.	3.15	1.40
	PBC5	The safety culture at my warehouse makes it easy for me to practice safety.	2.01	0.90
Intention	INT1	I expect to practise safety when working in the warehouse.	1.33	0.65
	INT2	I will practise safety when working in the warehouse.	1.34	0.78
	INT3	I intend to practise safety when working in the warehouse.	1.35	0.79

*Note on 7-point Likert scale: 1 = Strongly Agree, 2 = Agree, 3 = Somewhat Agree, 4 = Neutral, 5 = Somewhat Disagree, 6 = Disagree, 7 = Strongly Disagree

Table 1: Mean and standard deviation of Likert ratings for each item

For the full set of TPB items, Cronbach's alpha ranged from 0.563 to 0.863, indicating the items gave responses with reasonable to high levels of reliability. We tested the removal of items within each construct to see if Cronbach's alpha could be improved. The optimal set of items that gave the best Cronbach's alpha was removal of ATT4 and ATT5 in the attitudes construct (value increased from 0.563 to 0.775); keeping all items in the subjective norms construct (0.568); removal of PBC4 in the perceived behavioural control construct (value increased from 0.740 to 0.773); and keeping all items in the intention construct (0.863). The ratings for each item within the TPB constructs were then averaged to develop the composite ratings for further analysis.

Model Evaluation and Factors Affecting Safety Behaviour

Table 2 presents the results of multiple linear regression analysis to evaluate the goodness-of-fit of the TPB model. Intention to practice safety was set as the dependent variable, while attitudes, subjective norms and perceived behavioural control were the independent variables. For all workers surveyed, the adjusted R^2 indicated that the TPB model accounted for about 62% of the variability in data, which is considered a good fit. The model performed well for Singaporean workers (84%) but performed rather poorly for Malaysian (24%) and India/Bangladeshi workers (20%). There may be other factors at play not captured by the TPB model, e.g. cultural, language, and socio-economic factors.

Both attitudes and subjective norms were significant predictors (at the 5% level) of safety intention for all workers in the sample. Attitudes and subjective norms were also strong predictors for Singaporean workers. Subjective norms was the only significant predictor for Malaysian workers, while attitudes was the only significant predictor for Indian and Bangladeshi workers. Perceived behavioural control was not significant for all workers and across all groups.

Nationality	Singapore	Malaysia	India & Bangladesh	All Workers
Dependent Variable: Intention *"I expect / will / intend to practice safety when working in the warehouse"*				
Independent Variables	Regression Coefficients			
Attitudes *"Practising safety would result in safer workplace; better health; would be good for staff morale"*	**0.567***	0.157	**0.273***	**0.426***
Subjective Norms *"My supervisor / family / spouse / colleagues think that I should practice safety"* *"My colleagues are likely to practice safety"*	**0.534***	**0.528***	0.137	**0.514***
Perceived Behavioural Control *"I have the safety equipment / safety training needed to practice safety"* *"My warehouse has proper signs and floor markings"* *"Safety culture at my warehouse makes it easy"*	-0.125	-0.148	-0.021	-0.106
N	31	27	51	111
Adjusted R^2	0.843	0.238	0.200	0.618

Note: * $p < 0.05$, i.e. regression coefficient is statistically significant at 5% level

Table 2: Evaluation of the TPB model for warehouse safety behaviour

Implications

Importance of attitudes and social norms. Our results indicate that workers' positive attitudes toward safety and influence of subjective norms (e.g. expectations from supervisor, family and peers) had a strong positive effect on their intention to practice safety in the warehouse. Across all groups, perceived behavioural control was consistently not significant. We can only surmise that workers may feel they have adequate safety resources and safety culture at the workplace to work safely.

This suggests that efforts to enhance workplace safety should focus on reinforcing positive attitudes and leveraging social norms within the workplace. These initiatives should help workers see safety as valuable, beneficial, and integral to their work. Initiatives to strengthen positive attitudes toward safety can include safety awareness campaigns, safety training programmes, rewards and recognition programmes, and integrating safety into job evaluations. Initiatives to leverage social norms can include peer-led safety leaders, team-based safety challenges, safety pledges, and management and supervisor role modelling.

Importance of understanding cultural differences. Our findings suggest that workers from different cultural backgrounds may respond differently to safety practices and social norms. For instance, Singaporean workers may be more accustomed to local safety practices and compliance culture, where attitudes and subjective norms are key drivers of behaviour. Malaysian workers may depend more on collective or group norms, arising from a more community-oriented culture where peer and supervisor expectations are highly influential. Indian and Bangladeshi workers may come from environments with different safety standards that prioritise personal beliefs and attitudes on safety over workplace norms that they may find unfamiliar.

These differences suggest that interventions targeted at improving warehouse safety may need to be tailored to the cultural and demographic context of the workforce. By tailoring such interventions, organisations can foster a more inclusive workplace where safety becomes a shared priority across diverse cultural groups. Examples of culturally sensitive interventions can include culturally tailored safety training, customised communication of safety norms, tailored safety recognition programmes, culturally sensitive safety ambassadors, and multicultural safety awareness events.

Conclusions

This study builds upon previous research by applying the Theory of Planned Behaviour (TPB) to investigate safety behaviour of warehouse workers in Singapore. The combination of qualitative responses from the pilot survey and quantitative data from the main survey provided the basis for

understanding the factors influencing safety intentions. The results revealed that both attitudes and subjective norms on practising safety significantly affected workers' safety intentions, while perceived behavioural control did not have a significant impact. The study also highlighted important cultural differences in how workers from various backgrounds respond to safety practices.

Several limitations need to be noted in this study. First, the small sample size may limit the generalisability of the findings. Broader representation across different nationalities can provide a more nuanced understanding of safety behaviour in warehouses. Second, some respondents may have provided socially acceptable answers rather than honest ones, despite efforts to randomise the order of questions and conduct in-person interviews. Third, the TPB model, while effective in explaining safety intentions for local workers, performed poorly for foreign workers. This suggests that there may be other unmeasured factors – such as cultural, linguistic, or economic conditions – that play a role in influencing safety behaviour.

Future research can address these limitations by expanding the sample size and to include workers from other parts of Asia. Examining the impact of age, gender, and years of work experience on safety intentions may be worthwhile. Given the cultural differences between local and foreign workers, further work should explore how cultural factors affect safety norms and compliance. Developing tailored interventions that consider the specific cultural or social contexts of these groups may lead to more effective strategies for enhancing workplace safety in multinational environments.

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FRAMEWORK FOR ACCESS HUBS SYSTEM VEHICLE ROUTING WITH STOCHASTIC CUSTOMER DEMAND

Maharshi Dhada, Duncan McFarlane
Institute for Manufacturing, Department of Engineering, University of Cambridge, 17 Charles Babbage Road, Cambridge, UK

Abstract

Purpose: This paper presents a solution framework to a typical yet often encountered problem in last mile internal and external logistics. This is a case where a warehouse has a fleet of vehicles with limited capacities, and caters to customers in its neighbouring region with known locations. The customer demand is continuous, and each demand (package) is associated with weight, earliest start time, and latest arrival time.
Design/ methodology/ approach: This paper presents a solution framework to a typical yet often encountered problem in last mile internal and external logistics. This is a case where a warehouse has a fleet of vehicles with limited capacities, and caters to customers in its neighbouring region with known locations. The customer demand is continuous, and each demand (package) is associated with weight, earliest start time, and latest arrival time.
Findings: The findings presented in this paper are the results obtained using the proposed framework and a synthetic testing dataset approved by globally one of the largest shipping and logistics companies. The results show that the aforementioned problem can be solved using a framework relying on reinforcement learning technique that minimises the overall uncertainty while allocating and routing the fleet vehicles.
Originality/ value: This paper presents a solution framework to address the split delivery vehicle routing problem with stochastic and continuous customer demand. The paper is impactful as this is an often encountered problem in internal and external last mile logistics, and more so because the testing dataset used for obtaining the results presented in this paper is approved by one of the globally largest shipping and logistics service provider.
Keywords: Last mile logistics, vehicle routing, stochastic problem, probabilistic modelling, transportation

1 Introduction

There exist several systems for delivery vehicle routing, aiming to improve efficiency and reduce operational costs for their corresponding applications (Ghiani et al., 2022; Humes, 2016). The most prominent delivery systems include:

1. *Direct routing*, where vehicles deliver goods directly from warehouses to customers, minimizes stops but may increase the total distance travelled.
2. *The access hubs system*, which by contrast to the direct routing system, consolidates goods at central hubs before distributing them, reducing travel distances and optimizing delivery in high-demand areas.
3. *Dynamic routing*, which allows for real-time adjustments based on traffic, weather, or demand, offering flexibility for last-mile delivery.
4. *Multi-depot routing*, that optimises the operations by distributing vehicles across several depots, while crowdsourced delivery leverages independent contractors to offer flexible, cost-effective distribution solutions.

This paper particularly deals with the *access hubs system* for routing delivery vehicles, which is increasingly popular in urban areas. The access hubs system is an advanced centralised logistics approach, designed to enhance the efficiency of the delivery vehicle routing by consolidating goods at centralised hubs before distribution to their corresponding final destinations. The hubs act as intermediate points where goods are aggregated, sorted, and then dispatched to their destinations, making it easier to manage high-demand areas and streamline last-mile delivery. This system plays a crucial role in reducing the complexity of direct deliveries, especially in urban environments and large-scale supply chains. A typical vehicle routing model with hubs can be formulated as a mixed-integer linear programming problem (Faugère et al., 2020, 2022).

This system finds applications in various industries, including e-commerce, retail, and manufacturing. In urban logistics, access hubs allow for efficient distribution in densely populated areas, where direct delivery to each customer may not be practical due to traffic congestion and limited parking. For large-scale supply chains, especially those involving multiple regions, access hubs enable more scalable operations by allowing companies to manage logistics through regional distribution centres. By routing vehicles through hubs, companies can optimise the delivery routes, thereby lowering the transportation costs, reduce delivery times, and minimize environmental impacts through more efficient use of vehicles(Faugère et al., 2020, 2022).

One of the primary advantages of the access hubs system is its scalability. As demand grows, more hubs can be added to the network without significantly increasing operational complexity. Furthermore, the system promotes sustainable logistics by reducing vehicle miles travelled, thus lowering fuel consumption and carbon emissions.

The applications and design of the access hubs system have been extensively explored for urban logistics applications. The literature highlights the efficiency gains from modular hub networks that facilitate the sharing of logistics resources across companies. For example, collaborative logistics hubs can significantly reduce delivery times and costs in e-commerce networks, and improve the sustainability of supply chains by optimizing the use of transportation assets and minimizing empty miles (Crainic et al., 2023). A schematic representation of an access hubs delivery vehicle system is shown in Figure 1. As shown in Figure 1, multiple hubs may sometimes deliver to the same hubs, often making this a split-delivery vehicle routing problem.

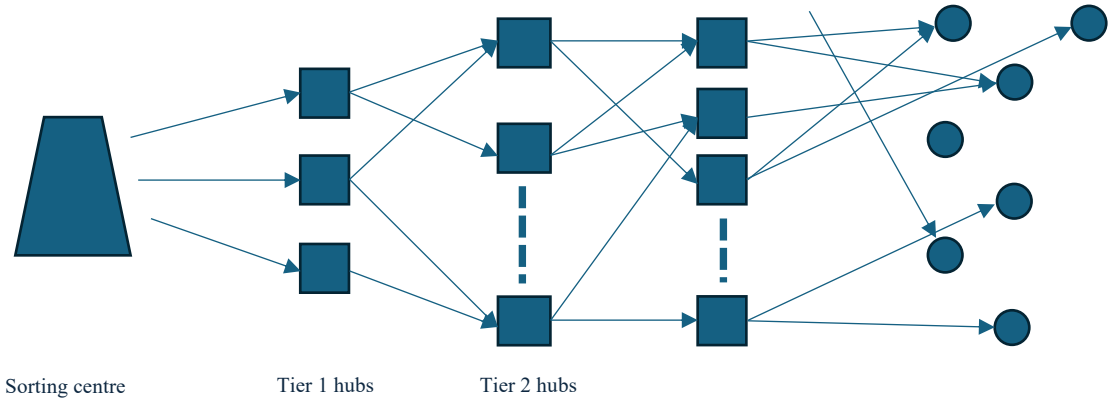

Figure 1. Schematic representation of an access hubs delivery vehicle system

Nonetheless, the access hubs systems are easily prone to propagations of a poor customer demand through the system. This is due to the fact that the access hubs delivery systems are largely serial systems, and therefore the inaccuracies in the customer demand compound as one goes higher up in the system. That is, away from the customer nodes (Liu et al., 2024).

More specifically, over-forecasting the customer demands in an access hubs delivery system leads to excess inventory at hubs, resulting in higher storage costs, inefficient use of transportation resources, and potential product spoilage. Under-forecasting, on the other hand, causes stock shortages at hubs, leading to delayed or incomplete deliveries, dissatisfied customers, and increased transportation costs due to emergency restocking. Both scenarios disrupt the balance of the hub-and-spoke model, reducing the efficiency of vehicle routing and increasing operational complexity. Ultimately, inaccurate forecasting undermines the system's ability to optimize last-mile delivery and meet customer expectations effectively.

This paper presents a basic simulation to demonstrate the impact of over and under forecasting the customer demand, on the overall cost of an access hubs delivery system for static customer demands. This simulation is explain and the results from the simulation are presented in Section 2. Section 3 presents a framework to enable the deployment of an access hubs delivery system by

incorporating the stochastic customer demand, especially for a split-delivery vehicle routing problem with continuous customer demand. Finally Section 4 summarises the key conclusions and future research directions.

2 Simulation to Demonstrate the Effect of Poor Customer Demand on the Access Hubs System

This section demonstrates a basic simulation to demonstrate the impact of a poor customer demand forecast on the overall cost of an access hubs delivery system for static customer demands.

Simulation Setup

A three-tier section of a bigger access hub system setup was considered for the purpose of this simulation, where a local hub tier 1 delivers to *20 local hubs* at the tier 2, and each local hub at tier 2 further delivers to *5 local hubs* each at tier 3. Each lower tier hub's (i.e. the hub next in the direction of the deliveries) demand would be forecasted by their corresponding higher tier hubs that serve them, and this demand would be relayed back to the further higher tier hubs and so on. The deliveries are then dispatched to fulfil the demands at corresponding lower tier hubs, who would then further fulfil their respective demands. A schematic of this is shown below in Figure 2.

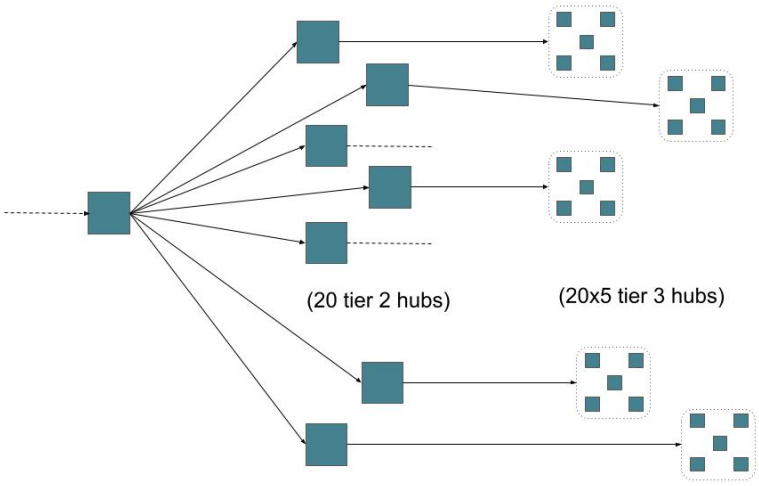

Figure 2. A schematic representation of the simulation, with 20 tier 2 hubs each delivering to 5 tier 3 hubs

For this section of the access hub that was simulated, a single delivery vehicle type with capacity of 50 packages was used for the simulation, and only one package type was considered. There were no time constraints for the deliveries. The demands for the lower tiers were generated as random integers between 10 and 50, and the demands for the higher tiers were the summation of the demands of their corresponding lower tiers. Total 1000 sets of demands for each of the lower tiers were generated, thereby representing 1000 simulation rounds for which the total delivery costs were calculated. Any given hub's demand was capped at 50, which is the capacity of the delivery vehicles. This is to avoid further complications in the routing algorithm. Nonetheless, there exist several heuristics to solve the routing problems where the customer demands are higher than the vehicle capacities (split delivery vehicle routing problems).

Each tier of the system was thus treated as a standard capacitated vehicle routing problem, which was solved using Google OR Tools Python library in this simulation. It should be noted that the goal of this simulation was to demonstrate the impact of a poor forecast in terms of the relative cost with respect to the case of accurate customer demand forecast. Therefore the routing algorithm at each tier does not impact the results significantly, and can be easily replaced with any other vehicle routing heuristic. The distances were kept consistent as the simulation focuses solely on the relative impact of the customer demand forecast of the system. The distance matrices used between the tier 2 to tier 3 hubs is shown below, with D resembling the location of the tier 2 hub and numbers 1 through 5 in bold resembling each of the tier 3 hubs which are being served:

	D	1	2	3	4	5
D	[0,	29,	20,	21,	17,	35]
1	[29,	0,	15,	29,	28,	40]
2	[20,	15,	0,	15,	14,	25]
3	[21,	29,	15,	0,	17,	30]
4	[17,	28,	14,	17,	0,	32]
5	[35,	40,	25,	30,	32,	0]

If the forecasted demand was higher than the actual demand, i.e. the case of over-forecasting, it would still be fulfilled by the previous hub in the system since the over-forecast was relayed to the previous hub earlier, but would end up as excess inventory at that hub in real life. This cost of increased inventory is not considered in this simulation. On the other hand, if the forecasted demand that was relayed to the previous tier hub is lower than the actual demand, the hubs that are served at the lower level would be removed from the route in the order of their decreasing total demands – so that the minimum number of hubs' demands are unfulfilled. In this simulation, the total number of hubs that are not fulfilled are counted at each level for this section of the access hubs, which also include the hubs served by the unfulfilled hub.

In summary, an over-forecast results in an increased travelling cost, whereas an under-forecast results in a number of unfulfilled customer demands. In this simulation, delivery costs associated with only the tier 3 hubs were considered while evaluating the impact of over-forecasting. However, while evaluating the impact of under-forecasting, demand unfulfillment at all the hubs are considered. Schematic representation for the case of an under-forecast is shown in Figure 3.

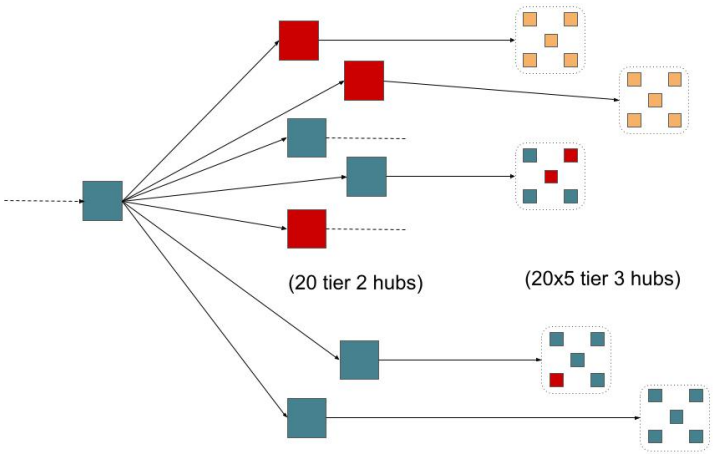

Figure 3. A schematic showing the under-fulfilled nodes in red. It is shown that if a tier 2 node is under-fulfilled, the corresponding tier 3 nodes are impacted as well

For the case of over-forecasting

To evaluate the impact of over-forecasting the customer demand, 1000 sets of baseline demands at each of the tier 3 hubs were generated. With total 20 tier 3 hubs, each delivering to 5 further hubs, a single demand set comprises of 20x5 numeric arrays. 1000 such arrays were randomly generated using integers between 10 and 50. Thereby representing 1000 simulation rounds, for which the total delivery costs were calculated. To evaluate the impact of over-forecasting, the demands corresponding to each of the baseline demands were systematically increased in steps of 2%, 5%, 10%, 30%, and 50%. This was to simulate that the forecasted demands are corresponding percentages higher than the actual baseline demand.

Total distance and number of vehicles used for each of these cases were evaluated across the 1000 demand sets, and the distributions over these 1000 sets are presented in Figures 4 and 5, for the distances and the number of vehicles used respectively. It is observed that the delivery costs exponentially increase with the increasing errors in the forecast. Moreover, the number of vehicles required for the deliveries also steeply increase as the error in the demand increases.

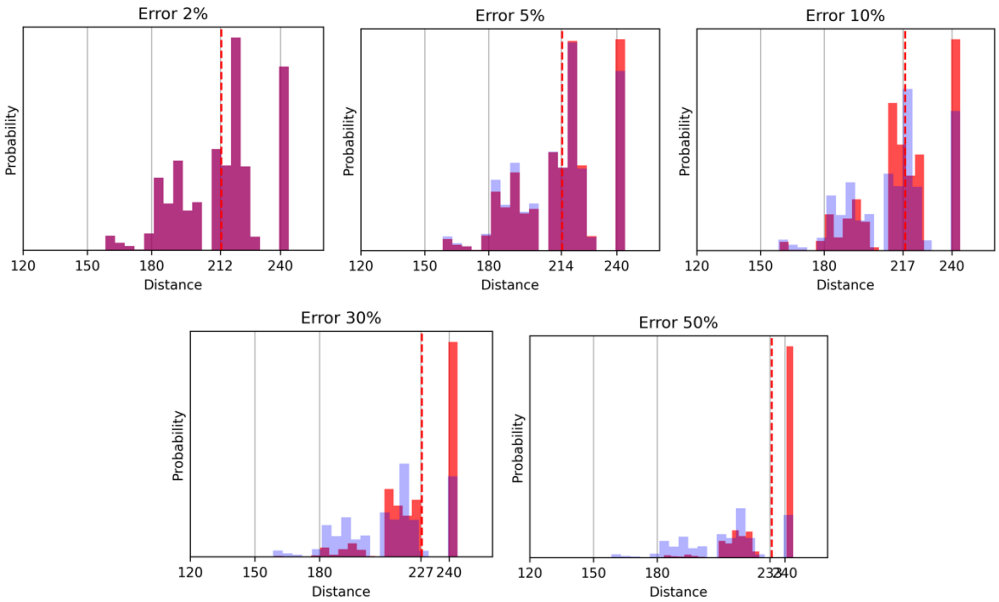

Figure 4. Increasing cost of deliver (shown in red) with respect to the baseline cost (shown in blue) as the forecasted demand is systematically increased

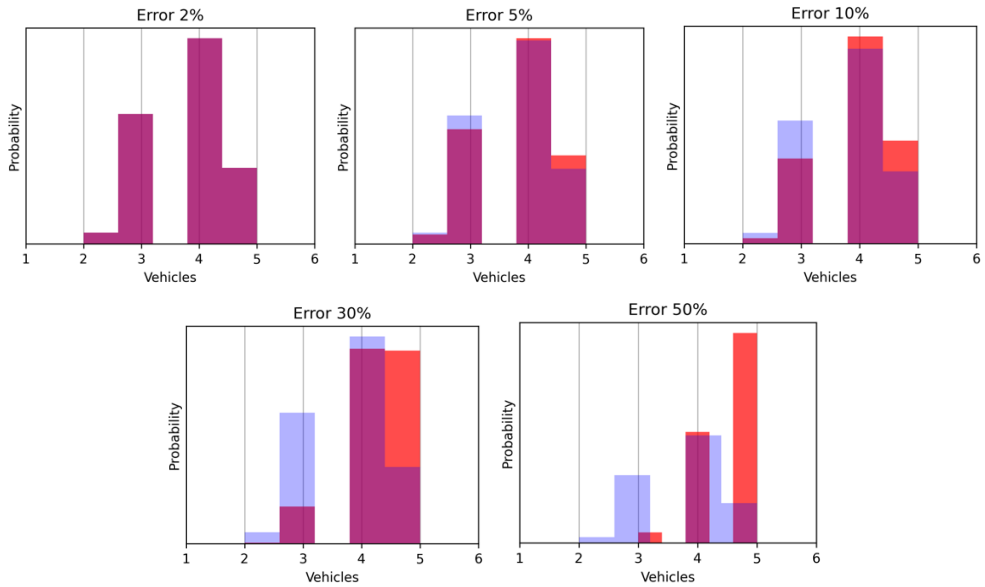

Figure 5. Increasing number of vehicles needed (shown in red) with respect to the baseline number of vehicles needed (shown in blue) as the forecasted demand is systematically increased

For the case of under-forecasting

To evaluate the impact of under-forecasting, 1000 sets of baseline demands at each of the tier 3 hubs were generated. This was similar to the case of over-forecasting simulation above. The forecasted demands for tier 2 hubs were the cumulative of the demands at their corresponding tier 3 hubs. To evaluate the impact of under-forecasting the demand, the baseline demand was systematically decreased in steps of 2%, 5%, 10%, 30%, and 50%. This was to simulate the fact that the forecasted demand was corresponding percentage lower than the actual baseline demand.

For each of the cases of under-forecasting, the number of under-fulfilled hubs were calculated. The hub chosen to be under-fulfilled would be the one with maximum demand, so that the number of under-fulfilled hubs are minimised. The actual impact of under-fulfilled hubs was also calculated based on the number of hubs the under-fulfilled hub delivers to. For example, the impact of one

under-fulfilled tier 2 hub results in under-fulfilment of five tier 3 hubs in this case. Table 1 presents the average number of tier 2 under-fulfilled hubs, resulting impact in the tier 3 hubs, and the number of under-fulfilled tier 3 hubs for each of the cases of under-forecasting the demand across 1000 simulation rounds. It can be observed in Table 1 that under-forecasting leads to a large number of under-fulfilled hubs, which is especially true for the case of an access hubs delivery system where the demand fulfilments of the hubs rely on the hubs before.

Table 1. Average number of under-fulfilled hubs at tiers 2 and 3

Under-forecast percentage	Tier 2 hubs under-fulfilled	Impact of the tier 2 nodes	Tier 3 hubs under-fulfilled
2	5	25	20
5	5	25	20
10	10	50	20
30	27	135	32
50	46	230	45

3 Proposed Framework for an access hubs system with continuous and stochastic demand

In Section 2 it is shown that an access hubs delivery system critically relies on demand forecast. Given the serial nature of the access hubs system, errors in demand can easily propagate through the logistics network leading to inefficient deliveries. This is especially challenging when the delivery network deals with a variety of old and new products, a fleet with a variety of vehicles associated with their own costs and capacities, and when the customer demand is continuous. A continuous customer demand refers to the case where the demand is received at every timestep, which means the vehicles must be loaded and routed continuously.

In all the above cases, it is critical to forecast the customer demands accurately. However for the particular cases of *cold-start* problems, for example when a new product is introduced or a new region is to be served where there exists limited historical data, the proposed statistical hierarchical modelling framework is deemed useful to *borrow* information from other *similar* components of the system. For example, a similar component for a newly introduced product can be a similar other product in the same category or in a complementary category, a similar component for a new region could be a similar other region already being served in terms of the demography, wealth, social behaviour, etc. Furthermore, the framework uses a Bayesian approach, allowing prior knowledge from higher levels to inform forecasts for the new hub, while gradually updating predictions as data accumulates. This ensures robust initial forecasts, improving hub performance from the beginning (Gelman et al., 1995).

Statistical hierarchical models, or multi-level models, have been conceptualised long ago and find applications in diverse applications such as infrastructure asset management, predictive maintenance, election results forecasting, or even burglary forecasting in urban areas (Bull et al., 2023; Davies & Bishop, 2013; Dhada et al., 2022; Gelman et al., 1995)! A hierarchical model is characterised by each individual (in this case a customer or a hub) being modelled with a forecasting algorithm, whereby the parameters of this forecasting algorithm are sampled from a higher level distribution. This higher level distribution is shared by *similar* components of the logistics network, as discussed above. In practice, when there is a lack of training data, the forecasts rely on the higher level distributions which represent in fact the prior information about the forecasts from similar other components.

By leveraging both granular and aggregated data, a hierarchical model can account for local variations while aligning with broader trends. This helps in more accurate predictions for each hub by sharing information across regions. The model reduces noise in smaller datasets, corrects biases, and incorporates temporal, spatial, and external factors, ultimately improving the forecast's precision and robustness, leading to more efficient resource allocation and delivery scheduling. For example, in the absence of sufficient historical data for a new hub, a hierarchical model leverages data from established hubs at higher levels in the hierarchy (regional or system-wide). This shared information helps in estimating demand patterns by recognising similarities in customer behaviours, geographic proximity, hub characteristics, etc. Figure 6 represents an example of a basic hierarchical model for a

newly introduced product, that relies on historical information from other similar products for improved forecasts.

4 Conclusions and Future Research Directions

This paper presented the impact of an inaccurate forecast for an access hubs delivery system. Demand forecast is especially important for an access hubs system due to its largely sequential or serial nature. In Figures 4 and 5 it is observed that the delivery costs steeply increase when there is an over-forecast of the demand, whereas an under-forecast renders several hubs/ customers under-fulfilled. The challenge with the demand under-forecasting is especially true for an access hubs system due to the sequential nature, where the hubs that are in the subsequent tiers are also impacted if a higher up hub is under-fulfilled. This is shown in Figure 3.

Moreover, a framework relying on statistical hierarchical modelling is also proposed in this paper as a solution for the case of continuous stochastic customer demand, which especially presents a real challenge for the access hubs system in the presence of sparse historical data.

There exist several future research directions stemming from this work, which include:

1. Conducting a sophisticated analysis of the impact of demand forecasting on the logistics network type. For example, defining the criticality of hubs based on the number of other hubs it is connected to, and studying the most important features that determine the impacts of an inaccurate forecast
2. Expanding beyond a standard capacitated vehicle routing problem, and into more realistic split delivery vehicle routing problems within the access hubs delivery system
3. Deploying the proposed hierarchical model framework for the case of an access hubs system in presence of a continuous and stochastic customer demand

5 Acknowledgements

This research was sponsored by the SF Express Research Fellowship in Logistics.

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GREENHOUSE GAS EMISSIONS IN COLD CHAIN AGRICULTURAL LOGISTICS

Nilubon Chonsawat 1, Natapol Thongplew 2, Channarong Puchongkawarin 3, 4 Poti Chaopaisarn,* Ganda Boonsothonsatit 5

1 Department of Agricultural Economy and Development, Faculty of Agriculture, Chiang Mai University; nilubon.chon@cmu.ac.th

2 Department of Biological Science, Faculty of Science, Ubon Ratchathani University; natapol.t@ubu.ac.th

3 Department of Chemical Engineering, Faculty of Engineering, Ubon Ratchathani University; channarong.p@ubu.ac.th

4 Supply Chain and Engineering Management Research Unit, Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University; poti@eng.cmu.ac.th

5 Graduate School of Management and Innovation, King Mongkut's University of technology Thonburi
**Corresponding: kanda.boo@kmutt.ac.th*

Abstract

Purpose - The transportation sector contributes to global greenhouse gas (GHG) emissions, accounting for approximately 26%. Considering this environmental challenge, this research aims to compare GHG emissions across three transportation modes in cold chain logistics of agricultural products.

Design/methodology/approach - The study quantified the environmental impact for each mode — air, road, and rail, using LCA methodology with a case study from northern to southern Thailand over 1,628 kilometres in cold chain logistics of agricultural products.

Findings - The results show that air transport, which is the fastest transportation mode, is also the most emission-intensive at 0.8191 kgCO2-eq/tonne-km, primarily due to high fuel requirements. Road transport offers more flexibility and is widely used, emitting 0.1591 kgCO2-eq/tonne-km. Rail transport is not widely used in Thailand, but it emerges as the most sustainable route, producing only 0.0817 kgCO2-eq/tonne-km.

Research limitations/implications - The analysis did not account for emissions due to factors such as traffic congestion, frequent stopping and starting of vehicles, or other operational delays. It also does not include greenhouse gas emissions related to support activities during loading and unloading.

Practical implications - Research findings underscore the potential for significant emission reductions in cold chain logistics through prioritizing rail transport, highlighting the importance of sustainable transportation in the agriculture sector and mitigating the environmental impact. Despite high initial construction costs, rail transport had lower overall emissions due to its longevity and energy efficiency.

Originality/value - This study provides a comprehensive comparison of GHG emissions across different transportation modes specifically for cold chain agricultural logistics in Thailand, contributing to sustainable transportation decision-making in the agriculture sector.

Keywords – agricultural products, cold chain logistics, greenhouse gas emissions, life cycle assessment, transportation modes.

Introduction

Developing cold chain logistics is a crucial strategy for enhancing logistics and supply chain management in the agricultural and perishable sectors (Han *et al.*, 2021). It aims to promote the development of operations, reduce losses, and ensure traceability in logistics activity. Nevertheless, transportation plays a significant role in climate change, contributing up to 26% of global greenhouse gas emissions (Rivera *et al.*, 2022).

Reducing transportation emissions is essential for reducing the impacts of climate change and achieving sustainability (Zhang and Fujimori, 2020). Assessing emissions from various activities and

processes within transportation is important for developing effective strategies for reducing environmental effects. This approach focuses on creating economic and social value while reducing environmental impact by maximizing resource efficiency (Ciliberto *et al.*, 2021). By considering the greenhouse gas emissions, Life Cycle Assessment (LCA) is an important technique to evaluate the environmental impacts of a product or service, from raw material, manufacturing, and transportation to product usage and disposal (ISO, 2022; Saxe and Kasraian, 2020). The development of circular economy-based cold chain logistics also presents a promising opportunity to address these challenges (Chester and Horvath, 2009).

In 2021, the demand for vegetables and fruits from northern Thailand in the southern region reached a significant 193 tonnes, equivalent to 96 20-foot containers. This volume was transported through air and road. While air transport offers speed, it comes at a high cost financially and environmentally. Though more flexible, road transportation contributes substantially to greenhouse gas (GHG) emissions and traffic congestion. Recognizing these challenges, the Thai government has initiated support for rail transportation, aiming to diversify and optimize the nation's logistics infrastructure.

The pressing need to implement circular economy principles in cold chain logistics for agricultural products necessitates a comprehensive evaluation of transportation modes. Thus, this research aims to conduct a comparative analysis of greenhouse gas emissions across rail, road, and air transport within cold chain logistics, transporting agricultural products from northern to southern Thailand, a total distance of 1,628 kilometres, by employing LCA methodology. This result is crucial for informing policy decisions and industry practices to support Thailand's growing demand for agricultural products while minimizing environmental impact.

The structure of this research is that the following research will proceed with a literature review, Life Cycle Assessment (LCA) application in cold chain logistics and greenhouse gas emissions. The third section outlines the research methodology, and the fourth section presents the results. Finally, the last section will present the research conclusion and the limitations.

Literature review

This section is a literature review that aims to synthesize current research on cold chain logistics, focusing on comparing different transportation modes using the LCA principle.

Cold chain logistics and sustainability

Generally, cold chain logistics ensures that sensitive products are transported under controlled temperatures (Pajic *et al.*, 2024) to maintain optimal temperature conditions for perishable products throughout the supply chain. That plays a crucial role in the global economy, ensuring the safe transportation of perishable goods (Titlo *et al.*, 2024). However, the energy-intensive nature of temperature-controlled supply chains contributes significantly to GHG emissions, raising concerns about environmental sustainability. According to Ndraha *et al.* (2020), efficient cold chain management can significantly reduce waste, lower costs, and improve product traceability. However, the energy-intensive nature of cold chain operations poses environmental challenges.

Hazen *et al.* (2021) emphasized the potential for circular economy models to reduce environmental impacts in logistics. Their study highlighted how integrating principles of resource reuse, remanufacturing, and recycling can minimize waste in supply chains. This approach aligns with broader sustainability goals and offers a framework for improving the environmental performance of supply chain in developed and developing nations. According to Banihashemi *et al.* (2023), emphasized the potential for circular economy models to reduce environmental impacts in digital transformation perspective.

LCA in cold chain logistics and transportation mode

LCA has emerged as a tool for evaluating the environmental impacts of cold chain logistics. LCA is a methodological framework for assessing the environmental impacts of product systems through circular economy principles, from raw material extraction through production, use, and disposal to improved circularity and resulting environmental impacts (Luthin *et al.*, 2024).

In the context of cold chain logistics, Dong *et al.* (2022) outline LCA approaches, including process-based, economic input-output. This establishes the context and aims to address the identified gap by using a hybrid LCA approach to estimate greenhouse gas emissions of cold warehouses in China

over 40 years. Shen et al. (Shen *et al.*, 2023) conducted an LCA-based energy analysis on cold food storage using strawberries as a case study. They highlighted the significant energy consumption in warehousing and suggested optimization strategies for reducing energy use and emissions.

A key focus of recent research has been comparing different transportation modes in cold chain logistics. Trevisan and Bordignon (2020) conducted an exploratory LCA comparing CO2 and GHG emissions across air, road, and rail transport. Their findings reinforced the environmental benefits of rail transport over road and air. Lee *et al.* (2008) further analyzed the environmental loads of gravel and concrete rail tracks using LCA.

This literature review highlights research on sustainable cold chain logistics and uses LCA methodologies to compare transportation modes and identify critical energy consumption and emissions points. As mentioned, this research consistently emphasizes the environmental impacts of different transportation modes in cold chain logistics, particularly in regions like Thailand, where the sector plays a vital role in economic development and food security.

Research methodology

This study aims to compare the greenhouse gas emissions of different transportation modes used to transport agricultural products from northern to southern Thailand. The methodology employs an LCA approach, focusing on three transportation modes.

Data collection

The functional unit for this study is defined as the transportation of 1 tonne of product over a distance of 1 kilometre (a tonne-kilometre, tkm). This unit allows for standardized comparison across different transportation modes. The system boundary encompasses the entire transportation process from the point of origin in northern Thailand to the final destination (customer) in southern Thailand, covering a distance of approximately 1,628 kilometres. Three primary transportation modes are considered in this study: air, road, and rail. Data for this study is collected from both primary and secondary sources. First, the primary data is obtained through interviews with relevant stakeholders, including:

- Consolidators and distributors of agriculture in northern Thailand
- Representatives from the State Railway of Thailand
- Logistics service providers

These interviews aim to gather information on transportation routes, vehicle types, load factors, and, where possible, fuel consumption data. Then, the secondary data is sourced from:

- The Ecoinvent database (Wernet *et al.*, 2016)
- The Intergovernmental Panel on Climate Change (IPCC) 2013 report (Secretariat, 2013)

GHG emissions calculation

Given that the transportation of agricultural products is often handled by third-party service providers, direct access to energy consumption or fuel usage data might not be available. In such cases, this study employs the activity-based calculation method to estimate greenhouse gas emissions, commonly used in life cycle assessment studies. The activity-based calculation method follows the general formula (1):

$$\text{GHG Emissions} = \text{activity data} \times \text{emission factor} \quad (1)$$

Where, *activity data* represents the tonne-kilometres of goods transported and Emission Factor is derived from the Ecoinvent database (Wernet *et al.*, 2016)and IPCC 2013 report (Secretariat, 2013).

Data analysis and comparison

The calculated GHG emissions for each transportation mode (railway, road, and air) will be compared to identify the most sustainable practices for transporting agricultural products from northern to southern Thailand. This comparison will consider factors such as distance, load capacity, and energy efficiency of each mode. The quantity of transported goods affects the amount of greenhouse gas emissions. This research also considers transportation volumes ranging from 100 to 200 tonnes to study the impact of greenhouse gas emissions when changes in shipment volume occur.

The results of this research will contribute to the knowledge of cold chain logistics. They may inform policy decisions to reduce the environmental impact of agricultural product transportation in Thailand.

Result

Greenhouse gas emission by mode of transport

Air transport is the primary method used by agricultural distributors in northern Thailand. The process begins with loading products into boxes and transporting by a 4-wheel refrigerated truck to Chiang Mai International Airport in northern Thailand. Here, the products are transferred to an aircraft equipped with cold storage, transporting products to the destination airport at Hat Yai International Airport, southern Thailand. Upon arrival at the destination, customers pick up agricultural products from the warehouse. The transportation details and emission factors for air transport are summarized, see Table 1.

Emission factors	Quantity	Unit
4-wheel refrigerated truck		
Load weight	290	kg
Fuel consumption rate	4.50	km/l
Total transportation distance	32	km
Fuel consumption	7.11	liters
Cardboard boxes	35	boxes
Aircraft Airbus A320		
Load weight	290	kg
Fuel consumption (Boonlasette and Worrapon, 2023)	7,400	liters

Table 3: Emission factors of agricultural transport from northern to southern Thailand by air

Road transport is used for special events, such as exhibitions, and employs a logistics provider. Products are packed in reusable plastic baskets and transported by a 10-wheel refrigerated truck from northern Thailand's distributors in agriculture to a Hat Yai, Songkhla distribution center in southern Thailand. There are no return shipments from the south to Chiang Mai in northern Thailand; only empty baskets are returned. The transportation details and emission factors for road transport are summarized in Table 2.

Transportation Details	Quantity	Unit
10-wheel refrigerated truck		
Load weight	3,250	kg
Fuel consumption rate	3.30	km/l
Plastic baskets	324	baskets

Table 4: Emission factors of agricultural transport from northern to southern Thailand by road

Rail transport is a new transportation model in this research. The process begins with loading products into reefer containers and transporting them by a crane truck from northern Thailand's distributors to Lamphun Railway Station. Then, the containers are transferred by rail using a reach stacker and transported from Lamphun Railway Station to Ban Phachi Junction Railway Station and Bang Sue Grand Station in Bangkok, then to the destination in Bang Klam Station in Songkhla, southern Thailand. At Bang Klam Station, the containers are unloaded using a reach stacker, and customers pick up the products with 10-wheel trucks. The transportation details and emission factors for rail transport are summarized, see Table 3.

Transportation details	Quantity	Unit
Crane truck		
Load weight	7,956	kg
Plastic baskets weight	1,734	kg
Fuel consumption rate (loaded)	2.8	km/l

Transportation details	Quantity	Unit
Fuel consumption rate (unloaded)	3.2	km/l
Transportation distance	26	km
Reach stacker		
Fuel consumption (Rani, 2010)	19	liters/hr
Train		
Fuel consumption rate (State Railway of Thailand, 2006)	0.25	km/l
Transportation distance	1,648	km
Refrigerated container		
Size	20	feet
Container weight	2,430	kg
Cooling equipment weight	465	kg
Generator weight	1,157	kg
Power consumption	2	kWh
Generator power	5	VA
Generator fuel consumption	1.1	liters/hr
Insulation material	Polyurethane	
Refrigerant	R407C	
Refrigerant amount	3	kg

Table 5: Emission factors of agricultural transport from northern to southern Thailand by rail

The greenhouse gas emissions for each transportation mode are calculated based on IPCC guidelines (Secretariat, 2013), using activity data from each mode and emission factors from various processes. Emissions are expressed in kg CO2 equivalent (kgCO2tkm). The coefficients for greenhouse gas emissions of vehicles and refrigerated containers are summarized, see Table 4.

Transport type	CO2 emission coefficient	Unit
Air Transport		
4-wheel refrigerated truck	0.488	kgCO2tkm
Refrigerated aircraft	0.761	kgCO2tkm
4-wheel truck (unloaded)	0.3345	kgCO2tkm
Cardboard box	0.57	kgCO2/ box
Road Transport		
10-wheel refrigerated truck	0.29	kgCO2tkm
10-wheel truck (50% load)	0.0852	kgCO2tkm
Plastic basket	0.2	kgCO2/basket
Rail Transport		
10-wheel truck	0.0533	kgCO2tkm
10-wheel truck (unloaded)	0.59	kgCO2tkm
Diesel engine operation	0.0421	kgCO2hr
Diesel train engine	0.0552	kgCO2tkm
20-foot refrigerated container	0.00693	kgCO2km /day
20-foot container	0.00013	kgCO2km /day

Table 6: Greenhouse gas emission coefficients for transport modes (IPCC).

Greenhouse gas emissions analysis

The greenhouse gas emissions analysis reveals significant differences among transportation modes. Rail transport is the most environmentally friendly option, emitting the most minor greenhouse gases at 0.0817 kgCO2-eq/tonne-km. Road transport follows with moderate emissions of 0.1591 kgCO2-eq/tonne-km. Air transport is the highest emitter at 0.8191 kgCO2-eq/tonne-km. These findings are visually represented in Fig. 1, which compares the emissions across the three modes.

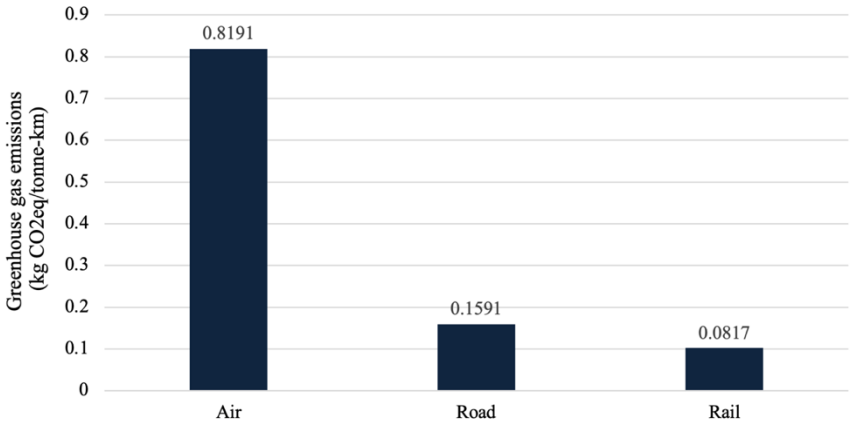

Fig. 2. Greenhouse gas emissions for different transportation modes

The stark contrast is evident in the data. Air transport produces 5.15 times more emissions than road transport and exactly 10.03 times more than rail. While the fastest, air transport is also the most energy-intensive and emissions-heavy mode. The higher emissions from air transport can be attributed to two main factors: the substantial fuel required for flight and the higher impact of emissions released at altitude. This is consistent with findings from Facanha and Horvath (2007) concluded that air cargo had significantly higher CO2 emissions per ton-mile than rail transport in their life-cycle analysis of freight transportation modes.

Road transport remains a dominant mode for cold chain logistics due to its flexibility and extensive infrastructure. However, it is also a significant contributor to GHG emissions. An environmental assessment of road transport revealed considerable energy consumption and emissions, emphasizing the need for more sustainable practices in this sector. In contrast, rail transport demonstrates the lowest emissions due to its energy efficiency compared to road and air transport. Rossi et al. (Rossi *et al.*, 2021) emphasize that intermodal rail-road transportation can significantly reduce carbon dioxide emissions, making it a viable alternative for perishable food logistics. These findings align with previous research, which conducted life cycle assessments of freight transport modes. Such studies consistently showed rail transport had lower environmental impacts, including global warming potential, than road and air transport. This efficiency can be attributed to rail's ability to move large quantities of goods with relatively lower energy consumption

Conclusion

Cold chain logistics is critical in maintaining product quality and reducing spoilage throughout the supply chain. However, the significant energy of this sector is significant, and it substantially contributes to greenhouse gas emissions. This study employed LCA methodology to evaluate the environmental impacts of different transportation modes within cold chain logistics for agricultural products in Thailand. It compared rail, road, and air transport regarding their GHG emissions.

A comparative study on the GHG emissions of air, road, and rail transport highlighted that air transport emissions were significantly higher than those of rail and road, making it the least sustainable option among the three. It is important to note that road transport remains dominant in cold chain logistics due to its flexibility and existing infrastructure. However, it is also a significant contributor to GHG emissions. Then, rail transport generally has lower emissions due to its energy efficiency compared to road and air transport, as it can transport large quantities of goods.

In conclusion, this study contributes to cold chain management for agricultural products. As the global focus on sustainability intensifies, the insights provided by this research will be crucial in shaping the future of environmentally responsible cold chain logistics in Thailand and potentially in other regions with similar logistical challenges. The insights from this study provide a foundation for understanding the potential benefits of changing to rail transport for reducing greenhouse gas emissions in agricultural product transportation.

It is important to note the limitations of this research. The analysis did not account for emissions due to factors such as traffic congestion, frequent vehicle stopping and starting, or other operational delays. It also does not include greenhouse gas emissions related to support activities during loading and unloading.

Future research should focus on developing more comprehensive LCA models that incorporate detailed operational data. There is also a need to explore innovative technologies for improving energy efficiency in cold chain logistics, particularly for perishable products.

Acknowledgements
This research project is supported by King Mongkut's University of Technology Thonburi (KMUTT), Thailand Science Research and Innovation (TSRI), and National Science, Research and Innovation Fund (NSRF) Fiscal year 2024.

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IMPACT OF KNOWLEDGE MANAGEMENT AND PORT DISRUPTION ON PORT PERFORMANCE: PERSPECTIVE OF CAMBODIAN SHIPPERS

Kimlay Chou*, Poti Chaopaisarn
1* Logistics Engineering and Supply Chain Management Program,
Department of Industrial Engineering
Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand
Tel: (+66) 62-2017029, Email: kimlay_chou@cmu.ac.th
2 Supply Chain Engineering Management Research Unit,
Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand
Tel: (+66) 53-944125, Email: poti@eng.cmu.ac.th

ABSTRACT

Purpose: This study investigates the impact of Knowledge Management (KM) and Port Disruptions (PD) on Port Performance (PP) from the perspective of Cambodian shippers. Specifically, it examines how KM, Human Errors (HE), and PD influence Port Reliability (PR) and overall port performance.

Approach: The research employs a combination of Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and Structural Equation Modeling (SEM) to investigate the relationships between KM, HE, PD, PR, and PP. Data were collected from 200 Cambodian shippers to test the proposed relationships and validate the findings.

Findings: The study finds that KM significantly reduces HE, thereby enhancing PR. PD has a marginally positive effect on PR, indicating that ports handle routine disruptions well but may be unprepared for severe crises. Notably, PD does not have a significant direct impact on PP. Instead, PR emerges as the most influential factor driving PP, highlighting the need to strengthen reliability through effective knowledge management and disruption mitigation strategies.

Research limitations: The study faced limitations in measuring PD due to the exclusion of items irrelevant to Cambodian ports, reducing construct validity. Limited respondent experience with severe disruptions further constrained insights. Enhancing model fit and adding variables can improve robustness and theoretical clarity. As the study focuses on Cambodian shippers, the findings on PD's impact on PR and PP may not generalize to contexts with more frequent severe disruptions.

Practical implications: The findings offer actionable insights for stakeholders. Academic institutions can incorporate these results into logistics curricula and promote further research. Policymakers can develop training and knowledge-sharing policies to reduce HE and enhance PR. Industry practitioners should adopt KM practices, such as training and collaboration, to minimize disruptions and improve reliability, applying academic insights to operational improvements.

Originality: This study integrates KM, HE, PD, PR, and PP into a comprehensive framework, demonstrating KM's indirect role in mitigating PD and highlighting PR as a key driver of PP. By bridging theory and practice, it offers new perspectives on enhancing port performance and resilience, contributing to both academic understanding and industry strategies.

Keywords: Knowledge Management, Port Disruption, Port Reliability, Port Performance, Human Errors

Introduction

Ports are the keystone of global trade and economic activity, functioning as critical hubs for the transportation and exchange of goods. They connect producers, manufacturers, and consumers across continents, ensuring the seamless movement of resources and supporting supply chains that sustain industries and communities. Despite their importance, port operations are often vulnerable to disruptions, both man-made and natural, that can hinder efficiency, reliability, and resilience. The research problem centers on the limited understanding of how KM and HE influence PD and, subsequently, PR and PP. While previous studies have investigated the impact of human errors on occupational accidents (Bowo and Furusho, 2018, Fabiano et al., 2010, Uğurlu et al., 2015) and analyzed the relationship between KM and organizational performance (Al-Bahussin and Elgaraihy, 2013, Asoh et al., 2007), a notable gap remains in exploring how these factors interconnect specifically in the context of port operations. Furthermore, the perspectives of shippers—key stakeholders who initiate and organize the movement of goods—have been underexplored, leaving a critical void in understanding how these dynamics influence their operations and decision-making.

The significance of this research lies in its potential to bridge these gaps and provide actionable insights for both academia and practice. By analyzing the relationship among KM, HE, PD, PR, and PP, this study aims to offer evidence-based strategies for mitigating risks and enhancing port reliability and performance. This is particularly important as man-made disruptions, including labor strikes and accidents, account for over half of port disruptions globally (Lam and Su, 2015). Employing methodologies such as EFA, CFA, and SEM, this research contributes to the academic discourse by uncovering causal relationships and validating theoretical frameworks. The findings will serve as a foundation for developing strategies that port authorities, policymakers, and shipping companies can implement to enhance operational resilience and reliability.

Literature Review

Ports are critical to global trade, yet they face persistent challenges related to KM, PD, PR, PP, and HE. The existing literature provides valuable insights into these factors but reveals gaps in understanding their interconnections and implications for operational resilience and efficiency. KM is recognized as a key enabler of organizational performance through continuous learning, knowledge sharing, and innovation. Studies highlight that KM facilitates operational efficiency by promoting trust, collaboration, and knowledge transfer across organizations (Al-Bahussin and Elgaraihy, 2013, Zhou et al., 2021). Maritime knowledge clusters and firms' absorptive capacities are shown to enhance performance, yet the direct role of KM in mitigating human errors and improving port reliability remains underexplored (Asoh et al., 2007).

PD, caused by natural disasters or man-made events, significantly affects global supply chains by halting material flows and causing economic losses (Lam and Su, 2015). Resilience frameworks, such as the Port Supply Chain Disruption (PSCD) model, combine risk management and business continuity to enhance port operations (Loh and Thai, 2015). However, these models often fail to capture cascading risks and their broader implications within port-hinterland networks (Kuang et al., 2021). PR and PP are closely linked to timely, accurate, and efficient service delivery. PR is influenced by infrastructure reliability, network configuration, and customer satisfaction, while PP balances internal efficiency and external service quality to meet stakeholder demands (Woo et al., 2011, Yue and Mangan, 2023). Despite these advancements, inconsistencies in definitions and measurement approaches hinder their universal application across diverse operational contexts.

HE remains the leading cause of maritime accidents, contributing to 75–96% of incidents (Antao and Soares, 2019). Errors are categorized into individual, team, application, and voyage management issues, often exacerbated by skill gaps and reliance on technology (Uğurlu et al., 2015). Limited research addresses how KM can reduce human errors in maritime settings. Although theoretical models like KM Theory, the PSCD framework, and error categorization frameworks provide structured approaches to these challenges, significant gaps remain. Specifically, the literature lacks integrated models linking KM, PD, PR, PP, and HE. Additionally, cascading disruption risks and the inconsistent application of PR metrics require further exploration. Addressing these gaps is crucial for developing comprehensive strategies to enhance port resilience and optimize operational performance.

Research Methodology

Data Collection

This study adopts a questionnaire-based design to investigate KM, HE, PD, PR, and PP among Cambodian shippers. The seven-step questionnaire process, adapted from (Stone, 1993), includes defining data needs, selecting items, designing questions, and piloting. Closed questions using Likert scales capture respondents' agreement or importance levels on key variables, ensuring clarity and reliability. Data collection involves pretesting and piloting the questionnaire to refine its validity and reliability. Two pilot tests, each with 15 respondents, assess framing, sequence, and comprehension. The final questionnaire is distributed online over two months, supported by follow-ups to enhance response rates. Demographic data, such as job title and years of experience, complement the scaled responses for non-biased responses. Sample selection focuses on Cambodian shippers, defined within the study's scope. Measurement items are derived from established literature to align with research objectives. Targeting professionals in shipping operations ensures relevant and actionable insights.

Data analysis techniques

The study employs SEM as the primary analytical tool to examine the complex relationships among latent and observed variables. Covariance-Based SEM (CBSEM) was chosen over Partial Least Squares (PLS) SEM due to its emphasis on theory testing, parameter estimation, and comprehensive goodness-of-fit measures, which align with the confirmatory nature of this research (Hair et al., 2010, Chao, 2011). SEM integrates EFA and CFA to validate measurement models before assessing structural relationships, ensuring robust construct validity and reliability. The analysis follows the six stages of SEM outlined by Hair et al. (2010).

EFA is utilized to identify underlying structures within the data, grouping related factors and evaluating measurement components' unidimensionality, reliability, and validity. Principal Component Analysis (PCA) is chosen for factor extraction, with varimax rotation applied to simplify the factor structure (Sawangwong and Chaopaisarn, 2021). EFA focuses on PD and PR, while other variables are based on previously validated findings from the literature.

Building on EFA, CFA tests hypotheses regarding factor structure and confirms relationships between observed variables and latent constructs. CFA validates port performance measures as outlined by (Woo et al., 2011). Items are retained if their factor loadings exceed 0.5 for new items and 0.6 for established items; those below these thresholds are removed. Validity is ensured by achieving an AVE of 0.50 or higher, and discriminant validity is assessed using Modification Indices (MI) in AMOS, with MI values greater than 15 indicating redundancy. To avoid multicollinearity, correlations between exogenous constructs are kept below 0.85. Fit indices such as Chi-Square ($p > 0.05$), RMSEA (< 0.08), GFI (> 0.90), Adjusted GFI (AGFI), CFI, TLI, and Normed Fit Index (NFI) (all greater than 0.90) are applied, with a Chi-Square/degrees of freedom ratio below 3.0 indicating a good fit. Reliability is measured using Cronbach's alpha (greater than 0.70) and CR (greater than 0.60) (Awang, 2014).

After completing CFA, SEM is employed to test the hypotheses and validate theoretical relationships between variables. SEM analyzes observed means, variances, and covariances through structural parameters such as factor loadings and regression paths. AMOS software is utilized due to its ability to analyze complex relationships, test theoretical models, and assess model fit. Its user-friendly graphical interface facilitates visualization and interpretation of results. Additionally, AMOS is recognized for its flexibility in handling missing data, robustness with non-normal distributions (Byrne, 2013), and capacity to conduct mediation and moderation analyses (Kline, 2011).

Result

Descriptive analysis, EFA, and CFA

A survey targeting logistics professionals via LinkedIn involved sending connection requests to approximately 1,411 individuals. With an acceptance rate of 31%, the survey was distributed to 411 individuals, resulting in 201 responses and a 15% response rate. Respondents were primarily Managers or Assistant Managers (40.77%) with 1–5 years of industry experience (63.86%). Over half

were employed by foreign-owned companies, and 50.50% worked in small to medium-sized enterprises with 1–250 employees. The study ensured robust data preparation by addressing missing data, outliers, and normality. Missing data, identified as MCAR through Little's test ($p > 0.05$), was imputed using the EM method, which preserves relationships between variables and is suitable for Likert scale data. Outliers were analyzed using Mahalanobis D^2, with decisions to retain all the items. Normality was confirmed as skewness (-2 to +2) and kurtosis (up to +7) values fell within acceptable ranges, validating the dataset for further analysis.

EFA identified distinct dimensions within PD and PR. For PD, four factors emerged: Operation Issues (OI), Security Incidents (SI), External Disruptions (ED), and Technical Failures (TF), with strong loadings and a KMO of 0.787, indicating suitability for factor analysis. For PR, three factors were derived: Service Reliability (SR), Operational Efficiency (OE), and Delivery Consistency (DC) supported by a high KMO of 0.842. These findings validate the constructs' multidimensionality, with well-defined factor groupings and robust item loadings. The CFA process was undertaken to ensure the reliability and validity of the measurement model, evaluating constructs using Composite Reliability (CR), Average Variance Extracted (AVE), and Cronbach's Alpha. CFA assessed model fit through indices like χ^2/df, GFI, RMSEA, CFI, and TLI, meeting thresholds for acceptable or good fit. The process involved refining the model in iterative steps:

1. **Evaluating Factor Loadings**: Items with loadings below 0.40 were flagged for removal. However, theoretically relevant items like KM-1 were retained despite low statistical contributions due to their significance in representing key constructs.

2. **Addressing Redundancy**: Standardized residual covariances and modification indices (MI ≥15) identified overlapping items, such as KM-4 and KM-3, leading to the removal of KM-4 to improve fit.

3. **Final Assessment**: The refined model demonstrated strong fit indices (e.g., $\chi^2/df = 2.5$, GFI = 0.92, RMSEA = 0.08, CFI = 0.91, TLI = 0.90), indicating reliable and valid constructs with internal consistency, convergent validity, and discriminant validity, supporting next structural analysis.

After the elimination process and calculation of validity and reliability, the refined constructs demonstrated an acceptable internal consistency and model fit. The results, including the final factor loadings, CR, AVE, and Cronbach's Alpha for each construct, are presented in Tables 1 to 5 for KM, PD, PP, PR, and HE, respectively. These tables provide insights into the refined measurement model, ensuring that constructs are supported in the subsequent structural analysis.

Constructs	Items	Std. loadings	t-value	AVE	CR	Cronbach's α
Knowledge Management (KM)	KM1	0.389	4.387	0.325	0.767	0.766
	KM2	0.504	5.348			
	KM3	0.575	5.845			
	KM5	0.650	6.288			
	KM6	0.611	6.065			
	KM7	0.659	6.331			
	KM8	0.556	-			

Table 1 Reliability and Validity Assessment of KM Construct

Constructs	Items	Std. loadings	t-value	AVE	CR	Cronbach's α
Security Incidents (SI)	SI-1	0.835	8.980	0.647	0.842	0.824
	SI-2	0.941	8.794			
	SI-4	0.599	-			
External Disruptions (ED)	ED-1	0.615	6.523	0.448	0.842	0.793
	ED-3	0.752	7.351			
	ED-4	0.789	7.517			
	ED-5	0.598	6.403			
	ED-6	0.563	-			
Technical Failures (TF)	TF-2	0.426	4.633	0.310	0.842	0.633
	TF-3	0.619	5.989			
	TF-4	0.512	5.331			

	TF-5	0.643	-			

Table 2 Reliability and Validity Assessment of PD Construct

Constructs	Items	Std. loadings	t-value	AVE	CR	Cronbach's α
Service Quality (SQ)	SQ1	0.692	8.668	0.526	0.847	0.844
	SQ2	0.785	9.622			
	SQ3	0.699	8.743			
	SQ4	0.750	9.278			
	SQ5	0.695	-			
Cargo Operation (CAO)	CAO1	0.760	8.021	0.565	0.793	0.778
	CAO2	0.861	8.083			
	CAO3	0.613	-			

Table 3 Reliability and Validity Assessment of PP Construct

Constructs	Items	Std. loadings	t-value	AVE	CR	Cronbach's α
Service Reliability (SR)	SR1	0.913	12.050	0.712	0.880	0.874
	SR2	0.883	11.925			
	SR3	0.723	-			
Delivery Consistency (DC)	DC1	0.650	6.284	0.390	0.760	0.750
	DC2	0.704	6.541			
	DC3	0.672	6.396			
	DC4	0.530	5.540			
	DC5	0.549	-			

Table 4 Reliability and Validity Assessment of PR Construct

Constructs	Items	Std. loadings	t-value	AVE	CR	Cronbach's α
Team Management Errors (TME)	TME1	0.611	9.045	0.600	0.855	0.850
	TME3	0.815	13.086			
	TME4	0.798	12.736			
	TME5	0.852	-			
Individual Errors (IE)	IE1	0.511	6.173	0.425	0.681	0.601
	IE4	0.609	7.138			
	IE5	0.802	-			

Table 5 Reliability and Validity Assessment of HE Construct

The fit indices for the measurement models in Table 6 indicate acceptable levels despite exceeding some ideal thresholds. For KM, the RMSEA of 0.098 and TLI of 0.857 are slightly above preferred values but are considered reasonable for complex or exploratory models (Browne & Cudeck, 1993; Hu & Bentler, 1999). Similarly, PP shows a χ^2/df of 3.511 and RMSEA of 0.112, which exceed ideal limits but fall within acceptable ranges for complex models, supported by strong CFI (0.926) and TLI (0.891). For HE, while the RMSEA of 0.099 is above the threshold, high CFI (0.954) and TLI (0.925) indicate good model fit overall. These deviations are consistent with literature recommendations for complex models, confirming the adequacy of the measurement models.

Constructs	Items	χ^2/df	GFI	RMSEA	CFI	TLI
KM	7	2.918	0.949	0.098	0.904	0.857
PD	12	2.133	0.923	0.075	0.925	0.902
PP	8	3.511	0.934	0.112	0.926	0.891
PR	8	2.131	0.953	0.075	0.965	0.948
HE	7	2.979	0.946	0.099	0.954	0.925

Table 6 Measurement Models

Structural Equation Modeling (SEM)

The SEM analysis tested relationships among key constructs: KM, HE, PD, PR, and PP. The model included 5 main constructs, divided into 10 sub-constructs, measured by 45 indicators. Key findings in Figure 1 showed that KM positively impacts PR (H3) and reduces HE (H6), while HE significantly reduces PD (H7). PD negatively affects PR (H4), and PR strongly enhances PP (H5). However, the paths KM → PD (H1) and HE → PP (H8) were not significant. Goodness-of-Fit indices indicate moderate model fit, with $\chi^2/df = 2.597$, RMSEA = 0.089, and marginally acceptable values for GFI (0.694), CFI (0.710), and TLI (0.689). While some relationships were supported with direct significance, others highlighted indirect effects. Table 7 summarizes the results of the hypotheses testing, showing that while most hypotheses are supported, such as H2, H3, H4, H5, H6, and H7, hypotheses H1 and H8 are not supported based on their p-values and estimates.

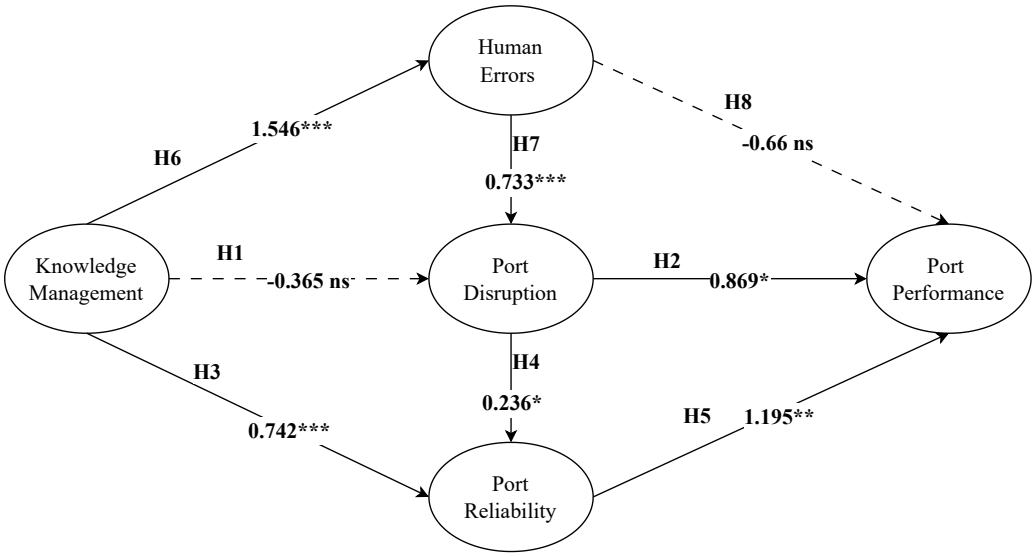

Figure 1 SEM Results

$\chi 2/df = 2.597$ ($\chi 2 = 2082.619$, df = 802); GFI = 0.694; RMSEA= 0.089; CFI = 0.710; TLI = 0.689
*** p < 0.001; ** p < 0.05; *p < 0.1; ns = not supported

Hypotheses		Estimate	P-value	Result
H1	The increase in KM leads to a decrease in PD.	-0.365	0.184	Not supported
H2	The decrease in PD leads to an increase in PP.	0.869	0.081*	Supported
H3	The increase in KM leads to an increase in PR.	0.742	***	Supported
H4	The decrease in PD leads to an increase in PR.	0.236	0.055*	Supported
H5	The increase in PR leads to an increase in PP.	1.195	0.007**	Supported
H6	The increase in KM leads to a decrease in HE.	1.546	***	Supported
H7	The decrease in HE leads to a decrease in PD.	0.733	***	Supported
H8	The decrease in HE leads to an increase in PP.	-0.660	0.136	Not supported

Table 7 Summary of Hypotheses Result

KM indirectly reduces PD by first minimizing HE. KM significantly improves HE management, supporting the idea that structured knowledge-sharing and employee training reduce errors in port operations. While KM does not directly impact PD, its indirect effect through HE is substantial, emphasizing that error reduction is a key mechanism through which KM enhances operational stability and prevents disruptions. These findings align with resilience-focused frameworks like Loh and Thai's (2015) PSCD model, highlighting KM's role in improving employee skills and reducing vulnerabilities. Similarly, the strong relationship between HE and PD underscores HE as a critical factor in mitigating disruptions, consistent with research by Lam and Su (2015) and Kuang et al. (2021) on the importance of managing internal vulnerabilities to ensure stable port operations

Paths		Direct Effect	Indirect Effect	Total Effect
H6	KM --> HE	0.862	0.000	0.862
H7	HE --> PD	1.180	0.000	1.180
H1	KM --> PD	-0.327	1.018	0.691
Indirect effect of KM on PD through HE: KM → HE → PD				

Table 8 Direct and Indirect Effects of KM, HE, and PD

HE indirectly improves PP by first reducing PD. While the direct effect of HE on PP is non-significant, its indirect impact through PD is substantial. The significant relationship between HE and PD demonstrates that managing HE effectively mitigates disruptions, which then enhances PP. This aligns with Loh and Thai's (2015) PSCD model, emphasizing that reducing disruptions fosters operational continuity, efficiency, and customer satisfaction. Managing HE is thus critical for maintaining stability and indirectly improving performance.

Paths		Direct Effect	Indirect Effect	Total Effect
H7	HE --> PD	1.180	0.000	1.180
H2	PD --> PP	0.996	0.323	1.319
H8	HE --> PP	-1.215	1.556	0.341
Indirect effect of HE on PP through PD: HE → PD → PP				

Table 9 Direct and Indirect Effects of HE, PD, and PP

Discussion and Conclusion

Result discussion

The SEM analysis demonstrated moderate model fit, with indices reflecting reasonable adequacy despite being slightly below ideal thresholds, due to the model's complexity. KM significantly enhances PR (H3), which in turn strongly impacts PP (H5), emphasizing PR's role as a mediator in ensuring operational reliability. Although KM does not directly reduce PD (H1), it indirectly mitigates disruptions by reducing HE (H6, H7), highlighting the importance of knowledge-sharing and training to minimize human errors. HE significantly impacts PD (H7), underscoring its role in preventing disruptions, but its direct effect on PP (H8) was non-significant, suggesting an indirect influence through PD. PR emerged as pivotal in enhancing PP, acting as a buffer against disruptions, and ensuring service continuity. Interestingly, the positive relationship between PD and PR (H4) suggests overconfidence in reliability due to limited exposure to severe disruptions, while PD's marginal effect on PP (H2) reflects ports' resilience. These findings underscore the importance of KM, PR, and HE management in enhancing port performance and ensuring service continuity despite potential disruptions.

This study examines KM's role in mitigating PD caused by HE and its impact on PR and PP. The findings reveal that effective KM practices indirectly reduce PD by minimizing HE, which strongly influences disruptions. While PD has a limited direct effect on PP, PR significantly enhances PP and buffers against disruptions. By addressing key gaps, the study clarifies KM's impact on port reliability and performance, highlighting PR's mediating role and integrating KM, HE, PD, PR, and PP as interconnected factors in port management. The results stress prioritizing KM practices and strengthening PR to improve operational efficiency and resilience.

Practical and Theoretical contribution

This study provides actionable insights for stakeholders to enhance port performance through targeted KM practices and HE reduction. Academic Institutions can integrate these findings into logistics curricula, using practical examples to enrich education and promote further research on KM's role in operational resilience. Policymakers are encouraged to develop policies that emphasize training and knowledge-sharing initiatives to improve port resilience and efficiency, leveraging these findings to strengthen logistics frameworks. Industry Practitioners can use the study's recommendations to enhance operations by addressing common disruptions through KM and employee training, thereby improving reliability and overall performance. Theoretical Contributions include empirical evidence of KM's critical role in improving PR and its indirect impact on PP, reinforcing the importance of

integrating KM and human factors in risk management frameworks to ensure operational stability and efficiency.

Research limitation and Future study

This study faced limitations in capturing the practical realities of PD in Cambodia, as some factors derived from prior research were not relevant or previously encountered by local operators, affecting construct reliability and validity. Despite these challenges, the research establishes a foundational framework for future studies. Future research should aim to improve the model fit by exploring alternative specifications and incorporating additional variables to enhance robustness. Additionally, the absence of a direct link between KM and PP suggests unexplored mediators, such as technological advancements or customer satisfaction, which should be examined to deepen understanding and improve the model's explanatory power.

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INTEGRATING ERP SYSTEMS FOR EXPERIENTIAL BUSINESS EDUCATION: A CROSS-DISCIPLINARY LEARNING FRAMEWORK

Wapee Manopiniwes[1] and Martin Tutko*
[1]Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University
**International College of Digital Innovation, Chiang Mai University*

Abstract
Purpose: This objective of this project is to explore how a comprehensive learning environment, combining a practice enterprise model, an ERP system, and AI techniques, enhances learning outcomes and the reasons behind it, particularly for students in the field of industrial engineering.
Design/ methodology/ approach: In this research, we begin by examining related research on the lecture-based model and IT-focused industrial engineering learning environments using Bloom's taxonomy. Next, we present a case study that compares the lecture-based model with an ERP-based business and AI techniques learning environment. We then analyze the learning outcomes and discuss the underlying reasons. Finally, we conclude with a discussion of the limitations, contributions, and recommendations for future research.
Findings: We use Bloom, Taxonomy as a framework to validate our research questions as well as to guide the interpretation of our results, following the three domains of learning: cognitive domain, affective domain, and psychomotor domain.
Originality/value: Efforts to deliver practical learning experiences have been made for decades, but each approach has its shortcomings. The practice enterprise model, for instance, requires the tools and dynamism that can be provided by information technology (IT). Meanwhile, ERP systems and simulations lack a comprehensive perspective. The combination of IT and human-to-human interaction in this project produces more effective learning outcomes than either technology or face-to-face interaction alone.

Keywords: Enterprise Resource Planning, Teaching and Learning Development, Simulation-Scenario Based Learning

Introduction

Criticism has been levelled at Industrial Engineering education for its theoretical nature and perceived lack of connection to the realities of the engineering profession. It has become increasingly evident that business management involves a more complex set of skills, including both disciplinary expertise and soft skills such as communication, teamwork, ethics, and social responsibility.

However, traditional classroom settings may not provide the ideal environment for acquiring these skills. A collaborative learning approach, involving both teachers and students, is needed to foster imagination and natural experiences. To this end, there are several alternative methods that can provide students with practical learning experiences. For example, business skills laboratories and practice enterprise models simulate real workplaces, allowing students to participate in role-play scenarios and make day-to-day business decisions in a risk-free environment. Enterprise resource planning (ERP) systems can help students learn about business processes, while business simulations offer dynamic learning situations.

The aim of this research is to investigate the impact and underlying reasons behind the effectiveness of a comprehensive learning environment, which includes a practice enterprise model, an ERP system, and AI techniques, in enhancing learning outcomes. Generative and discriminative AI approaches are integrated into teaching and learning management for content creation, personalized learning, simulation-scenario based learning, performance assessment and feedback, and adaptive learning. We conducted a year-long case analysis, comparing the learning outcomes of the comprehensive learning environment with those of student groups who experienced the lecture-based model.

Efforts to deliver practical learning experiences have been made for decades, but each approach has its shortcomings. The practice enterprise model, for instance, requires the tools and dynamism that can be provided by information technology (IT). Meanwhile, ERP systems and simulations lack a

comprehensive perspective. The combination of IT and human-to-human interaction produces more effective learning outcomes than either technology or face-to-face interaction alone. (Karoliina Nisula & Samuli Pekkola, 2019)

In this research, we begin by examining related research on the lecture-based model and IT-focused industrial engineering learning environments using Bloom's taxonomy. Next, we present a case study that compares the lecture-based model with an ERP-based business and AI techniques learning environment. We then analyse the learning outcomes and discuss the underlying reasons. Finally, we conclude with a discussion of the limitations, contributions, and recommendations for future research.

Our research endeavours to improve learning outcomes in various domains of Bloom's taxonomy. First, the approach in this project aims to enhance the cognitive learning of students who perform poorly and at an average level, an aspect that requires improvement in the lecture-based model. The improvements are due to the holistic learning environment acting as a boundary infrastructure where the practice enterprise model, the simulation and the ERP system are all different kinds of boundary objects. This aligns with previous studies suggesting that students with low performance benefit from a boundary infrastructure comprising multiple tangible boundary objects. (Monk and Lycett 2016; Pasin and Giroux 2011). This boundary infrastructure functions as a point of interaction and communication, and enables the students and teachers to cross social, cultural, and conceptual boundaries between different communities of practice, and importantly, between theory and practice.

For the affective learning, ERP simulation would be seen as motivation learning environments. The hands-on approach provided by ERP-based environment should be particularly valued by the students, indicating that real-life tools can enhance the sense of "learning by doing." This is a notable improvement compared to the lecture-based model, where this has been a challenging aspect to address. However, the measurement of psychomotor is limited to the ERP-based business learning environment, and therefore cannot be used to assess differences in learning between the groups. Nevertheless, analysis of the ERP log-file should indicate significant improvements in processing times, suggesting that learning has occurred.

Case Profile

The case in this research encompasses fourth-year students in the Department of Industrial Engineering, Faculty of Engineering, who have taken the course 'Industrial Engineering and Enterprise Resource Planning' from 2020 to present. The following are additional details:

(1) The control group

In the department of Industrial Engineering, the fourth-year students' batch of 2020 was taught by using an integrated curriculum approach, supported by the lecture-based model. However, the limitations of this approach became apparent over time, as it failed to capture the complexities of a real-world business environment. As a result, a project was launched to replace the lecture-based model with an ERP-based business environment from 2021 in the classroom. The primary objective of the project is to evaluate the learning outcomes resulting from this shift in the learning environment.

(2) The experimental group

Fourth-year students' batch from 2021 to present is our target for the experimental group while 2020 is the control group as mentioned earlier. The ERP-based business learning environment has been used in the classroom since 2021 instead of lectured-based approach. Both control and experimental groups followed identical curriculums. The program consisted of several modules, each focusing on a specific theme and incorporating various disciplines. Students were assigned to teams and received guidance from an appointed teacher-coach, who provided supervision and mentorship. The coaches collaborated to plan each module's implementation and held weekly meetings to discuss and prepare for upcoming activities. However, within this group, there exist subcategories outlined below.

- Batch 2021 and 2022

The students in this category were instructed using a business learning environment based on ERP. They were introduced to several modules on a selected ERP platform that were tailored only to the theme of industrial engineering. The specific core four modules included Sales and Distribution, Materials Management, Production Planning, and Warehouse Management.

- Batch 2023 and 2024

In the year 2023, we gained experience in facilitating joint learning between students of industrial engineering and the ICDI faculty through collaboration funded by Active & Integration Learning (Type C) from TLIC CMU. As part of this cooperation, we incorporated supplementary modules in Finance, Accounting, and Controlling for industrial engineering students, in addition to the four core modules specific to the theme of industrial engineering management. The collaboration with the ICDI faculty will also continue into the coming year of 2024 together with the integration of AI techniques in teaching and learning management. This expansion will give students in this category a broader perspective and practical experience in understanding and using finance modules within an ERP-based business environment.

Research Methodology

1. Research Design

We use Bloom's Taxonomy as a framework to validate our research questions as well as to guide the interpretation of our results, following the three domains of learning: cognitive domain, affective domain, and psychomotor domain. In the meantime, generative and discriminative AI techniques are applied to teaching and learning management in the context of ERP subject in several ways as follows.

(A) Generative AI for Content Creation:

- Use generative AI models, like language models (e.g., GPT), to create interactive learning materials such as tutorials, quizzes, and case studies related to ERP concepts.
- Employ generative models to generate synthetic ERP datasets for training purposes, allowing students to practice data analysis and decision-making within ERP systems without accessing real-world data.

(B) Discriminative AI for Personalized Learning:

- Utilize discriminative models to analyze student performance data and provide personalized recommendations for learning resources, study paths, and practice exercises tailored to individual learning styles and proficiency levels in ERP subjects.

(C) Generative AI for Simulate and Scenario-based Learning:

- Develop generative AI-driven simulations that mimic real-world ERP scenarios, allowing students to apply theoretical knowledge in practical contexts. For example, simulating inventory management processes, production planning, or supply chain optimization within ERP systems.
- Create virtual ERP environments using generative AI techniques, where students can experiment with different configurations, workflows, and decision-making strategies without the risk of disrupting actual enterprise systems.

(D) Discriminative AI for Performance Assessment and Feedback:

- Employ discriminative AI models to automate and the grading and assessment process for ERP-related assignments, projects, and exams. These models can provide detailed feedback on correctness, completeness, and the application of ERP concepts.

2. Sampling

The case in this research encompasses fourth-year students in the Department of Industrial Engineering, Faculty of Engineering, who have taken the course 'Industrial Engineering and Enterprise Resource Planning' from 2020 to present. Details have been stated in the earlier section.

3. Data Collection and Analysis

According to Bloom's Taxonomy framework, data collection and analysis are described as follows.

3.1 Learning outcomes in the cognitive domain: Both pre- and post-tests are used for experimental and control groups. The pre-test analysed the student's previous understanding and provided a basis to compare these two groups. Midterm and final examinations are considered as the post test. We use t-test analysis to check whether the differences in the results are significant.

3.2 Learning outcomes in the affective domain: The students are given a questionnaire on the learning environment halfway through the academic year. Our main goal is to collect feedback for immediate improvements in the learning environment. Questions in the survey are developed based on the curriculum objectives: integration between disciplines, overall business process understanding and teamwork. The survey aims to assess the impact of the learning environment project on students' motivation and their perception of versatility.

3.3 Learning outcomes in the psychomotor domain: Psychomotor learning outcomes are identified into 3 aspects: efficiency, accuracy, and response magnitude. Efficiency is measured by the time taken to finish a task, while accuracy is evaluated by counting the number of errors made during task completion. Response magnitude is determined by the complexity of the task accomplished. For example, the order-to-delivery process, the sales order process, and inventory management process, etc in ERP platform practice can be the indicators for an appropriate measurement to access psychomotor domain learning in this area.

4. Ethical Considerations

We ensure that the study is conducted in an ethical manner, with informed consent obtained from all participants and their anonymity and confidentially maintained

Research Discussion and Expectations

The improvement in learning can be explained by the holistic learning environment acting as a boundary infrastructure. A comprehensive learning environment has been implemented through the combination of a practice enterprise model and an ERP-simulation. We believe the research evidence would show that this approach improves the cognitive learning of poor and average-performing students, an area that needs improvement in the lecture-based model.

The lecture-based model provides the abstract discourse, while the ERP system concretizes it through standardized forms, processes, and simulation constructs that tie the boundary objects together. The boundary infrastructure provides a common ground for students, coaches, and disciplinary teachers. The ERP-simulation provides momentum and a sense of reality that are lacking in the lecture-based model. The combination of these concrete boundary objects reinforces each other, facilitating mutual understanding and the crossing of the boundary from novice to expert.

Indications of affective domain areas could show that students appreciate the benefits of crossing boundaries, including joining theory to practice, integrating the learning environment into the curriculum, and intersecting the social worlds of other students.

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LAST-MILE DELIVERY SERVICES: INVESTIGATING THE RISKS FOR CARGO MOTORCYCLE DRIVERS

Thanh Thi My Truong
Department of Urban Transport Planning, Faculty of Civil Engineering,
University of Transport Technology, Vietnam

ABSTRACT
Research purpose: This research aims to identify both internal and external risk factors affecting motorcycle cargo drivers and evaluate their frequency and impact levels from the perception of motorcycle cargo drivers.
Methodology: Based on the direct behaviour interview survey conducted in Hanoi, respondents from four e-commerce companies (Shopee, Lazada, Tiki, Sendo), six delivery companies (Giao Hang Nhanh, Giao Hang Tiet Kiem, Ninja Van, Kerry Logistics, Viettel Post, Nhat Tin) and two food-delivery companies (Shopee Food, Grab Food) were collected. The Risk Breakdown Structure (RBS) is selected for risk analysis, focusing on both occurrence probability and impact severity.
Findings: Results indicate that almost 25% of motorcycle cargo drivers reported being involved in at least one accident during the last 12 months. Of these, almost 90% indicated that traffic flow, road infrastructure, weather condition, and riding behaviour affect their road crashes. The study found that traffic flow, infrastructure conditions, environmental issues, and risky riding behaviours contribute to the possible accidents from the shipper's perception.
Value: The study provides empirical evidence to logistics service providers and urban transport planners to improve the traffic safety and level of service of urban logistics.

Keywords: Urban Logistics; E-Logistics; Last-mile Delivery; Logistics Services; Cargo Motorcycle Driver

Introduction

Cargo motorcycle drivers are people who use their motorcycles to deliver cargo or food to the end customers. This service is gradually popular in many cities in Asian countries due to the rapid development of e-commerce. Motorcycle riders are involved greatly in last-mile delivery since motorcycles have exceptional advantages of accessibility and mobility. Motorcycles can access houses and departments of customers who live in small alleys where small trucks hardly access. Moreover, due to the congestion in big cities, the riding time of a motorcycle can be more competitive than a truck within an equivalent distance. However, cargo motorcycle drivers often face many transport risks due to traffic congestion, the slippery road surface under the rain, the hot and humid weather in summer, and their hurry mentality to fulfil the delivery requirements. A study by Taniguchi, et. al. (2010) provided an overview of how to include risks from both natural and behavioural risks in city logistics modelling (Taniguchi et al., 2010). Their findings indicated that many accidents and crashes relating to food and cargo delivery are associated with transport risks. Various studies have revealed that unsafe travel situations are major causes of traffic accidents and crashes to motorcycle riders and cargo riders. A study of motorcycle food delivery professionals in Chiang Rai Province, Thailand shows that risky riding behaviours and the lack of safety equipment are major causes of travelling crashes (Arreeras et al., 2022). Similarly, research by Han Byun J, et. al. (2017) in Korea analysed the data on motorcycle crashes of 1,310 food delivery workers (Han Byun et al., 2017).

Such studies investigated factors associated with road accidents of traditional and app-based motorcycle taxi drivers, cargo last-mile delivery riders and food delivery. However, the limitations of these papers are that self-related risks are major focuses, especially the risky driving behaviour of motorcycle riders. Road accidents and crashes result from both internal and external risks, of which the road infrastructure, traffic flow, environmental issues, and riding behaviour are entirely involved. This research aims to identify both internal and external risk factors affecting the riding crashes of cargo motorcycle drivers and evaluate their frequency and impact levels from cargo motorcycle riders' perception. For this purpose, cargo motorcycle drivers were selected for the survey. The next section examines previous studies on the traffic risks of motorcycle riders. The experimental design and data collection are described in Section 3. Section 4 explains the data analysis and discussion, and the conclusions are presented in Section 5.

Review of Risk Factors

Risk is defined as the likelihood of loss (Hillson, 2003). Risk-related research has started to increase in the logistics and transport sector. Risk is a significant concern because it frequently is linked to reliability, efficiency, and safety in transport (Masár et al., 2019). Identification, analysis, and mitigation of risk are steps in the decision-making process involved in risk management. The Risk Breakdown Structure (RBS) method, which was adapted from the Work Breakdown Structure (WBS) used in project management, is used to identify risks. Risk-based risks can be properly defined and categorized for each level using RBS (Hallowell et al., 2013). Each risk is categorized using RBS. RBS is a collection of risks arranged logically, methodically, and systematically to form a traffic-related risk hierarchy.

The research evidence implies that drivers of cars generally incur lower transport dangers than those who ride motorcycles. The main reason for this is that motorcycle riders are not protected in collisions (Chen, 2009; Lin and Kraus, 2009); also, they are more likely to take risks, increasing the number of motorcycle-related fatalities (Rifaat et al., 2012). Numerous studies have been published in the literature that have revealed a wide variety of traffic risks related to riding behaviour, traffic flow, road infrastructure, and weather extremes. These are covered in this section. Table 1 provides a summary.

Risk Type	Code	Actual Traffic Risks	Explanation	Sources
Riding behaviour-related risks	RB1	Excessive speed	Riding over permitted speed*	(Quy Nguyen-Phuoc et al., 2023; Tran et al., 2022)
	RB2	Mobile using	Using a mobile phone while riding	(Eustace et al., 2011), (Arreeras et al., 2022)
	RB3	Ignoring road sign	Disregarding the road sign and notice during delivery riding	(Truong et al., 2020), (Rifaat et al., 2012)
	RB4	Red light pass	Riding over a red light at the intersection	(Lin and Kraus, 2009), (Chen, 2009)
	RB5	Bulky cargo	Carrying bulky and over-weighted parcels	(Horwood and Fergusson, 2000), (Iversen and Rundmo, 2002)
Traffic flow-related risks	TC1	Traffic congestion	The congested traffic flow due to the high volume of vehicles	(Golob and Recker, 2004)
	TC2	Lane rearrangement	The re-arrange of road lanes and other unexpected traffic organization due to traffic incidents	(Nguyen-Phuoc *et al.*, 2020; Tsubota *et al.*, 2018)
Infrastructure-related risks	IF1	Bumpy road	Poor road condition due to the road is not maintained regularly	(Fridstrøm *et al.*, 1995; Tsubota *et al.*, 2018)
	IF2	Slippery and muddy road	Deposit on the road as oil, or mud…due to unexpected material dropping or truck crashing	(Arreeras et al., 2022; Lin and Kraus, 2009)
	IF3	Poor road lighting	Poor light conditions along the roads at night or during dark day-light	(Chen, 2009; Iversen and Rundmo, 2002)
Weather-related risks	WE1	Rainy weather	Flood or slippery conditions due to heavy rain	(Brodsky and Hakkert, 1988; Keay and Simmonds, 2005)
	WE2	Hot weather	Strong hot and humid weather in the summer season	(Fridstrøm et al., 1995; Tsubota et al., 2018)

* Under the Vietnamese Road Traffic Law, the maximum speed for motorcycles when travelling in densely populated areas is regulated at 50km/h or 60km/h under a certain road type and number of lanes.

Table 1: Risk Breakdown Structure (RBS) for motorcycle crashes

Such literature provides a basic understanding of the possible transport risks for cargo motorcycle drivers, especially cargo motorcycle drivers in megacities such as Hanoi. The selected risks from the literature are designed for the RBS (Table 1), and then based on that RBS, the Cargo Motorcycle Rider Behaviour Questionnaires are developed to investigate and rank the transport risks from a cargo motorcycle rider's perspective.

Methodology

Survey design and data collection

About 7.3 million people are living in Hanoi, which serves as Vietnam's capital. In 2023, around 710 people are dead in traffic accidents in Hanoi (Ngoc and My Thanh, 2020). In Hanoi, where traffic is dominated by motorcycle riders (Ngoc and Thanh, 2020). This study utilizes information from a structured questionnaire survey of cargo motorcycle drivers that was conducted between May and June 2022. Based on the direct behaviour interview, 466 cargo motorcycle rider respondents (as shown in Table 2) from four e-commerce companies (Shopee, Lazada, Tiki, Sendo), six delivery companies (Giao Hang Nhanh, Giao Hang Tiet Kiem, Ninja Van, Kerry Logistics, Viettel Post, Nhat Tin) and two food-delivery companies (Shopee Food, Grab Food) were collected.

The interview collected the information of age, gender, degree of education, and income of respondents. They were also asked to provide the typical daily riding and working hours, considering waiting time. They disclosed their average weekly delivery travels and the number of years they worked as cargo motorcycle riders. Additionally, respondents were asked to mark their employment status (full-time or part-time). The survey questionnaire also gathered information from cargo motorcycle drivers about their road traffic accidents or slips and falls over the previous 12 months (self-reported). Based on survey questionnaires, cargo motorcycle drivers also evaluated the transport risks that occurred during their working travel, both the occurrence frequency (measured on a 5-point Likert scale from rare = 1 to certain = 5) and the impact severity (also measured on a 5-point Likert scale from low = 1 to high = 5).

Sample characteristics

Only 2.58% of the 466 cargo motorcycle drivers were female. Many females responded that motorcycling is often associated with risks and safety concerns. Women perceive it as a more dangerous occupation due to factors such as traffic accidents, physical demands, and potential harassment or assault during deliveries. Concerns about personal safety can deter women from pursuing this line of work. The average age of cargo motorcycle drivers was 27.1, ranging from 18 to 62 years old. Approximately 61.6% of them either completed or were pursuing education above the high school level (i.e. universities or vocation). Nearly 65% of the cargo motorcycle drivers worked part-time. Motorcycle shipping services enabled many drivers to work part-time or as casual workers. The average cargo motorcycle rider rode for work between 501 and 750 kilometres per week, and between 251 and 500 kilometres per week, respectively.

Attributes	Level Range	n	(%)
Number of respondents			466
Gender	Male	454	97,42
	Female	12	2,58
Working status	Full time	162	34,76
	Part-time	304	65,24
Age	18–29	197	42,20
	30–39	168	36,12
	40–49	92	19,70
	50–59	8	1,80
	60 and over	1	0,18

Education	High school or under	179	38,40
	University/Vocation (in process)	225	48,21
	University/Vocation (graduated)	62	13,39
Monthly household income	<3 million VND/month	3	0,69
	3 ~ < 6 million VND/month	13	2,80
	6 ~ < 10 million VND/month	181	38,77
	10 ~ <20 million VND/month	216	46,28
	20 ~ 40 million VND/month	47	10,12
	> 40 million VND/month	6	1,34

* VND – Vietnamese Dong, 1 USD = 23,375 VND (December, 2022)

Table 2: Descriptive statistics of respondents

Variables	**Average**	**Std.**
Shipping experience (years)	1,21	1,02
Weekly delivery trips	112	69
Daily working hours	9,32	17,41
Daily riding hours for work	7,11	2,88
Weekly riding distance for work (km)	412,66	206,52
Crash frequency	0,46	0,76

Table 3: Descriptive statistics of shipping trips (n = 466)

Chi-Squared test

A statistical technique called the chi-squared test is used to identify statistical correlations between variables under the null hypothesis that there is no association between a set of groups and the responses they receive. The null hypothesis was rejected if the p-value was less than 0.05 since the significance level was set at 0.05. The test statistic was

$$\chi^2 = \sum_{i=1}^{c}\sum_{j=1}^{r}\frac{(O_{i,j} - E_{i,j})}{E_{i,j}} \quad (1)$$

and

$$E_{i,j} = \frac{n_i n_j}{N}$$

χ^2 is Pearson's cumulative test statistic, which approaches a non-normal distribution with (r − 1) (c − 1). Row variables had a degree of freedom, but column variables were independent. Oi,j denotes how many observations are present in row I and column j. $E_{i,j}$ stands for the predicted frequency value in columns j and i. The number of cells in the table equals n, where n is the total number of observations. To examine the association between traffic risks and individual and trip variables for cargo transport, the chi-squared test was performed.

Questionnaire reliability

As indicated in Table 4, the reliability or internal consistency of the barriers was assessed using Cronbach's alpha. It is advised that infrastructure, performance, and financial obstacles have Cronbach's alpha values over 0.70, which denotes high reliability (Ben-Akiva and Boccara, 1995). Technically, Cronbach's alpha is a reliability coefficient that may be determined using the following equation:

$$\alpha = \frac{k \times \bar{c}}{v + (k-1)\bar{c}} \quad (2)$$

where α refers to Cronbach's alpha; k is the number of items; c is the average of all covariance between items; and v is the average variance of each item.

Risk Factors	**Category**	**Cronbach's Alpha**
Riding behaviour-related risks	RB1, RB2, RB3, RB4, RB5	0.766

Traffic flow-related risks	TC1, TC2	0.823
Infrastructure-related risks	IF1, IF2, IF3	0.845
Weather-related risks	WE1, WE2	0.803

Table 4: Reliability of questionnaires among risk factors

Results and Discussion

This paper has identified and evaluated the perception of possible internal and external risks involved in road crashes of cargo motorcycle drivers. Results indicate that almost 25% of cargo motorcycle drivers reported being involved in at least one accident during the last 12 months. Of these, almost 90% indicated that traffic flow, road infrastructure, weather condition, and riding behaviour simultaneously affect their road crashes.

Ranking the transport risks from cargo drivers' perception

In Table 5 and Table 6, the results of the descriptive analysis are summarized. Considering risk occurrence frequency, it is observed that traffic congestion (TC1) had the highest average score for the risks of travel crashes from a cargo motorcycle rider's viewpoint, followed by bulky cargo (RB5). Weather-related risks are also a major concern of many cargo motorcycle drivers, with rainy and hot weather ranked as the third and the fourth level respectively. Riding a motorcycle for very long distances under the hot and humid, or rainy and slippery roads are big challenges to various cargo riders. Most respondents are concerned about both external and internal risks. The external risks consist of traffic flow and the carried heavy cargo which are hard to control. The internal risks, including using a mobile during riding and passing the red light, are mostly under the awareness of the cargo riders as their dangerous driving behaviour for delivery jobs.

Risk ID	Traffic Risks	Min	Max	Mean ± SD	Rank occurrence frequency
TC1	Traffic congestion	1	5	4.22 ± 1.025	1
RB5	Bulky cargo	1	5	4.18 ± 1.008	2
WE1	Rainy weather	1	5	4.16 ± 1.062	3
WE2	Hot weather	1	5	4.16 ± 1.046	3
IF1	Bumpy road	1	5	4.14 ± 1.087	5
IF3	Poor road lighting	1	5	4.06 ± 1.078	6
RB1	Excessive speed	1	5	4.03 ± 1.122	7
RB2	Mobile using	1	5	4.02 ±1.127	8
IF2	Slippery and muddy road	1	5	3.97 ± 1.060	9
RB3	Ignoring road sign	1	5	3.94 ± 1.064	10
TC2	Lane re-arrangement	1	5	3.90 ± 1.155	11
RB4	Red light pass	1	5	3.83 ± 1.115	12

Table 5. Ranking the occurrence frequency of transport risks.

Risk ID	Traffic Risks	Min	Max	Mean ± SD	Rank impact severity
RB4	Red light pass	1	5	4.35 ± 1.003	1
IF2	Slippery and muddy road	1	5	4.12 ± 1.018	2
RB1	Excessive speed	1	5	4.08 ± 1.044	3
TC1	Traffic congestion	1	5	4.03 ± 1.034	4
RB5	Bulky cargo	1	5	3.95 ± 1.062	5
RB2	Mobile using	1	5	3.91 ± 1.061	6
WE1	Rainy weather	1	5	3.90 ± 1.159	7
WE2	Hot weather	1	5	3.85 ± 1.070	7
TC2	Lane re-arrangement	1	5	3.79 ± 1.062	9
IF3	Poor road lighting	1	5	3.73 ± 1.081	10
RB3	Ignoring road sign	1	5	3.71 ± 1.129	11
IF1	Bumpy road	1	5	3.70 ± 1.088	12

Table 6. Ranking the impact severity of transport risks.

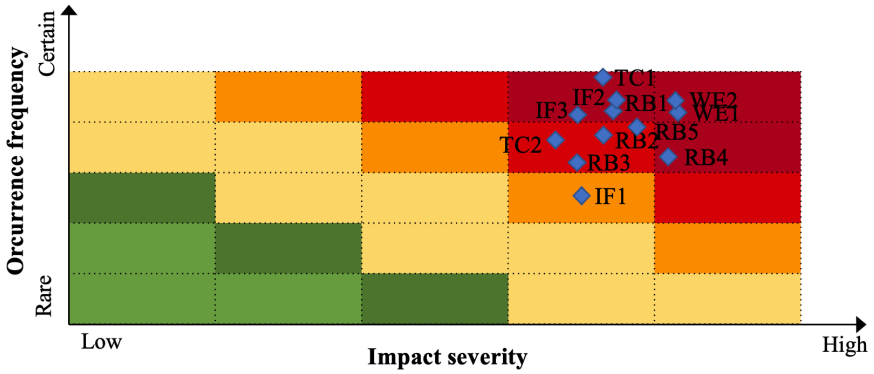

Figure 1: Matrix of traffic risks from cargo motorcycle rider's perception

The cargo motorcycle riders work dependently on motorcycle riding; therefore, congestion flow combined with carrying bulky cargo bothers most cargo delivery motorcycle riders and poses significant potential traffic risks to them, even though many traffic management strategies have been applied in big cities in Vietnam (Truong et al., 2021). These findings are in contrast with previous research, which investigated the risky behaviour of app-based motorcycle taxi drivers (Nguyen-Phuoc et al., 2020). Compared with passenger motorcycle riders, whose mobile use and neglecting signal are seen as the most dangerous behaviour affecting travel crashes, cargo motorcycle drivers daily faced with external risks of congestion and heavy cargo (Lin and Kraus, 2009). Driving with large parcel boxes behind them, most of the respondents admitted that they ride motorcycles with high concentration and carefulness to minimize the risk of crashes and avoid cargo damage.

However, due to the huge requirements of delivering goods on schedule, many respondents have dangerous driving behaviour as using mobile and passing the red light which were perceived as high severity levels when occurred. Mobile use is perceived as a significant traffic risk since it impacts the driving concentration and safety driving of respondents. Furthermore, riding with excessive speed and ignoring road signs are ranked as the sixth and the eleventh potential risks relating to travel crashes by cargo motorcycle drivers. These results are similar to many previous studies conducted in Asian cities such as Vietnam (Quy Nguyen-Phuoc et al., 2023; Truong et al., 2020), Indonesia (Susilo et al., 2015), Taiwan (Chen, 2009), and Thailand (Arreeras et al., 2022). This implied that the awareness of respondents on traffic legal and regulation is still low. Respondents were concerned about the damaged goods that they have to pay a fine; however, risky driving behaviour is perceived by many respondents due to the pressure of on-time delivery and huge order requirements.

Reveals from respondent characteristics and risk perception

Respondents were classified by age, shipping experience, monthly income, weekly delivery trips, and daily working hours which individual characteristics significantly impact crashes and traffic risk perception. Gender was not included in the analysis due to the substantial gender disparity (there were only 12 female drivers).

In terms of age, there was a statistically significant difference between groups RB1 (Excessive speed), RB5 (Bulky cargo), and TC1 (Traffic congestion). Respondents aged between 26 and 35 were found to be a higher risky group of delivery jobs. These respondents are at the beginning of their family life and are thereby having more financial pressure. They often take on more orders, so they need to travel longer distances and work more hours to deliver. As a result, these motorcycle delivery riders often take higher traffic risks. Respondents aged over 45 years old had the lowest score which implied that the older the cargo riders, the less risk-taker behaviour they have for their work-riding. This result is similar to studies conducted in Thailand (Arreeras et al., 2022) and Taiwan (Chen, 2009).

Regarding monthly income, there were two traffic risks with statistically significant results: RB1 (excessive speed) and RB5 (bulky cargo). Respondents with a lower income perceive excessive speed and riding with bulky cargo with the highest score. These results implied that the cargo riders who have higher financial pressure might take more delivery orders, ride a longer distance and tend to

exceed the speed to reduce travel time, which is consistent with studies in Indonesia (Susilo et al., 2015) and Taiwan (Chen, 2009).

Regarding weekly delivery trips, six traffic risks were statistically significant, including RB1 (Excessive speed), RB2 (Mobile use), TC1 (Traffic congestion), IF3 (Poor road lighting), WE1 (Rainy weather), and WE2 (Hot weather). Respondents who have more trips to deliver cargo thought that RB1 (Excessive speed), RB2 (Mobile using), and TC1 (Traffic congestion) significantly impacted the possible crashes during their riding and, hence, were impeditive in the ability to complete their daily workload.

Conclusion

The number of cargo motorcycle drivers increases significantly during and after the COVID-19 pandemic due to the huge shipping demand and the rapid development of e-commerce in Vietnam. Therefore, the delivery trips contribute strongly to the traffic congestion and traffic safety in cities. Both internal and external risks affect the road crashes of shipping drivers. The study found that traffic flow, infrastructure conditions, environmental issues, and risky driving behaviours contribute to the possible accidents from cargo motorcycle rider's perceptions. The results of the current study have various practical applications. First, safety measures should be conducted continuously from shipping service companies and transport authorities to cargo motorcycle drivers. Second, safety training and working-time limitations for cargo riders should be implemented more frequently. In addition, the improvement of road infrastructure and traffic signals should be strongly enhanced.

Although this study has shed light on how cargo motorcycle drivers perceive both internal and external risks, some limitations must be considered. First, the survey information was collected from a Hanoi, Vietnam, metropolitan agglomeration, whose features may differ significantly from those of other contexts. As a result, other investigations for different locations and nations would be required to compare with the findings of this study. Second, many of our participants were junior cargo drivers. It is hard to know if this is typical of crowd logistics adoption, though it appears to be the case; obviously, further research is needed.

Acknowledgement

This research was supported, in part, by Dong-A Corporation Joint Stock Company. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of Dong-A Corporation Joint Stock Company. Thanks are due to my colleagues at the University of Transport Technology who provided comments to the methodology section.

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LEVERAGING RISK-AFFECTING WAREHOUSING AND INVENTORY PRACTICE IN ASEAN REGION: CAMBODIAN SMEs PERSPECTIVE

Molika Mon*, **Poti Chaopaisarnhaopaisarn**
1 * Logistics Engineering and Supply Chain Management Program,
Department of Industrial Engineering
Faculty of Engineering Chiang Mai University, Chaing Mai, Thailand.
Tel: (+66) 62-2019139, Email: molika_mon@cmu.ac.th
2 Supply Chain Engineering Management Research Unit,
Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand.
Tel : (+66) 53-944125, E-mail : poti@eng.cmu.ac.th

ABSTRACT

Purpose: This study aims to investigate the impact of supply chain risk management (SCRM) on the inventory and warehousing practices of small and medium-sized enterprises (SMEs) in the retail sector prior and post pandemic in Cambodia.

Approach: The research employs a combination of quantitative and qualitative approaches to gain a comprehensive understanding of the dynamics within the Cambodian retail industry. The research methodology involves a questionnaire survey to collect data from SMEs in the Cambodian retail sector, followed by exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to uncover the underlying dimensions of supply chain risk and their relationships. Structural equation modeling (SEM) is then utilized to develop a comprehensive SCRM framework for Cambodian retail SMEs.

Finding: The findings of this research are include addressing the logistics challenges and supply chain risk management issues in the warehousing and inventory practices of Cambodian SMEs, suggesting improvements to domestic inbound logistics in Cambodia, and understanding the causal relationships between factors related to SME retail business and supply chain risk management.

Practical implication: This study is expected to contribute to academic knowledge in the field of supply chain management and provide practical insights to help Cambodian retail SMEs enhance their supply chain risk management capabilities, optimize their inventory and material handling activities, and improve their overall competitiveness in the market.

Originality: The study specifically targets Cambodian SMEs in retail sector, on developing country context that may contribute to the understanding of supply chain risk management challenges faced by small enterprises. This can provide practical recommendation for improving logistics activities in Cambodia, aligned with current industry standards.

Keyword: Supply Chian Risk management, Small and Medium Enterprises, Retail sector, Inventory and material handling activities challenges prior and post-pandemic.

Introduction

In today's globalized market, characterized by intense competition, rapid changes, and various risks, businesses must swiftly adapt and effectively manage risks to remain competitive (Kubíčková and Toulová, 2013). The issue of Risk Management (RM) has been a longstanding concern, with extensive research conducted over the years, particularly in supply chain management. Historical economic crises, such as those in 1998 and 2008, along with corporate scandals like Barings Bank (1995), Enron (2001), and WorldCom (2002), have brought significant attention to enterprise risk management (ERM) among scholars and industry professionals (Alawattegama, 2017). This focus has led to the development of supply chain risk management (SCRM), an innovative approach that integrates both financial and operational decision-making aspects.

While supply chain management has gained momentum, its adoption varies across regions, especially in developing countries. Many enterprises in these regions have yet to implement formal supply chain management practices. Despite the ongoing challenges, two primary sources of risk in supply chain

management—supply and demand—have been identified (Blos et al., 2009). Scholars agree that companies can only minimize, not entirely eliminate, supply chain risks, recognizing that losses may be unavoidable during unforeseen events. Nonetheless, adopting SCRM has proven effective in significantly reducing losses and damages (Blos et al., 2009).

Small and Medium-sized Enterprises (SMEs) are often managed by owners without formal management training (Millers and Gaile-Sarkane, 2021). In Cambodia, a developing country within ASEAN, approximately 40% of its 510,000 businesses are SMEs in the retail sector (Sambath, 2021). These enterprises have faced unexpected crises, particularly due to the global pandemic. To enhance the resilience of Cambodia's SMEs against potential disruptions, this study aims to improve their efficiency by addressing gaps in logistics activities, especially in warehouse and inventory management. Specifically, the focus will be on inbound logistics of SMEs to better understand potential risk factors.
Small, and Medium Enterprises (SMEs) are vital to global economies, especially in developing nations (Rahadi, 2016). They make up the majority of businesses worldwide, contributing significantly to job creation and economic development. SMEs account for about 90% of businesses and provide over 50% of global employment (Bank, 2019). However, the prolonged effects of the COVID-19 pandemic have led to closures and survival struggles for many enterprises, even within the same industry (Gupta et al., 2024). These risks, including natural disasters and man-made disruptions, hinder their adaptability due to limited resources and operational experience (Skouloudis et al., 2023). This vulnerability has been exacerbated by crises like COVID-19. The purpose of this study is to examine SMEs risk factors and challenges affecting warehousing and inventory practices prior and post-pandemic in Cambodia. The study answers the following research question:

1. What are the risk factors and challenges impacting warehousing and inventory practices, and how do these factors influence each other?
2. How did the risks faced by SMEs change before and after the COVID-19 pandemic?
3. What is the degree of risks affecting SMEs in the retail sector in Cambodia, and how can data analysis reveal these impacts?

To answer above question, questionnaire survey will be utilized to collect responses from the SME retail sector in Cambodia, specifically targeting participants found in Facebook groups. Additionally, factor analysis will be employed to assess the impact of risks on warehousing and inventory practices.

Literature Review

Small, and Medium Enterprises (SMEs) are vital to Cambodia's economic landscape, contributing significantly to employment and GDP. Approximately 40% of the 510,000 registered businesses operate within the retail sector, underscoring the importance of these enterprises in driving economic growth . However, despite their critical role, SMEs face numerous risks that threaten their sustainability and operational efficiency. The challenges face by SMEs in Cambodia are diverse and complex. Key issues include supplier disruptions, natural disasters, geopolitical tensions, demand fluctuations, and cybersecurity threats (Tukamuhabwa et al., 2017). The COVID-19 pandemic intensified these challenges, leading to operational disruptions, increased costs, and business closures. Many SMEs lacked the resilience to adapt to the rapidly changing environment, resulting in significant economic setbacks (Gupta et al., 2024).

In Cambodia, the classification of SMEs is based on factors such as employee count, turnover, and capital investment, which vary significantly across sectors (D.K.Nema, 2021). For instance, while some SMEs operate in agriculture, others are involved in industry and services. This diversity means that risk exposure can differ widely, with the retail sector particularly vulnerable due to its reliance on consumer demand and supply chain stability (Kosalsereyvuth and Julien, 2021). Cambodia's supply chain framework faces systemic challenges, including inadequate infrastructure, regulatory complexities, and logistical constraints (Hang, 2013). These challenges compel SMEs to adapt their supply chain strategies to navigate obstacles effectively. For example, many SMEs struggle with inventory management, often leading to stockouts or overstocking, which can tie up capital and reduce profitability (Hamza Kasim, 2015). The lack of expertise in supply chain management further intensifies these issues, making it difficult for small businesses to implement effective inventory control measures (Rubel, 2021).

Moreover, the COVID-19 pandemic highlighted the vulnerabilities in supply chains, as lockdowns and restrictions disrupted the flow of goods and services. Many local businesses faced delays in raw material deliveries, production bottlenecks, and distribution challenges, severely impacting their operational performance (Sambath, 2021). This situation necessitated a reevaluation of risk management practices among SMEs in Cambodia. To counter these challenges, it is essential for SMEs to adopt comprehensive risk management strategies. Enhancing supply chain resilience is crucial, particularly through improved inventory management practices. Effective inventory management helps prevent stockouts and minimizes excess inventory costs, ensuring that products are available to meet customer demand (Lenny Koh et al., 2007). Furthermore, implementing better forecasting techniques can aid SMEs in anticipating demand fluctuations and adjusting their inventory levels accordingly.

Investing in technology is another critical strategy for improving supply chain operations. Digital tools can streamline logistics, enhance communication with suppliers, and provide real-time data on inventory levels (Dallasega et al., 2022). By leveraging technology, SMEs can gain better visibility into their supply chains and respond more effectively to disruptions. Collaboration among stakeholders is also vital in mitigating risks associated with supply chain disruptions. Establishing partnerships with local suppliers, logistics providers, and even other SMEs can create a more resilient network capable of weathering challenges (Salleh Hudin et al., 2017). This collaborative approach allows for shared resources and knowledge, enabling SMEs to navigate complexities more effectively.

Research indicates that a structured approach to risk assessment can significantly enhance the performance of SMEs in Cambodia (Chen et al., 2013). Utilizing methods such as exploratory factor analysis (EFA) enables businesses to identify and prioritize risk factors, allowing them to focus on critical areas that require immediate attention (Piyanush Tooptompong and Piromsopa, 2018). This method provides a clearer understanding of the relationships between various risk dimensions, facilitating the development of targeted risk management strategies.

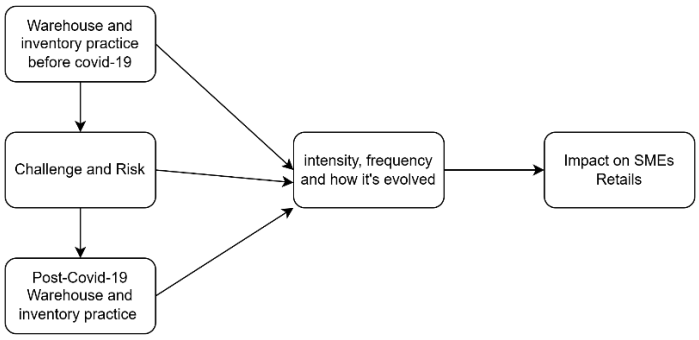

Figure 3. How warehouse and inventory practice impact on SMEs

The diagram above outlines the relationship and impact between warehouse and inventory practices before and after COVID-19. It highlights the challenges and risks faced by warehouses, such as supply chain disruptions and inefficiencies. Post-pandemic practices have adapted to address these issues, leading to changes in operational intensity and frequency. The implications of these shifts are particularly significant for Small and Medium Enterprises (SMEs) in the retail sector, affecting their operations and overall challenges. Additionally, training and capacity-building initiatives are essential for equipping SMEs owners and employees with the necessary skills to manage risks effectively. By fostering a culture of continuous learning, SMEs can enhance their operational resilience and adaptability in the face of emerging challenges. While SMEs in Cambodia face significant risks that threaten their sustainability and growth, strategic interventions can strengthen their resilience. By adopting improved inventory management practices, investing in technology, fostering collaboration, and implementing structured risk assessment processes, SMEs can better navigate the complexities of the Cambodian market. These measures not only enhance operational efficiency but also contribute to the overall economic stability of the country, ensuring that SMEs continue to play a vital role in Cambodia's economic development.

Methodology

The methodology of this study focuses on analyzing the challenges and risks in warehousing and inventory practices within SMEs in Cambodia's retail sector. The research uses a mixed-method approach combining both quantitative and qualitative techniques to ensure comprehensive data collection and analysis. For the quantitative part, data was gathered primarily through structured questionnaires and surveys, targeting SMEs in Cambodia. The surveys assess constructs such as post-pandemic challenges, cyber risks, and interconnection and material flow transparency, using a five-point Likert scale (Hair J.F, 1998) . To achieve this, the research employs Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). EFA is utilized to identify and explore the underlying relationships between observed variables, such as risks associated with supply chains, which are not initially known. Once these relationships are uncovered, CFA is then applied to validate and confirm the hypothesized structure of these connections, ensuring the reliability of the findings (Byrne, 2010). A pilot test was conducted to refine the questions and ensure clarity before distributing the survey to the broader target group. The goal is to achieve a sample size of at least 200 respondents, all of whom meet the criteria for being SMEs in retail. For the qualitative part, in-depth interviews with SME owners and key stakeholders were conducted to gather insights on their experiences and the challenges they face. This allowed for a deeper understanding of the operational dynamics within the sector.

Table 7 Construct items factor in dimensions before and post-pandemic.

Items	References
Prior Pandemic	
PPF1: Natural Disaster	**(Rahadi, 2016)**
PPF2: Geopolitical risk	
PPF3: Warehouse and inventory storage	**(Thun et al., 2011)**
PPF4: there overcapacity in transportation	
PPF5: Supplier with high quality product	
Post-Pandemic Challenges	
PECF1: Decreasing in Customer Purchasing Power	**(Anatan, 2021)** **(Chen et al., 2013)**
PECF2: Financial and Funding Management	
PECF3: Delivery speed	
PECF4: Customer satisfaction	
Interconnection and Material Flow Transparency	
IMFTR1: Product tracking	**(Dallasega et al., 2022)** **(Oyegoke et al., 2023)**
IMFTR2: Customer supplier connection	
IMFTR3: Inventory transparency	
IMFTR4: Material cost increase	
IMFTR5: Communication issues	

Cyber Risk CRF1: operating system of the computer CRF2: Website server compromise CRF3: Portable devices in the company (i.e. laptop, mobile phone or tablet) CRF4: knowledge awareness regarding IT security threats CRF5: Lack of Contingency	**(Amrin, 2014)**

In terms of data analysis, the study employs statistical tools such as SPSS and Structural Equation Modelling (SEM) using AMOS to examine the relationships between variables, supported by factor analysis to explore latent structures. Additionally, Microsoft Excel was used for initial data organization and exploratory analysis, including visualization techniques like pivot tables and charts. This comprehensive approach ensures that the findings are reliable and valid, providing valuable insights into the risks that SMEs in Cambodia face, especially concerning warehousing and inventory practices.

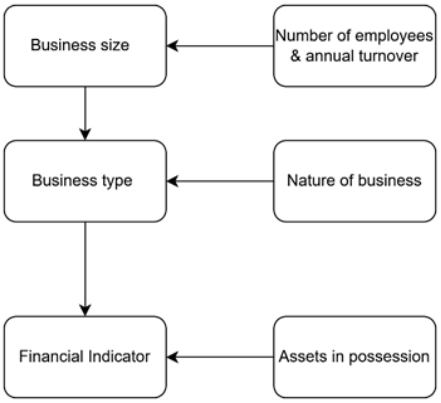

Figure 4 Designed Filter in Questionnaires

The study draws on an extensive literature review to identify key factors and constructs relevant to supply chain risk and uncertainty. This includes risks such as natural disasters, geopolitical challenges, and technological disruptions, all of which have been identified as critical to the operational efficiency of SMEs in Cambodia (Chen et al., 2013). The statistical models developed from this data are grounded in both empirical research and theoretical frameworks (Dallasega et al., 2022). This ensures that the models are robust and capable of providing meaningful insights into supply chain dynamics. An essential part of the methodology is the categorization of risks into manageable types, such as natural disasters, geopolitical risks, and technology-related uncertainties. These categories are crucial for understanding the vulnerabilities faced by SMEs (Salleh Hudin et al., 2017). By categorizing and analyzing these risks, the study provides a comprehensive view of the challenges that impact inventory management, logistics, and overall supply chain resilience.

Result: Leveraging Risk-Affecting Warehousing and Inventory Practice

The research focused on analyzing the challenges and risks associated with warehousing and inventory management practices among SMEs in Cambodia's retail sector. The findings revealed significant trends in how SMEs manage their supply chains, particularly in response to challenges that have intensified during and after the COVID-19 pandemic. The quantitative analysis, using data from questionnaires and surveys, highlighted several critical factors that influence SMEs' ability to manage risks effectively. Among these, post-pandemic challenges stood out, with many businesses reporting difficulties in transitioning from traditional sales methods to digital platforms. This transition brought

about a need for better interconnection and material flow transparency, as online sales require more sophisticated tracking and inventory management systems (Varma and Dutta, 2022). Additionally, cyber risks emerged as a significant concern, as the shift to digital platforms made businesses more vulnerable to cyberattacks and data breaches, further complicating supply chain operations (Chen et al., 2013). The data indicated that SMEs are particularly vulnerable to supply chain risks due to their limited resources and lack of advanced management systems. For instance, over 65% of respondents cited issues with inventory management and stockouts, which disrupted their ability to meet customer demand. In addition, 43% of businesses reported an increase in operational costs due to inefficient warehousing practices, such as overstocking or disorganization, which further exacerbated their financial vulnerabilities.

The qualitative interviews conducted with key stakeholders and business owners provided deeper insights into these quantitative findings. Many participants emphasized the challenge of maintaining sufficient inventory levels during the pandemic due to disruptions in both local and international supply chains. They also noted that geopolitical factors, such as regional trade restrictions, made it difficult to source materials reliably. Several business owners expressed concerns about the high cost of implementing new digital tools and systems necessary for efficient inventory tracking and warehousing operations. The Structural Equation Modelling (SEM) analysis confirmed the strong relationship between inadequate warehousing practices and increased supply chain risks. The results showed that businesses with poor inventory management systems were more likely to experience delays, stockouts, and higher operational costs. Furthermore, businesses that adopted digital tools for supply chain transparency reported improved performance, with more than 70% of these businesses noting better inventory control and fewer disruptions.

The research also highlighted the significant impact of external risks, such as natural disasters and geopolitical issues, on SMEs' supply chain performance. Businesses that were better equipped with resilient supply chain strategies, such as diversified sourcing and flexible warehousing, fared better in mitigating the effects of these risks. However, the majority of respondents expressed a need for more government support and financial assistance to adopt these strategies. The results of this study demonstrate that while SMEs in Cambodia's retail sector face substantial supply chain risks, particularly in warehousing and inventory management, there are clear opportunities for improvement through the adoption of digital tools and more robust risk management strategies. These findings offer practical insights that can guide SMEs in enhancing their resilience to supply chain disruptions in an evolving business landscape.

Discussion and Conclusion

The findings of this study provide a comprehensive analysis of supply chain risks faced by Cambodian SMEs in the retail sector, especially regarding warehousing and inventory management. The study demonstrates that Cambodian SMEs are particularly vulnerable to risks such as natural disasters, geopolitical tensions particularly post-pandemic challenges, cyber risks, and interconnection and material flow transparency. These risks have been exacerbated by the COVID-19 pandemic, which forced many SMEs to shift from traditional physical sales to online platforms. This transition, while necessary for survival, introduced new challenges such as cyber risks and the need for greater material flow transparency (Varma and Dutta, 2022).

The combination of quantitative and qualitative data collection methods proved effective in gathering a holistic understanding of these challenges. Surveys provided insight into the frequency and intensity of risks both before and after the pandemic, while interviews offered deeper context regarding the practical implications of these risks. The application of tools like SPSS and Structural Equation Modelling (SEM) allowed for a nuanced analysis of the relationships between different risk factors, uncovering how they influence each other and the overall resilience of SMEs (Hair J.F, 1998).

This study highlights the importance of effective supply chain risk management for Cambodian SMEs, especially as they navigate the post-pandemic business landscape. The findings emphasize the need for SMEs to adopt more robust inventory and warehousing practices, alongside enhanced digital resilience, to mitigate risks in an increasingly interconnected and volatile environment. The integration of quantitative and qualitative research methods, combined with advanced statistical analysis, has yielded valuable insights that can inform both academic research and practical strategies for SMEs in Cambodia.

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LOGISTICS IN MIDDLE EAST: STATE OF THE ART AND LOOKING AHEAD

Maharshi Dhada[1], Abdelrahman E. E. Eltoukhy[2], Adriana Gabor[3], Andrei Sleptchenko[3], Duncan McFarlane[1]

[1]Institute for Manufacturing, Department of Engineering, University of Cambridge, 17 Charles Babbage Road, Cambridge, UK

[2]Management Science & Engineering Department, Khalifa University, Abu Dhabi, UAE

[3]Khalifa University, Shakhbout Bin Sultan St - Hadbat Al Za'faranah - Zone 1 - Abu Dhabi - United Arab Emirates

Abstract

Purpose: This paper This paper aims to provide a comprehensive review of the current state of logistics in the Middle East, identifying key challenges and opportunities. It explores how advancements in technology and strategic initiatives can address existing inefficiencies and leverage the region, unique geographical advantages to enhance logistics operations.

Design/methodology/approach: A mixed-methods approach is employed, combining quantitative data analysis with qualitative insights from industry experts. The study analyses logistics performance indicators across Middle Eastern countries, examining parameters such as infrastructure quality, regulatory environment, and technological adoption via interviews and local analyses. Secondary data from industry reports and academic literature is also integrated to ensure a robust analysis.

Findings: The study finds that while the Middle East has made strides in improving logistics infrastructure, significant disparities exist between countries. Gulf Cooperation Council (GCC) states show higher logistics performance due to substantial investments in port and airport facilities. However, issues such as regulatory bottlenecks, lack of skilled workforce, and uneven technological adoption persist. The research highlights the potential of digital technologies to streamline operations and improve supply chain transparency, offering a roadmap for future developments.

Originality/ value: This paper provides valuable insights for policymakers, industry leaders, and researchers by presenting a detailed overview of the logistics landscape in the Middle East. It identifies critical areas for improvement and potential research avenues, emphasizing the need for collaborative efforts to foster innovation and efficiency in the sector. By outlining strategic recommendations and highlighting the role of emerging technologies, the study contributes to the discourse on sustainable logistics development in the region, ultimately supporting economic growth and regional integration.

Keywords: Logistics in Middle East, Shipping, literature review, digital logistics, global logistics, multimodal logistics

Introduction

The Middle East region comprises parts of Western Asia and North Africa. This region has historically played a crucial role in global trade, and includes countries like Saudi Arabia, the United Arab Emirates, Iran, Iraq, Israel, and Turkey, among others. Its position in the centre of Europe, Asia, and Africa makes it a strategic Logistics hub globally. Historically, the Middle East's central location connected the key trade routes like the Silk Road, facilitating the exchange of goods between Asia, Europe, and Africa. Cities like Babylon and Damascus were also the hubs for spices, textiles, and precious metals. The region's control of maritime routes, including the Red Sea and Persian Gulf, also made it important for global logistics and commerce (Acar et al., 2015; Shaw, 2002).

For the modern global logistics, the Middle East is significant due to its natural resources, particularly oil and natural gas, making it a vital energy hub. Countries such as Saudi Arabia and Iran are among the largest oil exporters, and the region's energy resources fuel industries around the world. Critical maritime trade routes like the Suez Canal and the Strait of Hormuz facilitate the movement of goods between Europe, Asia, and Africa. The region's airports and ports, such as Dubai's Jebel Ali Port, the Port of Salalah, and the Port of Jeddah, serve as major hubs for cargo transportation and air freight (Devlin & Yee, 2005).

While being key for global logistics, the Middle East also faces challenges in the Logistics sector, including geopolitical instability in certain regions, which potentially disrupt supply chains.

Infrastructure gaps in some countries hinder efficient transportation, despite advancements in others like the UAE. Heavy reliance on oil exports makes the region vulnerable to global energy market fluctuations. Regulatory barriers and inconsistent customs procedures across countries also complicate cross-border trade. Environmental factors, such as extreme temperatures and water scarcity, add further complexity, affecting transportation efficiency and the development of sustainable logistics solutions.

Drawing from the above, this paper presents a discussion around the state of Logistics sector in the Middle Eastern region, highlighting the key challenges, and the anticipation for the future of Logistics in Middle East. The following section is structured as follows: Section 2 discusses the current state of Logistics assets in some of the Middle East including the infrastructure, technological adoption, etc. Section 3 discusses the key challenges faced by the Middle Eastern Logistics sector. Section 4 presents the opportunities that lie for the Middle Eastern Logistics sector primarily thanks to its geographical advantages, finally followed by some strategic recommendations in Section 5.

Current State of Logistics in the Middle East

This section discuss the recent advancements and the state-of-the-art of the Middle Eastern Logistics.

Infrastructure and Development

In the recent years, countries like United Arab Emirates, Qatar, Saudi Arabia and Turkey have heavily invested in improving and expanding logistics infrastructure, aiming to become global logistics hubs (Harmon, 2024; Rebello, 2024). Jebel Ali Port in Dubai and King Abdullah Port in Saudi Arabia have been expanded, automated, and upgraded with state-of-the-art digital tracking technologies to be able to handle the latest generation container ships and improve cargo throughput (Harmon, 2024). Major airports in Qatar (Hamad International Airport), UAE (in Dubai) and Turkey have expanded their cargo facilities and introduced advanced logistics technologies to boost airfreight transportation (Rebello, 2024).

Besides developing the ports and airports infrastructure, the region aims to build a multi-modal transportation network for a more agile transportation of cargo. The Gulf Railway, connecting six GCC countries, is expected to boost intra-GCC trade and facilitate transportation to and from major logistics hubs in the region. At the national level, UAE builds Etihad Railways, linking important industrial and urban centers with maritime hubs (Harmon, 2024). Turkey is also investing in high-speed railway lines, expecting its cargo transport to increase from 5.08% in 2023 to 21.93% in 2053.

In order to support the logistics operations, several sustainable logistics parks, containing state-of-the art warehousing and distribution centers have been established in the region (Agility, 2024). A few examples of such parks are Hamad Port Free Zone (Qatar), Jebel Ali Free Zone (UAE), Khalifa Industrial Zone Abu Dhabi (UAE), King Abdullah Economic City (Saudi Arabia). These parks play an important role in streamlining transportation and connectivity across the region, ensuring smooth supply chain operations, green transportation, efficient custom procedures and an improved trade environment.

Technological Adoption

Currently, various digital technologies, including the Internet of Things (IoT), blockchain, Industry 4.0, and artificial intelligence (AI), are increasingly applied to logistics to enhance efficiency, transparency, and sustainability. (Balfaqih et al., 2023) presented a blockchain-enabled IoT logistics system designed for GCC countries to enhance the tracking and management of high-value shipments in smart cities. This system addresses challenges such as transparency and growing logistics volumes by integrating smart contracts for automatic approval and payment, alongside intelligent parcels (iParcels) equipped with sensors for violation detection. (Bleik, 2024) further examined factors influencing blockchain implementation in UAE logistics, highlighting critical aspects such as security, privacy, and technology infrastructure. The study found a strong correlation between blockchain adoption and awareness of the IT infrastructure, emphasizing the importance of data security for effective decision making.

(Alsharidah & Alazzawi, 2020) explored the role of digital technologies, particularly artificial intelligence and digital transformation, in enhancing supply chain management in Saudi Arabia. Their findings emphasize the positive impacts on efficiency, quality, flexibility, and productivity, highlighting the importance of these technologies for achieving sustainable economic growth in line with Saudi Arabia's Vision 2030 initiative. (Khan, 2019) identified eight major challenges associated with big data analytics (BDA) in UAE service supply chains, including technical, cultural, ethical, and operational issues, and proposed a comprehensive framework for effective integration of BDA. (Rahman et al., 2022) focused on the implementation of Industry 4.0 practices in the GCC logistics sector, noting that adoption remains in its early stages and requires further investment. (Albreem et al., 2023) explored green IoT (GIoT) practices in GCC countries to mitigate environmental impacts, evaluating renewable energy opportunities and AI integration to reduce carbon emissions and e- waste. Their research positions GIoT implementation as a key strategy for GCC nations to diversify their economies and promote environmental sustainability. Collectively, these studies highlight the critical role of digital transformation in optimizing logistics and promoting sustainable economic growth in the GCC.

Regulatory Environment

The logistics sector in the Middle East encounters substantial regulatory challenges, particularly in non-GCC countries, where bureaucratic hurdles and inconsistent regulations remain significant obstacles to efficient operations. Despite recent efforts to streamline processes, these bureaucratic complexities continue to slow down the movement of goods, create operational inefficiencies, and elevate costs for businesses involved in cross-border trade. Inconsistent regulations across different countries further exacerbate these issues, leading to delays and unpredictable compliance requirements that can disrupt supply chains. Moreover, restrictive trade policies in certain countries within the region add an additional layer of complexity, making it difficult for businesses to navigate the regulatory landscape and increasing the overall burden on logistics providers. These challenges underscore the urgent need for greater regulatory harmonization, streamlined customs procedures, and more open trade policies to enhance the efficiency and competitiveness of logistics operations across the Middle East (Obrecht et al., 2022)

Human Capital and Workforce

The logistics workforce in the Middle East heavily depends on expatriate talent, especially in the GCC countries, where rapid sector growth and technological advancements have outstripped the development of local expertise. Although expatriates bring important skills and experience, this reliance challenge workforce stability, with frequent disruptions due to high turnover rates and visa issues. Additionally, there is a noticeable shortage of skilled professionals in the sector, particularly in areas like supply chain management and technology-driven logistics roles. As the logistics industry more widely adopts advanced technologies such as AI, IoT, and data analytics, the gap in specialized skills becomes more evident, hindering the sector's ability to fully leverage these innovations (Benayoune, 2018; Koyuncu, 2023).

To address these challenges, both governments and private sector companies in the Middle East are ramping up investments in training and development initiatives. This includes the establishment of industry-specific training programs in collaboration with educational institutions and industry associations, focusing on logistics and supply chain management. Additionally, there is a pressing need for technological training programs that equip the workforce with digital skills necessary for modern logistics operations. As GCC countries implement localization policies like Saudization, which aim to reduce reliance on expatriate labour, these training efforts are crucial for building a skilled local workforce capable of sustaining the sector's growth and meeting the demands of a rapidly evolving logistics landscape. Continuous professional development programs are also essential, allowing existing workers to stay updated with the latest industry trends and technological advancements (Adair et al., 2024; Li & Miller-Hooks, 2023; Rosi & Obrecht, 2023).

Challenges and Gaps in the Middle Eastern Logistics Sector

This section discusses the key challenges faced by the Middle Easter Logistics sector, primarily including infrastructure disparities, regulatory issues, technological gaps, and a shortage of skilled labour. These issues collectively hinder the full potential and development of an integrated logistics network across the region.

Infrastructure Disparities

A prominent challenge in the Middle East logistics sector is the disparity in infrastructure development across countries. The Gulf Cooperation Council (GCC) states, particularly the United Arab Emirates (UAE), Saudi Arabia, and Qatar, have made substantial investments in logistics infrastructure. As discussed earlier, Dubai's Jebel Ali Port and Khalifa Port in Abu Dhabi are among the largest and technologically advanced ports globally, and state-of-the-art airports like Dubai International and Hamad International Airport in Qatar which serve as air cargo hubs. These countries have prioritized the development of roads, railways, and digital logistics solutions, positioning themselves as leading global logistics centers.

In contrast, several Middle Eastern countries face infrastructure challenges often due to the geopolitical tensions. There have been instances of prolonged conflicts leading to relatively underdeveloped logistics infrastructure. Disconnected road networks, outdated ports, and the absence of rail systems in the regions of conflicts contribute to the inefficiencies in transportation and trade.

This infrastructure gap exacerbates regional inequality and increases logistics costs, hindering economic integration across the Middle East.

Regulatory Issues

Regulatory issues present another major obstacle to the integrated logistics sector in the Middle East. For example, the non-GCC countries face complex and fragmented regulatory frameworks that complicate cross- border trade. Customs regulations, tariffs, and trade policies vary significantly from one country to another, creating delays and increasing operational costs for logistics companies (Obrecht et al., 2022).

There exists an especially visible regulatory disconnect between the countries within and outside the GCC, such as Jordan, Lebanon, and Iraq, leading to additional bureaucratic inefficiencies. Inconsistent import- export regulations, labour laws, and safety standards hinder the free movement of goods across borders and reduce the overall competitiveness of logistics operations. Regulatory inefficiencies not only affect logistics within countries but also disrupt regional supply chains, undermining the Middle East's potential to facilitate global trade efficiently (Obrecht et al., 2022).

Technological Adoption

Technological adoption in the logistics sector is uneven across the Middle East. The UAE and Saudi Arabia are at the forefront of adopting these technologies, investing in smart ports, digital customs processes, and automated warehouses to improve logistics operations. This has been discussed in detail Section 2.

However, many countries in the region have not kept pace with technological advancements. Limited financial resources, outdated infrastructure, and insufficient government incentives hinder the adoption of advanced logistics technologies. The lack of digitization in some countries leads to inefficiencies in inventory management, cargo tracking, and customs processing. The absence of integrated technological systems across the region further hampers the potential to form a seamless logistics network, resulting in operational delays and higher costs.

Workforce Training Needs

The logistics sector in the Middle East faces a particular shortage of skilled labour, relatively more in the non- GCC countries. Although the region has seen significant growth in logistics infrastructure, there has been insufficient emphasis on workforce development to support this growth. The shortage of specialized training programs in logistics, supply chain management, and related fields contributes to a skills gap, particularly in countries with underdeveloped education and training systems.

Most Middle Eastern countries rely heavily on expatriate labour to fill roles in logistics, particularly in highly technical and managerial positions. However, this reliance creates long-term challenges, as expatriates often do not remain in the region for extended periods, leading to a continuous turnover of

staff. Furthermore, there are limited opportunities for local talent to acquire the necessary skills through formal education or vocational training programs. This gap in training and education limits the capacity of the Middle Eastern logistics sector to adopt advanced technologies and practices in supply chain management. The shortage of a skilled workforce also reduces the region's ability to remain competitive in the global logistics industry.

Opportunities for Future Research and Development

There is a rising need for developments in the corresponding areas of infrastructure optimisation, technological integration, regulatory harmonization, and workforce development in the Middle East, as it is evident from Section 3. The Middle East logistics sector as such presents a range of opportunities for the Logistics research and development (R&D), more so by bringing together the industry and academia collaborations.

Infrastructure Development and Optimisation

The most prominent opportunity lies in mitigating the infrastructure disparities that exist across the Middle East. It must be explored how public-private partnerships (PPPs) and government-led initiatives can enhance logistics infrastructure, especially in underdeveloped regions. War-torn countries such as Iraq, Syria, and Yemen require reconstruction efforts that integrate modern logistical needs, and R&D could explore innovative approaches to rebuilding transportation networks, including roads, railways, and seaports.

Furthermore, there is potential for development of multi-modal logistics networks that combine road, rail, air, and maritime transport. Investigation of models for cross-border collaboration and supply chain integration, focusing on optimizing the use of existing logistics hubs, such as Dubai's Jebel Ali Port and Khalifa Port, must be deployed to facilitate seamless movement of goods across the region. Analysing the effectiveness of these hubs in serving both regional and global trade could help inform strategies for greater regional integration.

Technological Innovation and Digitalisation

As logistics moves increasingly toward digital transformation, there is significant potential for the adoption of advanced technologies in the Middle East. Areas of focus include blockchain for enhanced supply chain transparency, the Internet of Things (IoT) for real-time cargo tracking, and artificial intelligence (AI) for predictive analytics and demand forecasting. These technologies have already seen success in developed economies, but their tailored application to the unique challenges of Middle Eastern logistics is yet to be explored.

Countries with underdeveloped logistics sectors, provide fertile ground for research into low-cost, scalable Shoestring digital solutions. Future studies could explore the deployment of affordable technological innovations for improve inventory management, streamline customs processes, and increase efficiency in logistics operations. Such low-cost solutions have already been deployed in various applications for the small and medium scale enterprises in several other countries (Dhada et al., 2023; Macias-Aguayo et al., 2022; Yilmaz et al., 2022) Additionally, the potential use of AI for optimizing freight routing, predictive maintenance of vehicles, and minimizing fuel consumption offers valuable areas for exploration.

Regulatory Harmonisation

Regulatory harmonisation across the Middle East is instrumental in resolving cross-border trade inefficiencies. Inconsistent customs procedures, tariffs, and trade policies among countries create barriers to the free movement of goods, necessitating further research into standardization and best practices. Focus must now be on comparing successful models of regulatory harmonization from other regions, such as the European Union's single market, and how such frameworks could be adapted to the Middle East context.

E-government systems and digital customs platforms present additional opportunities for R&D. Research could examine how digitizing customs procedures might reduce bureaucratic delays and streamline trade across borders. The development of a regional trade corridor through harmonized

regulations and digital systems could significantly enhance the Middle East's role as a global logistics hub.

Sustainable and Resilient Logistics

The integration of sustainability practices into logistics operations is probably the most important and prominent emerging global trend, with significant research potential. As the Middle East moves towards more sustainable economic practices, the logistics sector could benefit from reducing the environmental impact of freight transport. This could be done by adopting electric and hydrogen-powered vehicles for freight transportation, as well as methods for reducing carbon emissions in air cargo, which remains one of the most polluting sectors of logistics (Rosi and Obrecht, 2023b; Obrecht et al., 2022).

The Middle East's abundance of solar energy resources presents another area for exploration. R&D could focus on utilizing solar power in logistics operations, particularly in warehouses, ports, and transportation hubs. Further research could also examine how reverse logistics and sustainable packaging could be applied on a large scale, contributing to both environmental goals and operational efficiency (Rosi and Obrecht, 2023b; Obrecht et al., 2022).

Parallel to the notion of sustainability, there is also a rising need to make the Middle Eastern Logistics more resilient to geopolitical shifts and disruptions in the global supply chains. This involves investigating risk mitigation strategies by analysing the external factors, and at the same time deploying resilient strategies such as decentralized supply chains, flexible sourcing, and adaptive logistics operations that reduce dependency on a single mode of transport or supply route (Sundarakani & Onyia, 2021).

These opportunities align with broader global efforts to integrate sustainability into logistics, offering a framework for environmentally friendly and socially responsible logistics operations.

Workforce Development and Training

Workforce development represents a critical gap in the Middle East logistics sector, providing ample oppor- tunities for research into education and training solutions. This combined with the growing pressure for localisation in certain countries amplifies the need for revamping the workforce training and motivation.

Many countries in the region rely heavily on expatriate labour for technical and managerial roles in logistics, highlighting the need for research into creating specialized training programs that can develop a local work- force capable of supporting the logistics industry's growth. Vocational training programs in collaboration with academic institutions and industry partners to bridge the skills gap must be organised. Additionally, there is a need for studies exploring the most effective ways to upskill the existing workforce in logistics technologies, including AI, blockchain, and IoT. Research into gender diversity and inclusivity in logistics could also inform policies aimed at increasing female participation in the workforce, helping to strengthen the sector by broadening its talent pool.

Strategic Recommendations and Conclusions

This section summarises the discussion in this paper. In Section 2 we see that the Middle East region, which has historically been pivotal for the global trade and logistics, continues to see unprecedented growth in the recent decade. Nonetheless, like with any other vast and diverse region, the Middle East still faces challenges which if address would unleash the maximum potential of an efficient and integrated logistics network. The key challenges faced by the Middle East Logistics sector, their impacts, and the opportunities that exist to mitigate those challenges are summarised in Table 1.

Table 1. Challenges, Impacts, and Strategic Recommendations for Middle Eastern Logistics

Challenge	Impact	Strategic recommendation
Infrastructure disparities across the Middle East, some countries investing and observing the rapid infrastructure growth while a few suffer from geopolitical conflicts	Hinders the connectivity in the region, leads to increased transportation costs, makes the logistics system less sustainable	Exploration into public private partnerships to close the gap between government focus and the on-ground reality. Research into post-disaster logistics, inclusion of the SMEs into the logistics infrastructure planning
Non-uniform regulatory laws, especially across the GCC and non-GCC countries	Hinders the logistics integration across the region, leads to increased operations costs, prevents the development of decentralised logistics networks	Thorough cost-effect analyses to facilitate free trade within the region, especially studying the impact through other global examples such as of the European Union and deploying pilot programmes for the short term
Technological gaps, where again we observe significant disparities in the technological adoption across the Middle East	Hinders the overall visibility of the logistics networks, increases the logistics network efficiency, could prevent the seamless integration with global logistics	In the short term, conduct systematic workshops with the SMEs to understand the prominent needs of the industry. Deploy pilots using low-cost technologies
The need for skilled workforce and updated training programmes in certain regions	Increases the reliance on expatriate labour, creates logistics network inefficiencies, hinders integrated logistics networks	Focus on talent retention, although expatriate, and enhance the collaboration between the experts and the trainee labour. Exhaustive training programmes in collaboration with global institutions

Acknowledgements

This research was sponsored by the SF Express Research Fellowship in Logistics.

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PREDICTING AND ANALYZING SHIPPING TIME USING ENSEMBLE TREE MODELS WITH SHAPLEY ADDITIVE EXPLANATIONS

Panupong Wanjantuk[1*] and Ruth Banomyong[2]
[1] Department of Computer Engineering, Khon Kaen University, Thailand
[2]Department of International Business, Logistics and Transport, Thammasat Bussiness School, Thammasat University, Thailand

Abstract

Purpose: This study aims to develop a predictive model for shipping times using advanced machine learning techniques, specifically ensemble learning models, to enhance accuracy and reliability in supply chain management. Additionally, the study seeks to interpret the model's predictions to understand the influence of various factors on shipping durations, providing actionable insights for optimizing logistics operations.
Design/methodology/approach: The research utilizes a dataset comprising 5,114 rows of historical shipment records. Data preprocessing included one-hot encoding for categorical variables, scaling numerical features, and addressing imbalanced distributions. Seven ensemble tree models were employed. The models were evaluated using cross-validation and various evaluation metrics. SHAP (SHapley Additive exPlanations) was used to interpret the best-performing model, providing insights into feature importance and interactions.
Findings: The CatBoost model demonstrated the highest accuracy in predicting shipping times, followed by Random Forest and LightGBM. SHAP analysis revealed that normalized shipment charges, processing days, and turnaround time thresholds were the most significant features influencing shipping times. Interaction plots highlighted the complex dependencies between features.
Research Limitation: The study's limitations include the quality and completeness of the dataset, which can affect model performance. Additionally, the models' predictive power may diminish when applied to significantly different future conditions or new shipping routes not represented in the training data.
Practical Implication: The predictive models developed in this study can be integrated into logistics management systems to provide real-time shipping time estimates and insights, enhancing inventory management, reducing costs, and improving customer satisfaction. The interpretability provided by SHAP helps logistics managers optimize processes, resource allocation, and scheduling.
Originality/value: This research demonstrates the effectiveness of combining ensemble learning models with SHAP for accurate and interpretable shipping time predictions. The study provides a comprehensive approach to understanding the factors influencing shipping durations, offering valuable insights for improving supply chain efficiency.

Keywords: Shipping Time Prediction, Ensemble Learning Models, SHAP, Supply Chain Management, Predictive Analytics

Introduction

Shipping times are critical in supply chain management, significantly impacting logistics efficiency and reliability. Timely delivery is essential for maintaining supply chain continuity and meeting customer expectations [1]. Delays can disrupt inventory levels, production schedules, and customer satisfaction, especially in sectors like retail, manufacturing, and healthcare. Modern supply chains are complex, driven by globalization and the need for just-in-time delivery, necessitating accurate shipping time predictions [2]. Accurate predictions help businesses optimize inventory management, reducing costs associated with overstocking or stockouts [3]. They also enhance customer satisfaction by providing reliable delivery estimates [4]. Additionally, accurate predictions improve decision-making within the supply chain by anticipating delays and allowing for operational adjustments, thus enhancing overall resilience [5]. Advanced predictive models using machine learning and deep learning techniques offer the potential for greater precision in shipping time forecasts by leveraging large datasets and sophisticated algorithms. Integrating these techniques is essential for maintaining competitiveness and efficiency in the modern business landscape.

The primary objective of this research is to develop a predictive model for shipping times using historical shipment data. By leveraging advanced machine learning techniques, we aim to create a model that can accurately forecast the time required for shipments to reach their destinations, enabling logistics companies to better manage their operations and provide more reliable delivery estimates to their customers. Additionally, a secondary objective is to interpret the model's predictions to understand the influence of various factors on shipping times. Employing interpretability techniques, we seek to uncover key determinants impacting shipping durations, which will validate the model and offer actionable insights for optimizing shipping processes and mitigating delays.

The rest of the paper is organized as follows: Section 2 reviews existing methods and models for predicting shipping times, focusing on statistical and machine learning techniques and the importance of model interpretability. Section 3 outlines the methodology, including data collection, preprocessing, model selection, training, and evaluation. Section 4 presents the results, highlighting performance metrics and interpreting the best-performing model with SHAP Tree Explainer. Section 5 discusses the implications, limitations, and future research directions. Finally, Section 6 concludes key findings and potential applications in supply chain management.

Literature Review

The research on predicting shipping times has seen significant advancements through the application of both traditional methods and machine learning techniques. Traditional methods often relied on tank model tests and semi-empirical formulas, as noted in the comparative study by [6], which highlighted the shift towards more sophisticate machine learning (ML) algorithms to improve operational efficiency and meet regulatory requirements. Machine learning has been particularly effective in enhancing prediction accuracy and efficiency. For instance, [7] developed a predictive model using multinomial logistic regression and other classifiers to estimate ocean import shipment lead times with high accuracy. Similarly, [8] used multiple regression techniques combined with marine traffic data to predict shipment ETAs with an 89% accuracy rate. [9] demonstrated the benefits of ML in the oil and gas industry by improving job scheduling and reducing costs through precise lead time predictions. [10] successfully applied a Random Forest algorithm to predict shipping times between Southeast Asia and North America, achieving superior results compared to traditional methods. Overall, the integration of ML in shipping logistics has proven to significantly enhance visibility, predictability, and efficiency across various applications. Additionally, [11] investigates using machine learning to predict delivery times early in the order process for small batch production companies. Using data from two German manufacturers, it develops a machine learning approach to predict delivery dates upon receiving a request for an offer, incorporating the desired customer delivery date. Results demonstrate that machine learning significantly improves delivery date prediction accuracy, reduces manual effort, and enhances competitive advantage.

Model interpretability in machine learning is critical for ensuring transparency, trust, and actionable insights, especially in high-stakes domains like healthcare, finance, and logistics. Interpretability allows stakeholders to understand the reasoning behind a model's predictions, making it possible to identify and correct biases, validate model outputs, and comply with regulatory requirements. Previous work on interpretability in machine learning models for predicting shipping times and related logistics processes is relatively scant but emerging. Studies have shown the importance of using interpretability techniques to understand the influence of various factors on model predictions, offering actionable insights for optimizing shipping processes and mitigating delays. For example, [12] explored interpretability in predictive process analytics, using machine learning models trained on historical process data to make predictions about business processes, such as shipment completions. Their study emphasized the need for interpretability to ensure the reliability of high-accuracy models by providing explanations for their predictions. Similarly, [13] conducted a comparative study on interpretability techniques for models trained on time series data, including shipping logs, to predict outages and delays. They highlighted the advantages and limitations of various interpretability methods such as LIME and SHAP in providing insights into model decisions. Additionally, [14] investigated the predictability of asset prices in shipping using a novel hybrid algorithm, underscoring the role of interpretability in improving forecast accuracy and understanding model behavior.

Methodology

To begin with, the original shipment dataset is preprocessed by eliminating redundant and erroneous information. The ensemble learning models, particularly those based on boosting, are initially developed based on data partitioning into training and testing datasets. The training dataset is used to build the predictive model, and the test dataset is used to evaluate the models' performance. Once the optimal model with the best performance is identified, the SHAP approach is utilized to establish additive attributes that are then employed to determine the importance of variables for shipping times and the contributions of various factors to each predicted shipping duration.

Data Collection

The dataset used in our experiments was sourced from Kaggle, comprising 5,114 rows of historical shipment records. Each record includes various features as detailed in Table 1.

Type of Feature	Feature name	Description
Location	pick_up_point	Pick Up Point
	drop_off_point	Drop Off Point
	source_country	Country from where the goods need to be shipped
	destination_country	Country to where the goods need to be shipped
Cost and Charges	freight_cost	Cost of transportation per kilogram
	shipment_charges	Fixed cost per shipment
	total_freight_cost	Total cost of freight (freight_cost * gross_weight)
	normalized_shipment_charges	Normalized shipment charges to account for variability
Weight	gross_weight	Gross weight in kilograms of the shipment
	freight_cost_gross_weight	Interaction term combining the freight cost and gross weight
Shipment Mode	shipment_mode	Method of shipment (e.g., air, ocean)
Shipping Company	shipping_company	Candidate shipping company
	selected	Whether the company in 'shipping_company' was selected or not
Timing	day_of_week	The day the shipment was sent
	month	The month the shipment was sent
	cut_off_time_binary	Binary indicator of whether the shipment was sent within the cut-off time
	tat_binary	Binary indicator if the shipment turnaround time is within a certain threshold
	processing_days_binary	Binary indicator of whether the shipment was processed on a working day
	is_weekend	Binary indicator if the shipment was sent on a weekend
Target	shipping_time	The amount of time that it takes for goods to reach their destination (in days)

Table 1: Data Description

Data Preprocessing

Data processing included one-hot encoding for categorical variables, scaling numerical features, and handling outliers to improve data quality. The shipping time target variable

showed a highly imbalanced distribution, addressed using the SMOGN (Synthetic Minority Over-sampling Technique for Regression with Gaussian Noise) technique [15].

Model Selection

In this study, we selected seven ensemble tree models for regression due to their effectiveness and versatility in handling various regression tasks. These models—Random Forest, Extra Trees, Gradient Boosting Machine (GBM), XGBoost, LightGBM, CatBoost, and NGBoost—were chosen for their unique strengths, such as robustness to overfitting, handling of categorical data, and providing uncertainty estimates. Random Forest combines multiple decision trees, improving accuracy and reducing overfitting through bootstrapping and feature randomness [16]. Extra Trees incorporate additional randomness in tree construction, which helps reduce variance and is suitable for complex data [17]. GBM builds sequential trees, correcting errors with each iteration using gradient descent [18]. XGBoost enhances gradient boosting with regularization, efficient handling of sparse data, and improved scalability [19]. LightGBM uses a histogram-based algorithm for faster training and better accuracy, especially with large datasets [20]. CatBoost efficiently handles categorical features and reduces the need for extensive preprocessing [21]. Finally, NGBoost employs a probabilistic framework, providing uncertainty estimates useful for decision-making processes [22]. By leveraging the complementary strengths of these models, we aim to achieve highly accurate and reliable predictions for shipping times in supply chain management.

SHAP (SHapley Additive exPlanations)

1.1 SHAP is a powerful interpretability technique in machine learning that provides consistent and locally accurate explanations for model predictions. By assigning each feature an importance value for a particular prediction, SHAP helps to understand the contribution of each feature to the final output. This method is based on cooperative game theory and provides both global and local interpretability. SHAP values are particularly useful for identifying the influence of features in complex models, making them essential for transparent and explainable AI in fields such as logistics, healthcare, and finance [23].

Model Training and Evaluation

To ensure the robustness and reliability of our predictive model, we employed a 5-fold cross-validation approach during the training phase. This method involves partitioning the dataset into five equally sized folds. In each iteration, one fold is used as the validation set while the remaining four folds are combined to form the training set. This process is repeated five times, with each fold serving as the validation set exactly once. The model's performance metrics are then averaged across all five iterations, providing a more comprehensive evaluation of its generalizability and stability. The metrics used include Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Percentage Error (MAPE), and R-squared (R^2).

Results

Model Performance

The performance metrics for the seven ensemble tree models in Table 2 indicate that CatBoost achieves the highest accuracy in predicting shipping times, with an MAE of 3.86 and an R-squared of 0.7659. Random Forest and LightGBM also perform well, with MAE values of 3.61 and 3.83 and R-squared values of 0.7616 and 0.7573, respectively. Extra Trees shows strong performance with the lowest MAE of 3.42 but slightly lower R-squared of 0.7589. Gradient Boosting, XGBoost, and NGBoost exhibit higher MAE and lower R-squared values compared to the top performers, indicating moderate prediction accuracy. Overall, CatBoost stands out as the most effective model for this application, closely followed by Random Forest and LightGBM.

Model	MAE	MSE	RMSE	MAPE	R-squared
CatBoost	3.860030	35.166733	5.923949	25.570718	0.765891
Random Forest	3.613944	35.767870	5.975536	21.440336	0.761555

LightGBM	3.836864	36.428714	6.030282	24.273327	0.757307
Extra Trees	3.417776	36.177137	6.008218	20.757644	0.758860
Gradient Boosting	4.093316	38.590532	6.207841	24.930634	0.742974
XGBoost	4.015028	39.003233	6.239473	27.141350	0.740433
NGBoost	4.115320	39.136199	6.252095	24.784378	0.739384

Table 2: Model Performance

Interpretation of Results

The analysis utilizes SHAP (SHapley Additive exPlanations) to interpret and visualize the impact of features on the predictions made by a CatBoost model. The SHAP TreeExplainer is employed with the trained model to compute SHAP values for the training dataset. Two types of SHAP summary plots are generated: a bar plot (shown in Figure 1) that highlights the overall importance of each feature, and a detailed feature importance plot that illustrates the distribution of SHAP values for each feature across all samples. These plots help in understanding which features have the most significant impact on the model's predictions.

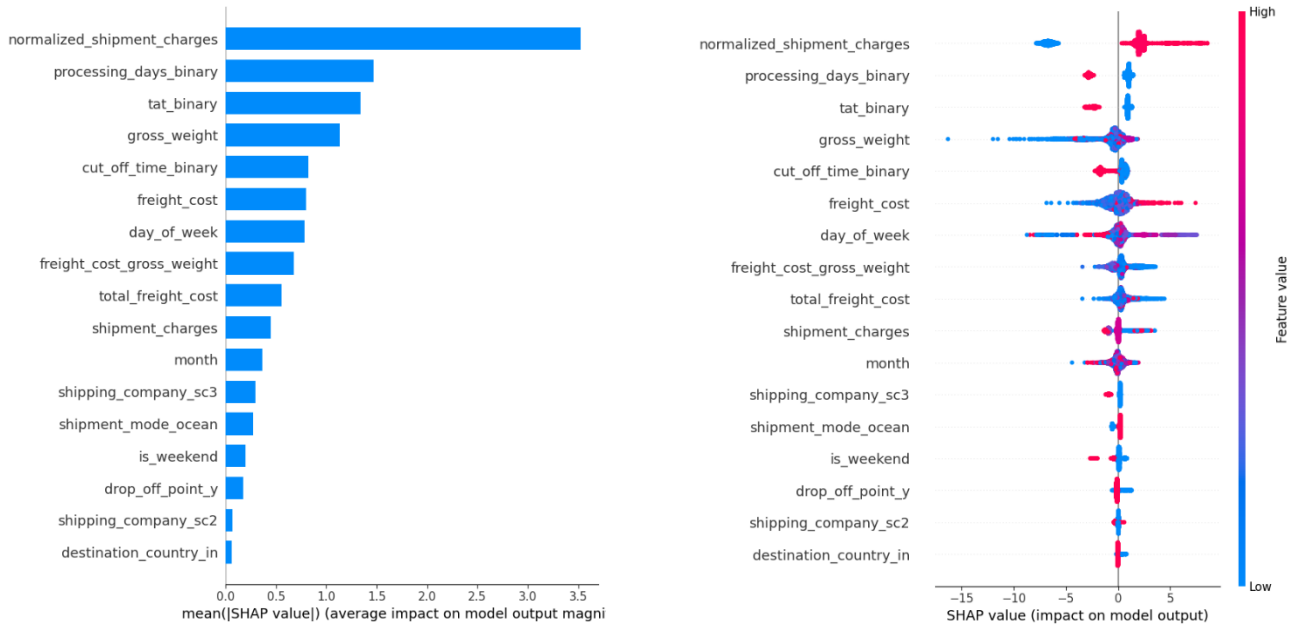
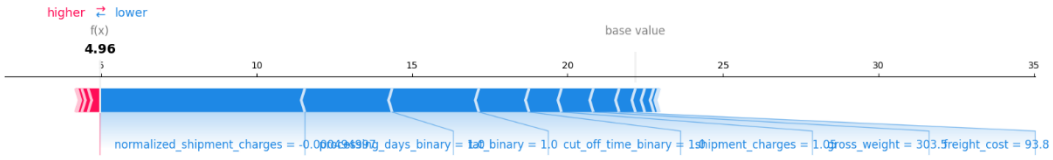


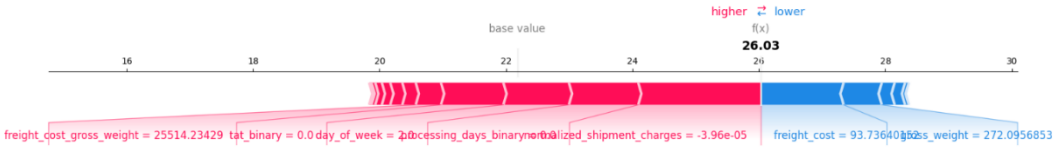
Figure 1: SHAP summary plots

The SHAP summary plot shows the impact of various features on the model's output for shipping time predictions. The most influential feature is 'normalized_shipment_charges' (Normalized shipment charges), indicating a significant effect on shipping times. 'processing_days_binary' (Binary indicator of whether the shipment was processed on a working day) and 'tat_binary' (Binary indicator if the shipment turnaround time is within a certain threshold) are also crucial, highlighting the importance of operational timing in meeting shipping deadlines. 'gross_weight' (Gross weight in kilograms of the shipment) and 'freight_cost' (Cost of transportation per kilogram) further emphasize the role of shipment weight and transportation cost in predicting shipping durations. Other important features include 'cut_off_time_binary' (Binary indicator of whether the shipment was sent within the cut-off time), 'day_of_week' (The day the shipment was sent), and 'total_freight_cost' (Total cost of freight). Less impactful features, such as specific shipping companies ('shipping_company_sc3', 'shipping_company_sc2'), shipment mode ('shipment_mode_ocean'), and destination country ('destination_country_in'), still contribute to the model but to a lesser extent. This analysis underscores the significance of cost-related and operational timing factors in determining shipping times.

The SHAP force plot in Figure 2 (a) details how each feature influences a specific shipping time prediction of 4.96 days, with the base value representing the average model prediction. Key operational efficiency factors—such as normalized shipment charges, processing on working days, meeting TAT thresholds, and sending shipments within cut-off times—significantly reduce shipping times. Conversely, the gross weight of the shipment increases the predicted time. These insights can help optimize logistics operations for more accurate and efficient shipping time predictions.



(a) plot for an instance value less than the base value

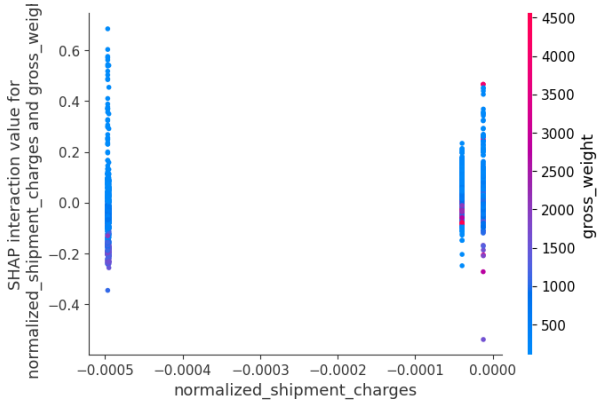


(b) plot for an instance value greater than the base value.

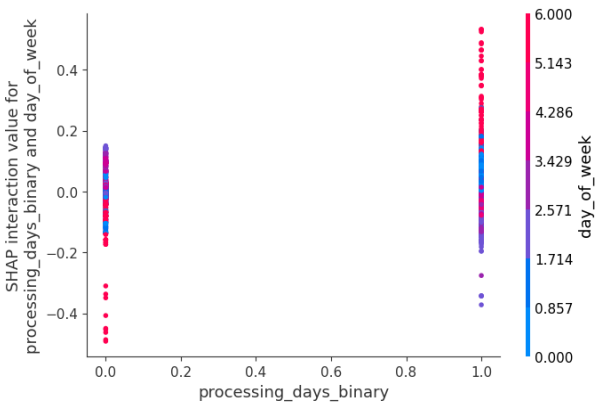
Figure 2: SHAP explanatory force plots

The SHAP force plot in Figure 2 (a) shows the contribution of each feature to a specific shipping time prediction of 4.96 days, with the base value representing the average model prediction. Key factors like normalized shipment charges, processing on working days, meeting TAT thresholds, and sending shipments within cut-off times significantly reduce shipping times, while the gross weight of the shipment increases it. These insights can help optimize logistics operations for more accurate and efficient shipping time predictions.

The SHAP interaction plot provides a detailed analysis of how pairs of features jointly influence the predictions made by the CatBoost model. The SHAP TreeExplainer computes SHAP interaction values for the training dataset, visualizing the combined effects of two features on the model's output. The interaction plot (shown in Figure 3) highlights how the interplay between specific features.



(a)



(b)

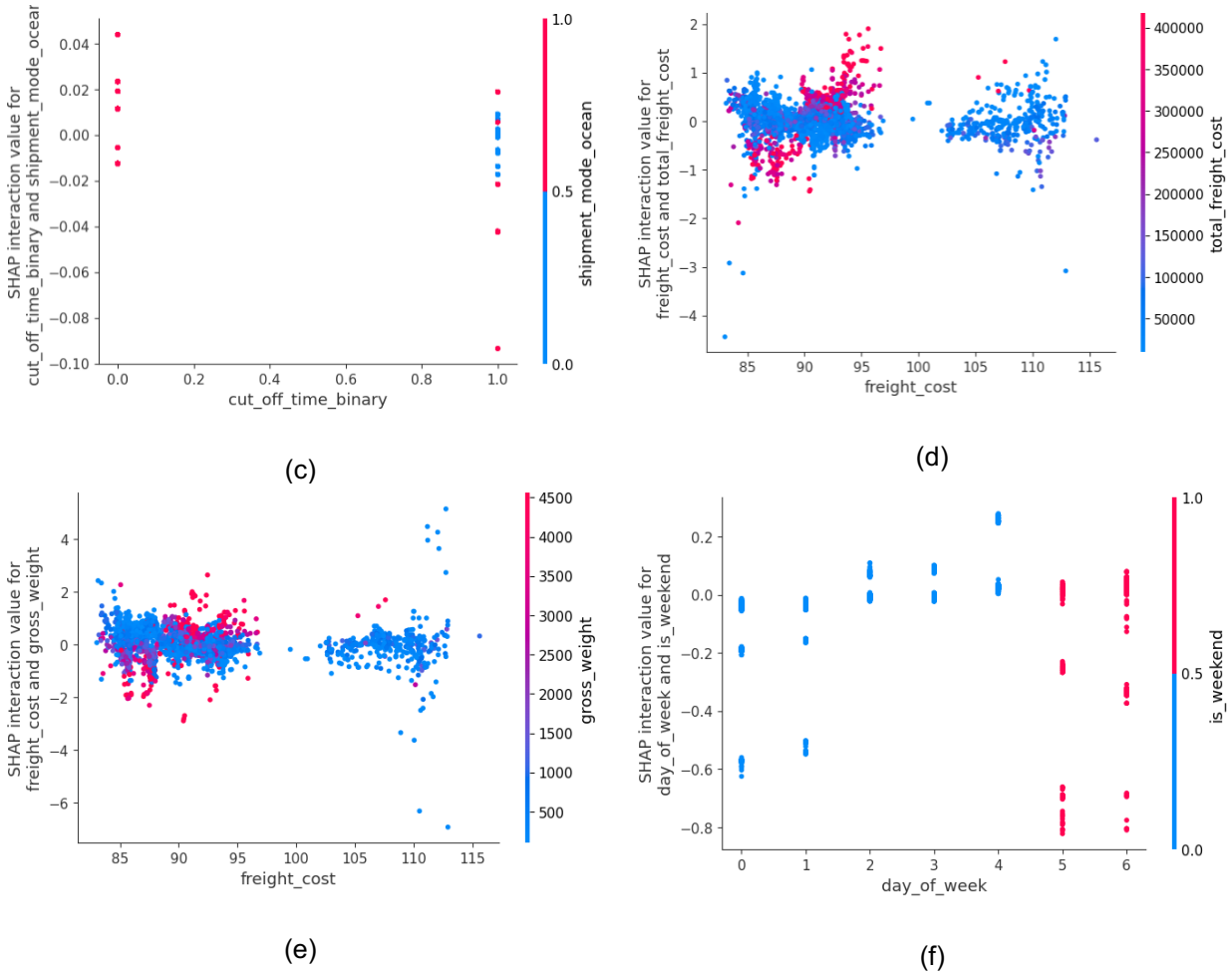


Figure 3: The SHAP interaction plots

The SHAP interaction plots reveal critical insights into how various factors jointly influence shipping time predictions. Higher normalized shipment charges, particularly for heavier shipments, lead to more consistent SHAP interaction values, highlighting the importance of cost efficiency and weight (Figure 3 (a)). The interaction between processing days and day of the week (Figure 3 (b)) shows that non-working days, especially near weekends, cause greater variability and longer shipping times, emphasizing the need to optimize non-working day processes. Cut-off times are crucial for consistent shipping times, with ocean shipments inherently slower, stressing the importance of careful planning (Figure 3 (c)). The relationship between freight cost and total freight cost (Figure 3 (d)) indicates that lower per kilogram costs can lead to higher total costs and varied shipping times, while higher per kilogram costs result in more consistent shipping times. Similarly, the interplay between freight cost and gross weight (Figure 3 (e)) shows that lower freight costs increase variability, especially for heavier shipments, whereas higher costs lead to more predictable times. Finally, the difference between weekday and weekend operations (Figure 3 (f)) underscores the need for efficient weekend processes to reduce delays and improve performance.

Discussion

Implications of Findings

The findings of this study have significant implications for improving logistics operations. By leveraging ensemble tree models combined with SHAP (SHapley Additive exPlanations), logistics companies can achieve more accurate and interpretable shipping time predictions. The ability to predict shipping times with high precision allows businesses to optimize their inventory management, reducing costs associated with overstocking or stockouts. Furthermore, reliable delivery estimates enhance customer satisfaction and trust, which are critical in sectors such as retail, manufacturing, and healthcare.

The interpretability provided by SHAP helps logistics managers understand the impact of various features on shipping times, enabling targeted interventions to address bottlenecks and inefficiencies.

For instance, insights into the effects of normalized shipment charges, processing days, and turnaround time thresholds can inform decisions about resource allocation, scheduling, and pricing strategies, ultimately leading to more resilient and efficient supply chains.

Limitations

While the study demonstrates the effectiveness of ensemble tree models and SHAP in predicting and analyzing shipping times, there are several limitations to consider. First, the quality and completeness of the dataset can significantly influence model performance. The dataset used in this study, although comprehensive, may still contain inaccuracies or missing values that could affect the results. Additionally, the models were trained on historical shipment data, and their predictive power may diminish when applied to significantly different future conditions or new shipping routes not represented in the training data. Another limitation is the computational complexity of ensemble models, which can be resource-intensive to train and deploy. This might limit their practical application in scenarios where computational resources are constrained. Furthermore, while SHAP provides valuable interpretability, it does not account for potential interactions between unobserved variables, which could lead to oversights in understanding the full context of shipping time predictions.

Future Work:

Future research should focus on addressing the limitations identified in this study to further enhance the model and its applications. One area for further investigation is the incorporation of additional data sources, such as real-time traffic information, weather conditions, and port congestion data, to improve the accuracy and robustness of shipping time predictions. Integrating these dynamic factors can help create a more comprehensive model that better reflects the complexities of real-world logistics operations. Additionally, exploring the application of deep learning techniques, such as recurrent neural networks (RNNs) or transformers, could potentially enhance the predictive performance, especially in capturing temporal dependencies in shipment data. Another promising direction is the development of hybrid models that combine the strengths of ensemble tree models and other machine learning approaches to achieve better predictive accuracy and interpretability. Finally, conducting case studies or pilot implementations with industry partners could provide valuable insights into the practical challenges and benefits of deploying these predictive models in real-world logistics environments, facilitating further refinement and adoption of the technology.

Conclusion

This study aimed to develop and interpret predictive models for shipping times using ensemble tree methods enhanced with SHAP (SHapley Additive exPlanations). The analysis demonstrated that ensemble tree models, particularly CatBoost, effectively predict shipping times with high accuracy. The models' interpretability, provided by SHAP, revealed critical insights into the impact of various features on shipping durations. Key determinants such as normalized shipment charges, processing days, and turnaround time thresholds were identified as significant influencers of shipping times. These findings underscore the robustness and practicality of using advanced machine learning techniques in logistics.

The predictive models developed in this study have substantial practical applications in the field of logistics. By implementing these models, logistics companies can enhance their shipping time estimates, leading to improved inventory management, cost reductions, and heightened customer satisfaction through reliable delivery promises. The interpretability provided by SHAP allows managers to pinpoint specific areas for operational improvements, such as optimizing processing schedules and adjusting pricing strategies based on shipment weights and costs. Furthermore, the models can be integrated into existing logistics management systems to provide real-time predictions and insights, enabling proactive decision-making and enhanced overall supply chain resilience.

The broader implications of this research highlight the transformative potential of integrating advanced machine learning models with interpretability techniques in logistics. As global supply chains become increasingly complex, the ability to predict and analyze shipping times accurately is more critical than ever. This study not only demonstrates the efficacy of ensemble learning models but also emphasizes the importance of understanding the underlying factors influencing predictions. Future research and practical implementations should continue to build on these findings, exploring new data sources and hybrid models to further enhance prediction accuracy and operational efficiency. Ultimately, the adoption of these advanced predictive tools can lead to more resilient, efficient, and customer-centric logistics operations, driving competitive advantage in the industry.

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PREDICTING LATE DELIVERIES IN HUMANITARIAN SUPPLY CHAINS USING AN ENSEMBLE MACHINE LEARNING APPROACH

Fahd Alfarsi and Mohammad Alshehri
University of Jedda, Saudi Arabia

Abstract

Purpose: This study focuses on predicting late deliveries within humanitarian supply chains using a case study dataset to address this critical issue.

Design/ methodology/ approach: This paper proposes several ensemble machine learning methodologies aimed at mitigating shipment risks by predicting the likelihood of late deliveries based on a detailed understanding of the procurement process.

Findings: Our findings demonstrate that an ensemble algorithm-based prediction model can effectively forecast the severity of late deliveries by suppliers in a representative case study of humanitarian supply chains.

Originality/ value: By providing a better understanding of shipment risks, this study aims to reduce uncertainty and improve the efficiency of humanitarian supply chain operations. This research contributes to the existing literature by showcasing the applicability of advanced machine learning techniques in enhancing the resilience and effectiveness of humanitarian supply chains.

Keywords: Humanitarian Supply Chains, Late Delivery Prediction, Supply Chain Resilience, Machine Learning, Delivery Forecasting

Introduction

The complexity of humanitarian supply chains presents unique challenges that differentiate them from commercial supply chains. Humanitarian logistics often operate in environments where timeliness is critical, as delays can have significant and sometimes life-threatening consequences. Whether responding to natural disasters, conflict zones, or public health crises, humanitarian organizations must navigate uncertain and dynamic environments with limited resources, fragile infrastructure, and unpredictable demand patterns. In this context, the ability to accurately predict late deliveries is crucial to improving the efficiency and effectiveness of humanitarian relief efforts.

Humanitarian supply chains differ significantly from their commercial counterparts in several ways. First, they are often designed to operate under extreme uncertainty, where demand can surge unexpectedly, as seen in disaster relief or during pandemics. Second, the geographical and logistical challenges—such as damaged infrastructure, political instability, or natural barriers—compound the difficulty of ensuring timely deliveries. Finally, humanitarian operations are mission-driven, prioritizing the well-being and survival of affected populations rather than financial profit, which often leads to challenges in resource allocation, coordination, and decision-making. Late deliveries in such contexts can lead to severe consequences, ranging from the failure to provide critical medical supplies, food, and shelter to displaced populations, to the exacerbation of crises due to delays in essential services. Therefore, mitigating delays in humanitarian supply chains is not merely a matter of operational efficiency but also one of ethical responsibility and social impact. In recent years, advances in machine learning have opened up new opportunities to enhance the predictability of supply chain outcomes. Traditional methods, such as statistical analysis and deterministic models, have struggled to account for the variability and complexity inherent in humanitarian logistics. Machine learning, particularly ensemble methods, offers a promising alternative by leveraging data-driven insights to make more accurate predictions about delivery times. Ensemble machine learning models, which combine the strengths of multiple algorithms, have shown significant improvements in prediction accuracy across various domains.

The present paper aims to apply various EML approaches to predict late deliveries in humanitarian supply chains, thereby improving the timeliness and reliability of relief efforts. The study leverages various machine learning techniques, namely Extremely Randomised Trees (ET), Gradient Boosting Machines (GBM), Adaptive Boosting (AdaBoost), and Stochastic Gradient Boosting (XGBoost), to

build a predictive model that can identify potential delays before they occur. By utilizing historical data from humanitarian logistics operations, the model is trained to recognize patterns that are indicative of late deliveries, such as geographical challenges, transportation bottlenecks, and supply chain disruptions. The key contributions of this research are threefold. First, it develops a novel ensemble-based predictive model specifically tailored for humanitarian logistics, addressing the unique challenges posed by these supply chains. Second, it offers insights into the most influential factors contributing to late deliveries, providing valuable information for supply chain managers and policymakers. Third, the study demonstrates the practical applicability of EML models in improving the resilience and responsiveness of humanitarian operations.

Literature Review

A few studies adopted ML for managing SC disruptions, e.g., predicting late delivery. Thomas and Panicker (2022) used eight features, namely unit weight and quantity, plant code, customer ID, Carrier ID, export and destination ports and product ID, to develop their ML-based framework for predicting order delivery delay. Since the data was significantly imbalanced, with a ratio of 97:30 for on-time and delayed cases, respectively, a common technique, SMOTE, was used to oversample the minor class, which handles imbalanced datasets by generating synthetic samples for the minority class, has been employed. Using various conventional ML algorithms, Random Forest (RF), k Nearest Neighbors (k-NN), and Support Vector Classifier (SVC), the delayed delivery predictive model was built on only data captured from one day, which may arguably introduce a potential algorithmic bias.

Baryannis, Dani and Antoniou (2019) developed a delayed delivery risk prediction model, considering the trade-off between model interpretability for non-AI experts and the model's performance. The data was obtained from an aerospace manufacturing supplier (AMS) to partners in Europe and Asia and contains the historical deliveries of 450 suppliers. The features utilised for building the predictive model were 15 features, including details about the quantities prices of the purchased items, the detailed dates of the purchase orders, the due dates, the original request as well as delivery dates. Various performance metrics were adopted to examine the performance of the proposed model, including Recall, Precision, Matthews Correlation Coefficient, F1 and Accuracy.

Brintrup *et al.* (2020) used historical data from an Original Equipment Manufacturer (OEM), precisely a complex engineering assets company, to predict first-tier SC disruptions. The experiment involved three defined phases: (1) identifying potential representative variables that can be valuable in predicting disruptions, (2) developing performance metrics to assess the model performance successfully, and (3) experimentally analyse the performance of various predictors (algorithms), and finetuning their parameter. The study indicates that including further pre-processed variables with the dataset helped the model outperform other experiments with a promising accuracy of 80% on average.

Unlike the above studies, which built disruption prediction models, Kosasih and Brintrup (2022) examined the visibility of supply chains from a link prediction perspective and detected potential links unidentified to the buyer using Graph-based model. The study applied Unified Gradient to enhance the explainability of the proposed model by identifying key input features that impact GNN's decision-making process. Additionally, the benefits and limitations of GNN for link prediction were analysed. The dataset utilized in this research consists of real automotive data, including 8,663 firms and 68,812 procurement relationships from international companies.

Concerns Regarding the Present Studies

The above studies have novelly contributed to the area of applying ML for SC disruption detection and timely prediction. However, a few methodological concerns emerged based on in-depth reading of the surveyed works. One concern is the inappropriate selection of the metrics utilised to assess the model performance. While the metrics that are commonly used with imbalanced datasets have already been identified and used, including AUC and the three computed versions of F, reporting the Rec. at the level of class was surprisingly missing from all the surveyed works. This would provide insight into how the model successfully detected each class (delayed or not delayed) independently, which is a critical indicator when the dataset is imbalanced.

Discussing the reported metrics has consequently highlighted the misselection of the validation architecture (VA) in two of the surveyed studies, specifically Thomas and Panicker (2022) and Baryannis, Dani and Antoniou (2019). Adopting SMOTE, conducted by these two works, to handle

imbalanced datasets via oversampling minor classes with synthetic instances has been commonly known as a critical methodological step. However, using cross validation (CV) as a VA would potentially allow the model to train and test on the same data (original and synthetic). Therefore, the train-and-test splitting strategy is the proper VA for oversampled datasets.

One concern is the misrepresentation of some of the datasets used for building the disruption predictive models. While this limitation is typically out of the authors' control, it is important to note that the proposed models may be either ungeneralisable or biased. This concern is highlighted in Thomas and Panicker (2022), where the data used was captured from the supplies of one calendar day only (May 26th, 2013). Since building actionable and valid predictors requires various time points over the supply chain history, which is expected to inform various potential disruption events, Thomas and Panicker (2022) model may typically not be suitable to implement in the real-life world.

Preliminary filtration is a crucial step in data preprocessing, as it helps remove noisy and unrepresentative data, such as system logs and missing values. However, a significant limitation observed in some of the reviewed studies is the excessive filtration applied during experiments, which can reduce the generalizability of the results and limit the sample to a small subset of supply chains. One instance is Brintrup *et al.* (2020), who removed the Product Description in the first run of feature selection without weighing its potential correlation to the model binary outputs. While texts are relatively more challenging to preprocess than numerical data and occasionally require complex architectures, such as the state-of-the-art Natural Languages Processing (NLP) models, they may contain rich assets that would significantly help improve the disruption predive models.

Proper model output setting, explicitly defining the target variable, is a crucial step of data preprocessing; nevertheless, this was not done appropriately in some of the surveyed studies. For example, Baryannis, Dani and Antoniou (2019) selected the delivery status (early: when it is 8 or more working days ahead of schedule, on time: when it is between 7 working days earlier than the schedule and 3 working days behind the schedule, late: if it is 4 or more working days behind the schedule) as their predictive model output. Next, and for simplification as claimed, both early and on time were merged as on-time delivery. Early delivery may impose some challenges based on the nature of the procured items, and, therefore, it may not necessarily be considered an advantage. This includes (1) the increased holding cost, (2) inventory disruption, e.g., excess inventory leading to tying up capital and warehouse space, (3) insufficient space resulting in stockouts and production delays and (4) potential for overproduction.

Another methodological concern observed is the adoption of incorrect feature selection methods. Deciding on the correct feature selection mainly relies on the type of data in the dataset itself. More specifically, the input and output variables' data type (numerical or categorical) must be considered before choosing which feature selection approach can be adopted. We noticed that some studies, such as Baryannis, Dani and Antoniou (2019), randomly adopted one or more feature selection approaches regardless of the type of input and output features analysed. This would result in selecting fewer representative features and, hence, lower performance for the predictive model.

Methodology

Data Collection and Preprocessing

The dataset used in the present research was obtained from the U.S. Agency for International Development (USAID). The dataset includes comprehensive data about all health commodity orders (dated between 31/01/2016 and 05/03/2024). The dataset contains 105 features including:

- General information (e.g., Order Number, Country Destination, Type of Order, Method of Fulfilment, Mode of Transportation, Category of Item Tracer and Product, Product ID, Name of Product, Unit of Measure, Ordered Quantity, Shipped Quantity)
- Financial information (e.g., Funding Health Programme, Funding Source, Fiscal Year, Illustrative Price)
- Delivery Information (e.g., Estimated Lead Time in Days, Vendor Incoterm, Destination Incoterm, On Time Delivery, delay in Days, Delivery Progress).
- Dates (e.g., Decided Delivery Date, Revised Agreed Delivery Date, Order Entry Date, Requested Delivery Date, Estimated Delivery Date, Actual Delivery Date).
- Times in days for (Order Cycle Time, shipment Approval by USAID).

Ensemble Models
These types of models use several algorithms in the perdition processes. It aggregates the outcomes from different classifiers to produce a majority vote output. While each individual algorithm learns differently and its performance is application- and data-dependent, ensemble models address this by delivering a generalizable result, as they rely on multiple "voters" (algorithms). This approach also helps build a reliable model that reduces variance and mitigates the risk of overfitting (Asharf et al., 2020).

Ensemble model can be implemented through bagging or boosting. The former trains n base learners utilising the technique of random samples with replacement, allowing for parallel processing. In contrast, boosting works sequentially, with each model focusing on the misclassifications of the previous one (Teja, 2019). In bagging, different decision trees (DTs) are trained on various samples of the training data, and the final prediction is an average of all the trees' outputs. A prime example of this technique is Extremely Randomized Trees (ET). In boosting, ensemble members are added sequentially to correct the errors of previous models, adjusting the input data to emphasize the misclassified instances. The final output is a weighted average of the predictions (Brownlee, 2021). Boosting models contain adaptive boosting (AdaBoost), gradient boosting machines (GBMs), and stochastic gradient boosting.

Extremely Randomised Trees (ET)
This method shares a similar structure with Random Forest (RF), as both select a random set of features for node splitting. However, ET differs in two key areas: sampling and node splitting. This method samples from the whole dataset when constructing a tree, whereas RF uses bootstrapped samples (input subsampling with replacement). This reduces bias in ET by ensuring more diverse data subsets. Additionally, ET randomizes node splitting, reducing the influence of specific input variables and lowering variance. This enhanced structure has demonstrated improved performance on benchmark datasets compared to RF (Geurts, Ernst and Wehenkel, 2006).

Adaptive Boosting (AdaBoost)
AdaBoost is an early boosting-based ensemble algorithm developed to address challenges related to some specific games. The algorithm preforms a combination of weaker learners to build a robust model (Freund and Schapire, 1997). As its name suggests, adaptation occurs through the errors of previous trials, assigning less weight to misclassified instances and focusing on those in subsequent models. This adaptiveness helps correct earlier misclassifications (Schapire, 2013).

Gradient Boosting Machines (GBM)
Unlike AdaBoost, which focuses on penalizing misclassifications, GBM minimizes a loss function (such as log loss for classification or mean absolute error for regression) to improve prediction accuracy. It continuously reduces the loss using gradient descent until the model reaches an optimal point (Friedman, 2001).

Stochastic Gradient Boosting (XGBoost)
XGBoost is an optimised version of GBM with enhanced efficiency, flexibility, scalability and better performance in tasks that handles sparse data. As a more regularized and extended version of GBM, XGBoost improves generalization and overall model performance (Chen and Guestrin, 2016).

Evaluation Metrics
Several performance metrics were utilised to assess the models developed in this study. These include standard metrics such as Rec and Prec, which can be derived from the confusion matrix. Recall measures a model's ability to predict positive instances, while precision calculates the ratio of predicted positives that are indeed true positives. The formulas for these metrics are: *Rec = True Positives (TP) / (True Positives (TP)+False Negatives (FN))* and *Precision = True Positives (TP) / (True Positives (TP) + False Positives (FP)).*

Since these metrics evaluate class-level performance, additional metrics such as *F1* score and Weighted Recall (*WRec*) were adopted to assess the model's performance more comprehensively. The *F1* score balances precision and recall, while WRec computes each class's recall being weighted by the proportion of instances in that class relative to the entire dataset. This ensures that the performance on larger classes has more influence on the overall recall score, preventing smaller classes from disproportionately affecting the result.

Results and Discussion

Table 1 presents the performance of the four ensemble ML algorithms adopted for the present study for predicting late deliveries within a humanitarian supply chain. Each classifier's performance is evaluated using several key metrics: Precision (*Prec.*), Recall (*Rec.*), F1-Score (*F1*), and Weighted Recall (*WRec*). These metrics are calculated for both class 0 (on-time delivery) and class 1 (late delivery), offering valuable insights into how well each model performs in different delivery scenarios.

Classifier	**Class**	***Prec.***	***Rec.***	***F1***	***WRec***
ET	0	0.97	0.98	0.97	0.96
	1	0.91	0.89	0.90	
AdaBoost	0	0.97	0.97	0.97	0.96
	1	0.91	0.89	0.90	
GBM	0	0.97	0.98	0.97	0.95
	1	0.91	0.88	0.89	
XGBoost	0	0.97	0.95	0.96	0.94
	1	0.85	0.89	0.87	

Table 1: Late delivery prediction results distributed by classifier,
class 0 = on-time delivery, class 1 = late delivery.

Extra Trees (ET) demonstrates high effectiveness in predicting on-time deliveries, with an impressive Prec. of 0.97 and a Rec. of 0.98, hence F1 = 0.97. This indicates a reliable ability to classify on-time deliveries accurately. For late deliveries, ET shows a slight decline in performance, with Prec. and Rec. of 0.91 and 0.89, respectively, and an F1-score of 0.90. Nevertheless, the model remains robust in predicting late deliveries, as indicated by the weighted recall of 0.96, suggesting a well-balanced approach to both classes.

AdaBoost performs similarly to ET, with equally strong results for on-time delivery predictions. Both Prec. and Rec. for class 0 are 0.97, resulting in an F1-score of 0.97. For late deliveries, AdaBoost's performance closely mirrors that of ET, with a Prec. of 0.91, Rec. of 0.89, and an F1-score of 0.90. This consistency across classes suggests that AdaBoost is a reliable classifier for predicting both on-time and late deliveries, evidenced by its weighted recall of 0.96, which aligns with ET's performance.

Gradient Boosting Machine (GBM) also achieves comparable results, with class 0 Prec. of 0.97 and Rec. of 0.98, resulting in an F1-score of 0.97. However, its performance for class 1 (late deliveries) is slightly lower than ET and AdaBoost, with a precision of 0.91, recall of 0.88, and an F1-score of 0.89. Despite this small reduction, GBM still performs well overall, as reflected by its weighted recall of 0.95, demonstrating that it is a reliable model, though slightly less balanced than ET and AdaBoost. In contrast, XGBoost performs slightly less effectively than the others for predicting on-time deliveries, with a Prec. of 0.97, Rec. of 0.95, and an F1-score of 0.96. More notably, XGBoost shows a more significant drop in performance for class 1 predictions, where its precision is 0.85, recall is 0.89, and the F1-score is 0.87. These results suggest that XGBoost is less effective at predicting late deliveries compared to the other models. The weighted recall of 0.94 further reflects this decline, indicating that XGBoost is less balanced in handling both classes, particularly when predicting late deliveries.

Across all classifiers, the performance for predicting on-time deliveries (class 0) remains consistently high, with precision, recall, and F1-scores generally above 0.95. This consistency indicates that all models are highly effective at correctly identifying on-time deliveries. However, when it comes to predicting late deliveries (class 1), all classifiers show slightly lower performance, with XGBoost displaying the most significant drop. Both ET and AdaBoost strike the best balance between class 0 and class 1, while GBM follows closely behind, and XGBoost lags in late delivery prediction accuracy.
In a practical sense, the prediction of late deliveries is particularly crucial for humanitarian supply chains, where timely deliveries can significantly impact relief efforts. The results suggest that Extra Trees and AdaBoost are the most reliable classifiers for this task. Gradient Boosting (GBM) also performs well but is slightly less consistent, particularly in predicting late deliveries. XGBoost, though powerful in many machine learning contexts, appears to underperform in this specific scenario, especially in predicting late deliveries.

Conclusion

The study successfully demonstrates the potential of ensemble machine learning techniques to predict late deliveries in humanitarian supply chains. Through a representative case study, we show that models such as Extra Trees and AdaBoost outperform other approaches, providing a well-balanced capability to predict both timely and late deliveries. While Gradient Boosting Machine yields acceptable results, its slightly lower performance in predicting late deliveries suggests it may not be ideal in critical contexts where late deliveries are of paramount concern. XGBoost, despite its widespread use in various domains, proves less effective in this particular scenario, highlighting the need for more tailored approaches in the humanitarian supply chain domain. This research adds several contributions to the existing body of knowledge by offering valuable understandings into the integration of advanced machine learning techniques, improving both the resilience and operational efficiency of humanitarian supply chains.

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SUSTAINABILITY ACTIVITIES AFFECTING COMPETITIVE ADVANTAGE OF CONTAINER PORTS

Sehwa Lim, Stephen Pettit, Wessam Abouarghoub, Anthony Beresford
Logistics and Operations Management, Cardiff Business School, Cardiff University, UK

Abstract

Purpose: This study aims to strategically analyse the sustainability activities that drive competitive advantage in container ports. It focuses on addressing the strategic management of sustainability in the port sector by identifying and prioritising sustainability activities that influence the competitive advantage of container ports.
Design/methodology/approach: Adopting a strategy-as-practice view, the study employs the Relative Importance Index methodology to assess and rank the perceived significance of sustainability activities in achieving competitive advantage. Data were collected from port managers across 35 countries, and the analysis considered differences in regional contexts, port sizes, and managerial perspectives to provide a nuanced understanding of sustainability priorities for strategic decision-making.
Findings: The study found that social sustainability practices are the most critical for enhancing container ports' competitive advantage, making a shift from the traditional focus on economic factors. The findings suggest potential opportunities for strategic collaboration, particularly between Asian and European ports. Additionally, the significant role of port managers at different levels is emphasised in decision-making processes for effective sustainability strategies and superior competitive performance.
Originality/value: This study contributes to the theoretical understanding of port sustainability by integrating a strategy-as-practice perspective, which has been underexplored in port studies. Methodologically, it advances the application of the RII in evaluating the strategic importance of sustainability activities in ports. The research also provides practical insights for port managers and policymakers by identifying best practices in sustainability that align with competitive strategies, thus expanding the scope of port studies for strategic sustainability management.
Keywords: Port sustainability, Port competitive advantage, Port competitiveness, Relative Importance Index, Strategy-as-practice

Introduction

Fully embracing sustainability involves a complete shift in how organisations operate, requiring them to rethink their goals and strategic approaches (Thakhathi *et al*., 2019). In this sense, the ability to effectively manage their sustainability performance is of strategic importance in the current competitive environment. Strategic implementation of sustainability management enables organisations to generate additional value for sustained success, while contributing to their better competitive position (Porter, 1985). Therefore, it is important for ports to explore strategic ways to implement port sustainability to ensure that the transformation process is sustainable and beneficial to port performance. Many studies on port sustainability reach a consensus view that sustainability practices have positively contributed to the financial performance of ports through improved eco-efficiency and effectiveness (e.g. Lu and Chiang, 2016; Jiang *et al.,* 2020; Castellano *et al.,* 2020). As environmental and social regulations have influenced the dynamics of the port market, sustainable operations have been recognised as a crucial factor influencing port competitiveness (Yu *et al*., 2023). Although numerous variables and factors of port sustainability have been examined and employed to evaluate the sustainability performance of ports (Lim *et al*., 2019), there is currently a dearth of research clarifying sustainability activities that can impact the competitive advantage of ports. This complexity can make it challenging for port managers to identify key priorities, determine areas for improvement, and acquire the necessary resources and expertise to manage sustainability effectively.

Thus, this study aims to identify sustainability activities that affect port competitiveness to develop strategic port sustainability management that enhances port performance from a competitive point of view. Drawing upon the Strategy-As-Practice (SAP) approach and utilising the Relative Importance Index (RII) to analyse these activities, it explores how port sustainability practices can be conceptualised as strategies for driving the competitive advantage of ports.

Theoretical background

Sustainability presents a considerable challenge to organisations as it poses a threat to their existing systems and competitive positions. However, this situation also offers valuable opportunities to create and implement novel tactics that establish a clear distinction from other ports. These two facets suggest that ports should actively cultivate strategic competencies in sustainability to ultimately attain the desired competitiveness and ensure the long-term thriving of ports through value creation or value capture from port management (Beresford and Pettit, 2019). Port sustainability analysts have stressed the strategic need for sustainability practices to realise sustainable port development (Hossain *et al.*, 2021), affirming that port's strategic actions can determine better sustainability management.

Strategic management has been extensively developed based on Porter's concept of competitive advantage (1985), prompting numerous studies to examine how firms' strategies impact organisational performance. Recent research suggests that differences in performance outcomes can be linked to the implementation of different practices, emphasising the relationship between the actual practice management of an organisation and a set of key activities (Jarzabkowski *et al.*, 2022). This scholarly view has been fuelled by the emergence of the SAP perspective to understand strategic planning and implementation while shedding light on the strategic activities that an organisation should pursue for better competitiveness (Whittington, 1996). The SAP view focuses on how strategies are formed through the actions of organisations and individuals. It sees strategy as an ongoing activity performed by people and the importance of those involved in the practice. Its focus is on the practices that constitute daily activities in organisations that are essential for survival and creating value (Mantere, 2008). Whittington (2006) proposed three key components for strategising: practices, practitioners, and praxis. Jarzabkowski *et al.*, (2016) further argued that the three components should demonstrate strategic outcomes resulting from conducting practice, proposing a strategic practice model. By adopting the model, this study develops a conceptual strategy model in the context of port sustainability operations and management, as illustrated in Figure 1. This study examines the relationship between sustainability practices, activities, and the desired outcomes of sustainability, i.e. competitive advantage.

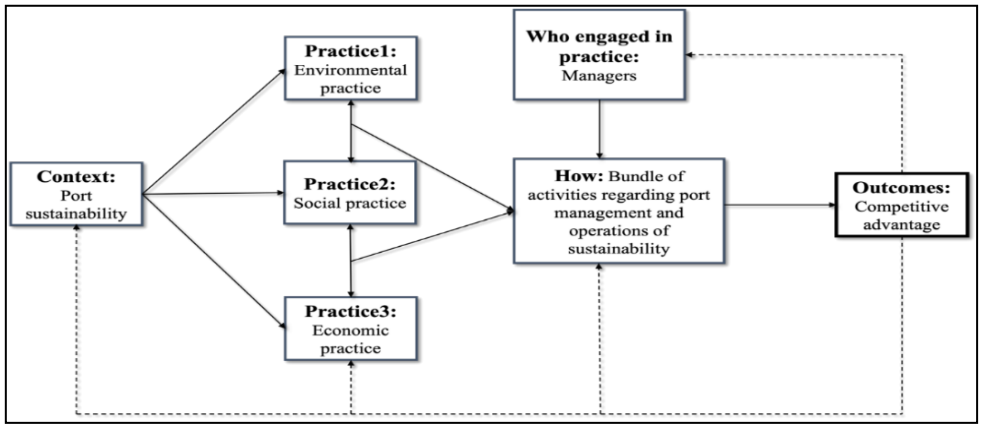

Figure 1: A proposed strategic practice model (Source: Authors)

Methodology

The RII is used to analyse the significance of the factors or attributes in a study. It helps prioritise these elements for quantitative evaluation by assigning rankings to each factor according to their relative importance (El-Sayegh, 2008). By employing the RII method, this study analyses how port practitioners perceive sustainability activities that impact the competitive advantage of ports and prioritise them in terms of their importance to the overall competitive advantage of ports. It also explores how these perceptions vary based on practitioners' backgrounds. The RII value ranges from 0 to 1, with 0 indicating no inclusivity, and a higher RII value representing a stronger impact of sustainability activities on the competitive advantage of ports. For the measurement items, the 30 sustainability indicators identified by Lim *et al.,* (2019) were adopted, and examples of survey questions are as follows: *'Public relations strengthen the competitive advantage of my port/terminal'* and *'Container throughput strengthens the competitive advantage of my port/terminal'*, including a

detailed description and definition of each sustainability activity and competitive advantage in the study. The survey was distributed to port managers at various management levels, from frontline to top-level managers in container ports and terminals worldwide. Data were gathered between March and July for five months in 2020.

Result and Discussion

A total of 217 valid responses were collected from participants across 35 countries and analysed using spreadsheet tools. All the activities from the three aspects of sustainability were assessed and assigned specific priority levels. The prioritisation of sustainability activities was examined based on respondent characteristics such as geographical location, port size, and managerial levels.

Sustainability activities

The overall indices for the three aspects of sustainability were calculated using the average RII values. The average RII values were 0.782, 0.862, and 0.856 for environmental social, and economic sustainability, respectively. This indicates that social sustainability is viewed as the most significant practice for enhancing the competitive advantage of ports, with only a slight difference from economic sustainability. The acknowledgement of social sustainability as a critical component of long-term value differentiation may reflect a shift in the perceptions of the social aspects of port operations, which have been neglected. However, this shift may have been a snapshot of being affected by the COVID-19 pandemic during which the study was conducted. The pandemic experience might lead to a heightened awareness of social resilience and the importance of employee and stakeholder well-being. This finding suggests that port sustainability strategies for a competitive advantage should incorporate socially oriented practices. In a context where social considerations have been a blind spot, ports that proactively develop social strategies can secure a first-mover advantage and be acknowledged for their expertise in social initiatives. According to the RII values for 30 sustainability activities, overall, economic sustainability ranked highest, followed by social and environmental activities (Table 1).

Sustainability aspect	Sustainability activity	RII	Ranking
Social	Health and safety	0.909	1
Economic	Port operational efficiency	0.907	2
Economic	High-quality services	0.905	3
Economic	Port infrastructure construction	0.886	4
Economic	Value-added productivity	0.877	5
Economic	Operating revenue	0.876	6
Economic	Container throughput	0.871	7
Economic	Cost-efficiency	0.871	8
Social	Job training	0.870	9
Social	Public relations	0.867	10
Economic	Reducing operating costs	0.864	11
Social	Social image	0.862	12
Social	Quality of working and living environment	0.862	13
Social	Job creation and security	0.850	14
Social	Social participation	0.850	15
Economic	GDP	0.840	16
Economic	Port development funding	0.824	17
Social	Gender equality	0.822	18
Economic	Benefits from external stakeholders	0.819	19
Environmental	Waste pollution management	0.812	20
Environmental	Green port management	0.811	21
Environmental	Energy and resource usage management	0.803	22
Environmental	Air pollution management	0.789	23
Environmental	Green construction and facilities	0.787	24
Environmental	Soil occupation and pollution management	0.780	25
Environmental	Ecosystem and habitat protection	0.777	26
Environmental	Water pollution management	0.769	27
Environmental	Odour pollution management	0.758	28
Environmental	Noise pollution management	0.733	29
Economic	Foreign direct investment	0.733	30

Table 1: RII values and rankings of all 30 sustainability activities (Source: Authors)

The recognition of “Health and safety” as the most important activity to strengthen the competitive advantage of ports highlights the need for a detailed plan to promote occupational health and safety

management within port areas. The least important was “Establishing open and direct foreign investment”. This finding contrasts with those of previous research, which identified this activity as a key indicator for assessing the economic sustainability of ports (Lim *et al.,* 2019). Consequently, it may not be a suitable measure to evaluate port competitiveness. Additionally, ports appear to prioritise internal factors over external ones for economic sustainability. Traditionally, internal-related activities have been considered crucial for physical port development, but the changing view of their significance might indicate that many ports have reached a mature stage, focusing on leveraging existing resources for competitive advantage.

Ranking by port size

The annual container throughput was used as a criterion for categorising the port size: small (500,000 TEUs or less), medium (between 500,000 and less than 5 million TEUs), and large (more than 5 million TEUs). The majority of the respondents (53%) were involved with medium-sized ports, while 23% were involved with small ports and 21% with large ports. Table 2 provides a summary of the rankings of the three aspects of sustainability activities across different port sizes.

Sustainability		Port size		
		Large	Medium	Small
Environmental	Water pollution management	9	8	7
	Air pollution management	5	4	5
	Energy and resource usage management	1	3	3
	Noise pollution management	10	9	10
	Green port management	2	2	2
	Ecosystem and habitats protection	7	5	8
	Soil occupation and pollution management	8	6	4
	Waste pollution management	3	1	1
	Green construction and facilities	4	7	6
	Odour pollution management	6	10	9
Social	Health and safety	1	1	1
	Job creation and security	5	6	7
	Job training	2	3	4
	Public relations	3	2	3
	Gender equality	8	8	8
	Social image	4	4	5
	Quality of working and living environment	6	5	2
	Social participation	7	7	6
Economic	Foreign direct investment	12	12	12
	Value-added productivity	7	4	4
	Port operational efficiency	1	2	2
	High quality services	2	1	1
	Reducing operating costs	9	8	6
	Benefits from external stakeholders	11	11	9
	Port development funding	10	10	10
	Port infrastructure construction	3	5	3
	Container throughput	4	3	11
	GDP	8	9	8
	Operating revenue	5	6	7
	Cost-efficiency	6	7	5

Table 2: Sustainability activities by port size (Source: Authors)

Large-sized ports prioritise “Energy and resource usage management”, while medium and small ports consider “Waste pollution management” as the most important for competitive advantage. Large ports generally have a higher volume of activities, more complex operations and extensive infrastructure. Efficient management of energy and resources can lead to significant cost savings and is crucial for sustainability and port competitiveness. They are also more likely to face regulatory scrutiny and stakeholder pressure to adopt green practices, making energy management a competitive advantage (Ashrafi *et al.,* 2020). Although the overall rankings were similar, it is worth noting that large ports prioritise “Odour pollution management” higher than medium and small ports. This is likely due to the higher volumes of garbage and ship waste generated during cargo operations and maintenance, leading to increased odour issues.

In terms of social sustainability activities, regardless of port size, “Health and safety” was prioritised, while “Gender equality” was deemed least important. Large ports had the highest average RII value (0.874), indicating a greater recognition of social sustainability activities in enhancing competitiveness.

This is likely because of their larger workforce, broader stakeholder engagement, and greater impact on the surrounding communities. Furthermore, large ports are more likely to be visible and may face greater scrutiny from the government, international organisations, and the public (Ashrafi *et al.,* 2020). As such, focusing on social sustainability can enhance reputation, attract talent, and reduce conflicts with internal and external communities, all of which can contribute to maintaining a competitive edge. Notably, small ports ranked "Quality of working and living environment" as a higher priority than large and medium ports.

In the analysis of economic sustainability activities, large ports prioritised "Port operations efficiency" as the most important, while medium and small ports emphasised "High quality services". All port sizes agreed that "Foreign direct investment" was the least important activity. Furthermore, large ports rank "Value-added productivity" lower compared to medium and small ports. This reflects that larger ports have relatively established facilities and services, thus viewing this activity as less critical. The ranking for "Container throughput" showed differences among port sizes; it was ranked 4th by large ports, 3rd by medium ports, and only 11th by small ports. This discrepancy indicates that smaller ports may face capacity challenges that hinder competitiveness.

Ranking by geographical location

The RII analysis included 35 countries that were grouped into seven regions for comparison by geographical location: Africa (6.5%), Oceania (12.4%), North America (10.5%), South America (9.6%), East and Southeast (ESE) Asia (25%), West and South (WS) Asia (10%), and Europe (26%). Table 3 summarises the rankings of environmental, social, and economic sustainability activities by geographical location, showing these regional differences.

Sustainability		Region						
		Africa	Oceania	North America	South America	ESE Asia	WS Asia	Europe
Environmental	Water pollution management	4	3	7	3	7	9	9
	Air pollution management	3	2	1	8	4	6	3
	Energy and resource usage management	7	5	2	10	5	1	1
	Noise pollution management	10	1	9	9	10	8	10
	Green port management	8	8	3	5	1	2	3
	Ecosystem and habitats protection	6	4	4	1	9	3	8
	Soil occupation and pollution management	5	6	8	2	6	5	7
	Waste pollution management	1	7	5	4	2	4	2
	Green construction and facilities	9	9	6	7	3	7	4
	Odour pollution management	2	10	10	6	8	10	6
Social	Health and safety	1	1	3	1	1	1	1
	Job creation and security	2	7	1	3	7	4	6
	Job training	3	3	5	7	2	5	3
	Public relations	5	2	2	5	6	3	2
	Gender equality	4	8	6	8	8	7	8
	Social image	6	4	7	4	4	2	5
	Quality of working and living environment	7	6	4	2	5	8	4
	Social participation	8	5	8	6	3	6	7
Economic	Foreign direct investment	12	12	12	12	12	12	12
	Value-added productivity	2	7	8	8	4	3	4
	Port operational efficiency	3	2	3	3	1	1	2
	High quality services	6	3	2	2	2	2	1
	Reducing operating costs	9	8	9	5	8	5	5
	Benefits from external stakeholders	10	9	11	9	11	9	11
	Port development funding	11	11	7	11	10	11	9
	Port infrastructure construction	1	4	6	6	3	10	3
	Container throughput	7	1	5	1	5	4	10
	GDP	4	10	10	10	9	6	8
	Operating revenue	5	5	1	4	6	8	7
	Cost-efficiency	8	6	4	7	7	7	6

Table 3: Sustainability activities by geographical location (Source: Authors)

In terms of environmental sustainability, Africa prioritises "Waste pollution management" and "Odour pollution management". By contrast, these activities are considered less important in other regions.

Oceania emphasises “Noise pollution management”, reflecting the increasing concerns related to noise from seagoing vessels that affected local residents (Miller, 2019). ESE Asia and Europe showed a similar trend, prioritising “Green construction and facilities” more than other regions.
Regarding social sustainability, the “Health and safety” activity ranked as the top priority for port competitiveness in all regions except North America, where it placed third. This finding reinforces previous studies highlighting the importance of occupational health and operational safety in managing operating costs and mitigating risks to humans in ports (Antão *et al.*, 2016). Conversely, “Job creation and security” received higher priority in North America, Africa, and South America, but were ranked lower in Europe, Oceania, and ESE Asia. This suggests a potential correlation between financial capacity and employment stability in port competitiveness, as ports in the latter regions tend to have greater financial soundness due to higher container throughput. Interestingly, Africa places significant importance on “Gender quality” compared to other regions, reflecting the efforts of African ports to promote social justice and community value, particularly in the context of national laws addressing poverty and inequality (Molelu and Enserink, 2018).

When it comes to economic sustainability, it appears that “Foreign direct investment” has a limited impact across various regions. A similar trend was observed in ESE Asia, WS Asia, and Europe, where the busiest container ports face common economic sustainability concerns. Overall, different regions exhibit varying perceptions of the economic activities that strengthen the competitive advantage of ports. This implies the need to develop distinct strategies for sustainable economic growth tailored to individual ports. Collectively, similarities are noted between the Asian (particularly East and Southeast) and European ports. Considering that leading container ports are primarily in Asia and Europe, both regions share common sustainability challenges and responsibilities, suggesting potential mutual benefits of communication and benchmarking between Asian and European ports for strategic sustainability development.

Ranking by management level
In this study, respondents were classified into three management levels: top managers (14.2%), middle managers (59%), and frontline managers (26.8%). The rankings of sustainability activities by different levels of management are outlined in Table 4.

Sustainability		Management level		
		Top	Middle	Frontline
Environmental	Water pollution management	4	8	7
	Air pollution management	5	5	3
	Energy and resource usage management	3	3	2
	Noise pollution management	9	10	10
	Green port management	1	1	4
	Ecosystem and habitats protection	7	7	8
	Soil occupation and pollution management	6	6	9
	Waste pollution management	2	2	1
	Green construction and facilities	8	4	5
	Odour pollution management	10	9	6
Social	Health and safety	1	1	1
	Job creation and security	7	7	3
	Job training	4	2	4
	Public relations	2	3	6
	Gender equality	8	8	7
	Social image	3	4	5
	Quality of working and living environment	5	6	2
	Social participation	6	5	8
Economic	Foreign direct investment	12	12	12
	Value-added productivity	3	4	7
	Port operational efficiency	2	1	1
	High quality services	1	2	2
	Reducing operating costs	6	6	9
	Benefits from external stakeholders	9	11	11
	Port development funding	10	10	10
	Port infrastructure construction	4	3	4
	Container throughput	5	8	5
	GDP	11	9	8
	Operating revenue	8	7	3
	Cost-efficiency	7	5	6

Table 4: Sustainability activities by management level (Source: Authors)

Frontline managers view “Green port management” as less important, contrasting with top and middle managers, who rank it as a top priority. This difference implies that management authority influences the perceptions of environmental activities. Top and middle managers, with greater evaluative and diagnostic responsibilities, focus on monitoring sustainability plans and guiding processes, leading them to recognise the significance of green port management for their ports’ competitiveness (Egels-Zandén and Rosén, 2015). According to the average RII of social sustainability, all levels of management agree that “Health and safety” held the most importance, recognising its foundational role in both operational success and social sustainability. Frontline managers gave more importance to internal human resource management as “Quality of working and living environment” and “Job creation and security” place higher rankings. On the other hand, top and middle managers placed greater emphasis on external factors such as “Social image”, “Public relations”, and “Social participation”. In terms of economic sustainability, there is a relatively consistent perception of importance across management levels. Managers at all levels prioritise business and service-related activities over those related to the economic structure. This perception highlights a strategic focus on enhancing service quality and operational performance as key drivers for achieving economic sustainability for competitive advantage.

Overall, the findings of managerial levels highlight the significance of internal capacity in achieving a competitive advantage in port sustainability management. It appears that managers perceive critical sustainability activities differently based on their capacity to influence performance, suggesting a link between management level and competitive sustainability outcomes. Hence, participative decision-making that involves managers at all levels can enhance the design and implementation of multilevel port sustainability strategies, leading to superior performance through more impactful sustainability initiatives (Lim, 2022).

Conclusion

This study aims to investigate key sustainability activities that strengthen the competitive advantage of ports. Using the RII analysis, the perceived priority of 30 sustainability activities was assessed and ranked in relation to their impact on competitive advantage. This study provides valuable insights for decision-makers with the best practices for managing port sustainability. The priorities identified for sustainability activities can help set specific targets to maintain competitive advantage and update the determinants of sustainable practices. Port managers can use this information to effectively allocate resources, leading to improved competitiveness. Additionally, this study considers various factors, such as port region, size, and manager roles, to present a holistic view of sustainability priorities. These classifications can serve as benchmarks for identifying areas of improvement and developing focused strategies and supporting policies. Furthermore, this study introduces the SAP approach to port research, expanding the theoretical knowledge of port sustainability management from a strategic perspective. By clarifying which sustainability activities to prioritise for competitive advantage, this study enhances the understanding of the ‘what” aspect of SAP and advances the literature on strategising port sustainability performance at the operational level. From a methodological perspective, this study introduces the RII approach as the first application of this technique in port research, traditionally dominated by the AHP method for relative importance analysis. By presenting RII as an alternative for prioritising attributes, it enables port researchers to compare various analytical methods, thereby expanding the methodological landscape in the field.

Nonetheless, the data for this study were collected unevenly across different regions, with some areas contributing as many as 57 responses, whereas others provided only 14 responses. This could potentially lead to biased results that offer a limited perspective on the circumstances in particular regions. A more evenly distributed sample across regions or targeted regions would be beneficial for obtaining more focused perspectives and facilitating the identification of region-specific factors and their corresponding sustainability activities. Furthermore, the findings of the study may possess limited applicability to current conditions because of the elapsed time since data collection. The COVID-19 pandemic has potentially altered viewpoints on sustainability performance in ports; therefore, future research is needed to obtain updated information and to conduct comparative research before and after the pandemic.

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THE APPLICATION OF PHYSICAL INTERNET PRINCIPLE IN DISTRIBUTION CENTER

Napas Klamthuan[1], Poti Chaopaisarn[2]

[1] Master' Degree Program in Industrial Engineering, Faculty of Engineering, Chaing Mai University, Chiang Mai' Thailand

[2]Supply Chain Engineering Management Research Unit, Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand. Tel: (+66) 53-944125, E-mail: poti@eng.cmu.ac.th

Abstract

Purpose: This study aims to conduct a comparison between the Physical Internet and traditional transportation systems in the northern regions of Thailand. The focus is on examining the efficiency, cost-effectiveness and overall effectiveness of both approaches in addressing the unique logistical challenges faced in this region. By providing a detailed analysis, this research seeks to highlight the potential advantages and limitations of implementing the Physical Internet as an innovative solution for improving transportation and logistics in northern Thailand.

Design/methodology/approach: In terms of design, this study employs a mixed methods approach to compare the Physical Internet with traditional transportation systems in the northern regions of Thailand. The research design includes both qualitative and quantitative analyses to ensure a comprehensive evaluation. primary data will gather from local business based on industry standards. And simulation a data in traditional and the implemented of physical Internet principles in python model to define the result of the implemented.

Finding: the study revealed improvements in physical internet implementation in the northern region. The improvement has focused on the maximization of warehouse utilization and cost effective in the logistics and supply chain in the northern region.

Originality/value: the physical internet principle can be implemented in the logistics industry in Chiang Mai. The Physical Internet can improve utilization and lower operational costs by convincing a business to share assets and information in warehouse operation to maximize a warehouse's utilization. The concept of the physical internet can improve the logistic performance of the logistics business to compete with large corporations.

Keywords: Logistics, Supply Chain Management, Physical Internet, Sustainability, Distribution Center, Simulation

Introduction

In the modern industry, logistics and supply chain management are the areas that directly impact a company's operational efficiency and competitiveness. Logistics are focused on optimizing the complex processes involved in the flow of goods, information, and services from suppliers to end consumers. The business integrates new techniques and technology to improve their effectiveness and can satisfaction more customers.

After the globalization and sustainability are main topic in the world, Thailand's government has been creating a policy to improve their logistics and supply chain to enhances whole logistics. (Government of Thailand, 2023) Thailand has the goals to represent itself to logistics hub in Southeast Asia and support Thai's entrepreneur to global market and provide regional value chain and engage a digital economy and innovation development. But in the real-world context, logistics provider has been struggling in the logistics from the rapid growth of e-commerce industry in Thailand. The logistics provider has to find more complexity solutions to solve the problem. (Song et al. 2022), are represent an implementation of sharing economy in term of smart grid electricity. The structure is divided into three main components: electricity producers, electricity consumers, and electricity storage administrators. The process begins with the producer supplying electricity to the storage administrators, who manage and store the electricity while also evaluating its price based on demand and supply levels. These administrators play a key role in determining and overseeing the distribution of electricity to meet the needs of various areas.

(Montreuil B., 2011) are represented the concept called Physical internet, the concept is talked about sharing assets with competitor businesses, including information and logistics strategic to collaborate

and improve a decision making in distribute practice. Physical internet has 3 concepts are hyperconnected, seamless movement of goods and Standardize Package. The goods have been transported to their destination by using collaborative distribution center, packed in standardize packages, and transport to destination with seamless time. And logistics information is synchronized with other cooperative companies to solve problems, improve performance and make better decision making.

In the research field, researchers are trying to implement this concept in many countries. Europe onion has been implementing this concept to real world. (Crainic, T. G. and Montreuil, B. 2016) has been published a integrate a concept of physical internet in France. And after that, the result of this research is the framework for multi-level of logistics and transportation in France in Physical internet. (Leung, E. K. H et al. 2022) has been published a implement concept of physical internet in distribution center in terms of synchronization of information to improve a distributed practice In distribution center.

In this paper, I present an adapted Physical Internet framework specifically designed for the northern region of Thailand. The framework focuses on distribution practices within distribution centers operating from Bangkok to the northern region. It focused on how Physical Internet concepts can be implemented in these distribution centers to enhance logistics efficiency. The study highlights the integration of modular, standardized, and synchronize processes that align with the core principles of the Physical Internet, optimizing the flow of goods and resources within the supply chain in this distribution center in northern region of Thailand.

Literature review

Physical internet

(Montreuil B., 2011) says the current logistics network are fragment, inefficient and highly error in the modern business. The PI seeks to address these issues by creating a global, standardized logistics system inspired by the digital internet's architecture. In this context, goods are treated like packets of data, traveling through an optimized network of hubs, like data packets moving through routers on the digital internet.

Key elements of the PI include modular packaging units, standardized protocols, and shared logistics networks. These elements facilitate efficient goods movement, reducing overall costs, environmental impact, and delivery times. The foundational theories behind the PI draw heavily from systems engineering, network theory, and open innovation models, creating a cohesive framework for logistics transformation.

The core concept of physical internet is:

1. **Hyperconnected and openness**: to improve traditional transportation by make a synchronize data and distribution practices between collaborative warehouse and distribution centers and using shared data to decide in distribution practices. And the transportation of goods and parcels flow through the network, like internet signal flow from computer to destination's computer. The physical internet are change digital internet and adapted to physical.

2. **Seamless of transportation**: From traditional logistics. The parcels are moving through a logistic and transportation had many problems. Lack of tracking, unsuccessful transportation, missing documentation. Seamless transportation can reduce a problem by using real-times data exchange for estimate time of distribution practices. To reduce waiting times and bottlenecks of operation.
3. **Standardize package:** The goods and parcels come to warehouse and distribution center in various shapes, come from box, file, envelopes or even container. That's the huge problem to design and align a package to transport to distribution centers. The concept represents a modular package to handle a package. the package is various size for various packages. The standardized package can maximize inside a container and maximize utilization of container. And the standardized package can protect the inside package and make a package in the best condition.

The physical internet is the new method are served a new business model and green logistic, they can improve the performance of the business to satisfice a customers and their can provide advantage to

the small business their can not provide a large amount of logistics equipment and can't afford to has many location of distribution center. to compete with major companies or huge logistics providers. The competitive advantages are good for logistics and everyone in the supply chain. Logistics providers are receiving a competitive advantage to improve their business. customers are receiving their package in good condition and for the shortest times. The governance is receiving a point to improve their infrastructure for support growth businesses are established from rapid growth logistics and transportation.

Methodology

Problem description

The researcher focuses on implement Physical Internet concept in Thailand's Logistics landscape. The researchers are focusing particularly on the route from a Central Region distribution center to a Northern Region center. The process begins with receiving parcels from branches for sorting and inspection, including checking the delivery addresses and parcel conditions. sorting, the parcels are loaded onto trucks for derived from actual operations within the distribution center. The simulation incorporates details such as parcel inflows and outflows, truck entry and exit times, and average processing times, aiming to identify and resolve inefficiencies in the current logistics operations.

Research framework

The research began by collecting extensive data on both the operational processes and logistics activities of a distribution center, focusing specifically on the route from the Central Region to the Northern Region of Thailand. The collected data included information on parcel handling, sorting operations, transportation schedules, and other relevant logistics metrics. Before the simulation process, the data was preprocessed to ensure accuracy, with irrelevant information excluded and the remaining data structured for simulation modeling.

data	Type of data
Travel time	Hours
Number of parcels	Parcels per day
Inbound time	Times
Outbound time	Times
Dock In distribution	Num. of bay
Number of workers	People
Utilization rate of equipment	Hours per days

Table 1: example of data in simulation

The simulation model was designed to replicate the real-world operations of the distribution center, including parcel reception, sorting, inspection, and transportation. Python was chosen as the programming language due to its flexibility and extensive libraries. Specifically, the SimPy library was employed for event-driven simulations, while ManPy was used for simulating industrial and logistics processes. These tools allowed for the creation of a model that mirrored the actual workflows of the distribution center and logistics network, enabling a realistic simulation of both internal operations and transportation activities along the target route.

Before utilizing real-world data, the model underwent initial testing with synthetic data to verify its stability and accuracy. These preliminary tests were crucial for identifying and addressing potential issues in the model's design. Once validated, the model was run using actual operational data to simulate the logistics processes. The outputs from these simulations were analyzed to evaluate performance metrics such as processing times, transportation delays, and overall system efficiency. Additionally, a detailed cost analysis was conducted, focusing on real transportation costs, which provided insights into the economic viability of the logistics operations.

To further enhance the model, key concepts from the Physical Internet were integrated into both the distribution center and transportation processes. The study focused on the application of principles such as hyperconnected networks, seamless goods flow, and standardized packaging. These principles were incorporated into scenario analyses to explore their potential impact on logistics efficiency and cost reduction. The scenarios modeled within the simulation aimed to assess the feasibility of applying these concepts specifically to the transportation route from Bangkok to the Northern Region.

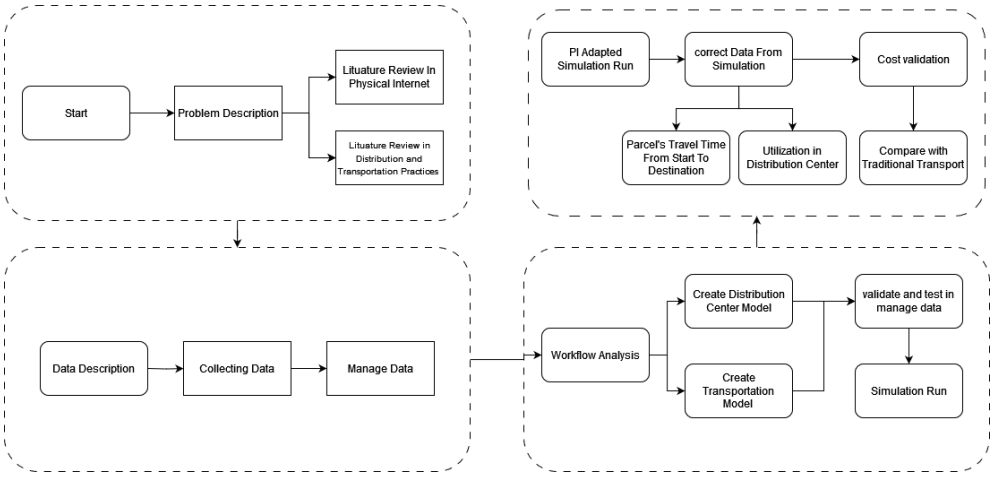

Figure 1: Simulation Flowchart

Result: The implementation of Physical Internet in Northern Thailand region
From the data we gathered from the distribution center and logistic provider, that respondent have potential to implement the physical internet in northern regions of Thailand. However, there are plot hole between successful of implementation and when are the traditional transportation are improved itself. The concept of physical internet can improve and contribute the good result for small logistics providers because there has not too much money to expand their distribution practice. There the concept is implemented and help their growth the margin and profit. But if the big logistics provider is improved their operation to satisfy customer. Their can provide more cost than small provider. This research is motivate small providers to implement the Physical internet in their operation and improve their logistics advantage to compete with large providers and reduce operational cost of their operation and use it In marketing operation.

Goal	Objective	Activity
The implemented of physical internet in northern Thailand region	Maximize a utilization of distribution center	• Testing and developing simulation of distribution center and simulation in the implement of Physical internet concept • Collect and analyze the utilization in the simulation

	Reduce operational cost in supply chain	• Testing and developing simulation of distribution center and simulation in the implement of Physical internet concept • Testing and developing simulation of transportation process and simulation in the implement of Physical internet concept • Collect and analyze the utilization and operational cost in the simulation

From the research, the expected result we need to provide is how's the Physical internet concept can implement and improve logistics and distribution practices effectively. And the result of research is motivating the first step of Thailand's logistics and supply chain improvement and crate more opportunities in this sector.

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THE CURRENT STATE OF SAFETY MEASURES IN THE JAPANESE DOMESTIC SHIPPING INDUSTRY

Nanami Takemoto
Japan Coast Guard Academy

Abstract
Purpose: This study aims to clarify the current state of safety measures among domestic shipping companies in Japan. It examines measures to prevent ship accidents in the companies, most of which are small and medium-sized, and contribute to improve the safety of domestic shipping in the future.

Design/methodology/approach: Semi-structured interviews were conducted with six Japanese domestic shipping companies regarding safety measures.

Findings: "Ship visits," was the adequately implemented measure by companies and the companies themselves recognized it as an effective measure for safe navigation. Four safety measures that reflected differences in the efforts of companies were "safety management and manuals," "capital investment," "education and training," and "utilization of near misses." As some companies were implementing these sufficiently, it was clear that there was room for improvement and ingenuity by other companies.

Originality/value: Most previous studies on domestic shipping in Japan have focused on economics or commerce; however, this study is original in that it considers the issue from the perspectives of accident prevention and safety. Moreover, it considers comprehensive safety measures and not simply safety management. This study provides suggestions for safety measures for domestic shipping.

Keywords: Domestic Shipping, Safety Measures, Accident Prevention, Safety Management, Safety Culture

Introduction

Japan's domestic shipping transports 154.0 billion ton-kilometers of cargo in 2022 (Ministry of Land, Infrastructure, Transport and Tourism, 2024), making it one of the most important modes of transport, accounting for approximately 40% of domestic freight transport. In recent years, it has also attracted attention as a modal shift destination because it emits less carbon dioxide per unit compared to trucks. It is also expected to serve as an alternative means of transporting goods to trucks and railroads in the event of a major earthquake or other disaster and as a form of reverse logistics for transporting industrial waste and other materials. Additionally, because all domestic ships are registered in Japan and consist of Japanese crew, it is considered significant in terms of security and maintaining public order.

Conversely, the domestic shipping industry mainly comprises "owners," which are companies that own and lease ships, and "operators," which are companies that operate ships chartered from owners or their own ships, and transport cargo requested by shippers, with small and medium-sized owners constituting the majority. Additionally, because this industry has a multiple contract structure of affiliation and subcontracting, the relationship between the owner and operator tends to be fixed and stable. The bargaining power of many small owners is extremely low compared to that of shippers and prime operators, making them vulnerable to changes in the market environment (Tezuka, 2024).

Furthermore, shipbuilding requires a large amount of capital; however, the high investment risk makes raising funds difficult, while alternative construction is onerous (Tezuka, 2024). Consequently, aging ships is becoming a serious problem; the proportion of ships over 14 years old increased from 45% to 66% (based on the number of ships) from 2000 to 2023 (Japan Federation of Coastal Shipping Associations, 2024). Additionally, owing to the working system that requires long periods of continuous onboard work, the job is not attractive to young people (Mori, 2012). With 47% of seafarers over the age of 50, there are concerns about their aging as well (Japan Federation of Coastal Shipping Associations, 2024).

Such weaknesses can be factors that impede the safety of the Japanese domestic shipping industry. In other words, if the business is not stable, it is difficult to invest in safety measures in addition to regular expenses such as employee wages and costs related to ship maintenance and operations. However, neglecting safety measures increases the risk of accidents and occupational injuries; if they occur, the ship and crew are at risk and the business would be unable to continue. Therefore, ensuring safety is an important issue from the perspective of business survival, even for small and medium-sized companies.

Most research on domestic shipping safety in Japan has focused on companies' safety management systems. Hatamoto (2017), focusing on small and medium-sized companies and small domestic ships, proposed measures necessary for establishing a safety management system for domestic shipping by examining ways to improve the policy of utilizing ship management companies. Nagatani (2014) developed a safety culture measurement tool and pointed out the need to establish a safety management system, including partner companies, and assess branches based on an analysis using the tool. Habara (2009) presented a basic idea of the important elements of safety management based on human factor explanation models such as "4M" and "m-SHEL models" to establish a safety management system for ship operation. Although there are a few studies on safety management systems for domestic shipping in Japan, how companies establish safety measures or what problems they face in implementing them are unclear.

Therefore, this study aims to clarify the current state of safety measures among domestic shipping companies in Japan, by examining measures to prevent ship accidents in small and medium-sized companies, and contributes to improving the safety of domestic shipping in the future.

Transport Safety Management System in Japan

In Japan, the Transport Safety Management System is a measure for transport companies to ensure their own safety management. In 2006, following a series of transport accidents and serious incidents in the previous year, transport-related business laws, including the Coastal Shipping Law, were significantly revised, making it mandatory for companies to ensure safety. The Transport Safety Management System was introduced in conjunction with a major revision to transport-related business laws and commenced in October 2006. The system is based on the concepts of ISO9001 and consists of transport companies building a safety management system, which is assessed by the government. Revisions to each business law made it mandatory for companies to address three main points: first, the creation of safety management regulations and their notification to the Minister of Land, Infrastructure, Transport and Tourism (MILT); second, the appointment and notification of a safety manager for each company; and third, the publication of their safety information (Kinoshita, 2019).

The guidelines indicate the specific actions that companies should take, and present the following 14 items: (1) responsibilities of top management, (2) safety policy, (3) safety priority measures, (4) responsibilities of the safety general manager, (5) personnel responsibilities and authority, (6) information transmission and communication, (7) collection and utilization of accident and near-miss information, (8) response to serious accidents, (9) ensuring compliance with relevant laws and regulations, (10) education and training necessary for establishing and improving the safety management system, (11) internal audits, (12) management review and continuous improvement, (13) document creation and management, and (14) record creation and maintenance. Each company can execute the series of steps in the PDCA (Plan-Do-Check-Action) cycle by addressing these issues. By repeating these steps, the safety management system would be improved step by step, and consequently, a safety climate and culture is expected to be established within the company. Meanwhile, the government would assess companies' safety management systems. This assessment differs from traditional audits or inspections in that it is intended to support companies' efforts to ensure safety and is non-binding. Specifically, it is conducted according to 14 items set out in the guidelines (Kinoshita, 2019).

The Transportation Safety Management System for domestic shipping applies to all registered operators, excluding owners. Specifically, according to an interview with the Safety Policy Division of the Maritime Bureau of the MLIT on July 27, 2022, the number of companies covered under the system was 597, which is approximately 21% of the actual number (2,849) of domestic shipping companies as of April 1, 2021. The assessment of all companies, which are approximately 4,500 in the maritime mode, including domestic passenger shipping companies, was completed in the fiscal year 2012; since then, the assessment has focused on companies with large transport volumes

(Kinoshita, 2017). In domestic cargo shipping, 597 companies were covered under the system, and 1,271 companies were assessed. Thus, many companies have only been assessed once to date.

Research Method

This study clarifies the status of the safety measures of domestic shipping companies based on interview surveys conducted by the author. Interviews were conducted with six domestic shipping companies. Table 1 summarizes the companies' profile. The target companies were selected to avoid bias in terms of type, size, and cargo transported.

The following six questions were asked in the form of free response.
(1) Status of implementation of safety management (safety measures) and creation of manuals
(2) Status of implementation of ship visits
(3) Capital investment related to safety measures and reducing the burden on crew members
(4) Status of implementation of education and training for seafarers
(5) Status of collection and utilization of near misses

Issues in the analysis of domestic ship accidents include optimizing crew workload, stimulating communication among crew members, securing watch-keeping personnel, and creating a safety culture (Takemoto & Abe, 2023). Of these, securing watch-keeping personnel is an issue as the industry faces a crew shortage, and increasing personnel any further is unrealistic. Therefore, questions (1) to (5) were constructed based on safety measures that are considered necessary to improve the other three issues.

The interview results were organized according to these questions. These are then classified into measures that companies are taking and those they are not. In the latter case, I consider whether there are differences in the efforts of companies and how the government and business associations should be involved, as some measures cannot be implemented by companies alone.

companies	A	B	C	D	E	F
kinds of companies	Operator, Owner	Operator, Owner	Operator, Owner	Operator, Owner	Owner	Owner
number of employees	230	225	66	24	28	2
number of seafarers	5	25	21	0	25	0
number of ships	18	15	5	1	3	2
number of owned ships	1	4	4	1	2	2
main cargo transported	steel, scrap, gypsum, etc.	chemicals	scrap, coke, coal, cement, limestone, silica	machinery, wheat, logs, gravel, etc.	black oil, biomass	chemicals
interview date	July 25, 2023	July 8, 2023	October 7, 2021	August 8, 2023	July 28, 2023	August 4, 2023

Table 1: Overview of the Companies Interviewed

Results

The safety measures taken by the companies are shown below for each question.

First, regarding the status of their efforts under the Transport Safety Management System, of the companies interviewed, Companies A, B, C, and D are covered under the system. Although the timing varied, Company A, a major operator, was assessed by the MLIT six times, and Company B was assessed five times. In response, each company reviewed its internal audit methods and methods of collecting and utilizing near misses. However, Companies C and D, which are small, are not very familiar with the system, perhaps because they have not been assessed as often, and the system has

not had any impact on their safety measures. However, Company C had taken measures similar to the safety management system required by the Transport Safety Management System, such as creating, implementing, and reviewing safety, health, and compliance plans.

All companies have established and operate safety management systems except for Companies D and F, which do not employ their own crew members. Companies A and B operate according to the regulations of the Transport Safety Management System. Company C likely focuses on safety measures, such as establishing its own safety management system, because (1) the president, who is the top executive, has a proactive attitude toward safety, and encourages studying the "Study of Failure," and (2) the company adopts safety measures from land-based businesses, which have more advanced safety measures than the shipping industry. Companies B and E must handle the Ship Inspection Report (SIRE) Vessel Inspections. Furthermore, although Company E has not obtained the International Safety Management (ISM) code certification, it operates based on this code. Companies A and E have dedicated safety officers within their organizations.

As each company introduced a safety management system, the operations were systematized, and safety measures were addressed in an organized manner. Specifically, the top management's commitment to safety has been strengthened, crew handovers and training have become smoother, meetings have become a habit before work, and the operational standards for vessels have been clarified. Consequently, the companies stated that safety has improved since the introduction of the system.

However, companies have realized that close communication between shore-based employees and ship crew members through ship visits is effective in reducing accidents. By communicating with shore-based staff to improve the problems they face daily and showing a willingness to support their work, seafarers' motivation to do their jobs can increase, which can ultimately lead to them trying to operate safely. Therefore, the introduction of a safety management system alone is not sufficient to ensure safety, and steady efforts by shore-based staff to improve the onboard environment daily are necessary for seafarers to perform better.

In principle, the responsibility for the education and training of crew members and capital investment in ships and other equipment lies with the owner, as they are contractually obligated to maintain seaworthiness. However, companies A and B, which have many chartered ships, provide support to ship owners while taking measures primarily for their own ships. Company A established a ship management company as a group company, which then performs ship management and crew dispatch on behalf of the owners of its affiliated ships, thereby reducing the owners' burden of labor management and other matters. Company B also conducts regular visits to chartered ships, safety training for seafarers during docking, and organizational training for owners. Company E also received support from its operator, such as the provision of educational materials.

Companies C and E are particularly proactive in terms of seafarer education. Company C has a good environment because it owns a vessel specializing in seafarer training. Additionally, it does not just conduct training, but also adopts a method that makes use of the "Study of Failure." Company E changes its training methods for new employees depending on whether they are new graduates or have experience as seafarers, a detailed approach that can only be achieved by a small company. Furthermore, pre-boarding training provides seafarers with information about the ship and the work that occurs during their leave before they board the ship, which has the advantage of helping seafarers quickly adapt to the job and preventing them from making mistakes. Company D asked another owner to cooperate and hold a training session with a current captain as the lecturer. Training is more effective when the captain, seafarers, or people with experience on board talk about their own experiences, as this makes it easier for crew members to better understand the issue that affect them, rather than having employees on land provide training to them.

All companies interviewed collected and utilized near misses. Particularly, proactive efforts were observed in companies A and C. At company A, the staff of the Ship Safety Management Office compiled cases reported by their seafarers, commented on the causes and countermeasures, and provided feedback. If necessary, staff also visit the ship to explain and instruct in person. If feedback is given only by distributing documents, some crew members may not check it; however, by providing feedback with explanations and instructions, they have time to think about it, which is likely to lead to improved crew behavior in the future. Company C conducts an analysis using a risk assessment

method, which led to the implementation of specific countermeasures. Additionally, company E's operator distributes prepaid cards as rewards to crew members who better report near-miss cases, to encourage more proactive reporting by crew members.

Discussion

Table 2 summarizes the companies' safety measures. The measures that were prioritized in all six interviewed companies were classified as "measures in which the company's efforts were sufficient," and measures in which the efforts varied by company were classified as "measures where there is room for improvement or ingenuity by the company." Furthermore, since there are measures that cannot be implemented by a company alone, these were classified as "measures that require the involvement of business associations" or "measures that require the involvement of the government."

	The company's efforts were sufficient.	There is room for improvement or ingenuity by the company.	The involvement of business associations is required.	The involvement of the government is required.
safety management and manuals		○	○	○
ship visits	○			
capital investment		○		
education and training		○	○	
utilization of near misses		○		

Table 2: Summary of Companies' Safety Measures

All six companies were fully committed to "ship visits." These visits are not only conducted for safety measures but have also been conducted for some time by owners to check vessel malfunction and the condition of the crew members. Company A saw a decrease in the number of accidents and problems since it began to focus on these activities by assigning dedicated staff, while Company F saw a decrease in the number of accidents and problems since it proactively communicated with crew members, even though they were not employed by the company. Other operators also recognized the importance of communicating with crew members, which can play a significant role in ensuring safe operations.

Next, regarding the four measures of safety management and manuals, capital investment, education and training, and utilization of near misses, there are differences in approaches among companies, suggesting that there is room for improvement and ingenuity.

There are differences in the efforts of each company in terms of the implementation status of safety management. Generally, tankers are subject to stricter regulations than cargo ships; therefore, safety standards tend to be higher. However, some cargo ship operators and owners, such as Company C, are also actively working on it. Ideally, safety staff should be assigned to the company organization; however, there are limits to what companies can achieve on their own because of labor costs. To achieve this, receiving freight or charter fees that reflect those costs is necessary. To ensure that freight and charter fees are determined based on cost calculations, business associations and the government must be involved and appeal to the shippers for review.

Seafarers must follow several safety guidelines. Company E has made efforts to reduce the burden on its crew members by creating documents that can be prepared on land. Thus, companies must organize multiple manuals and distribute them to crew members so they can concentrate on their original duties. However, if the owner operates a ship as a captain and the company has only one or two onshore employees, it is not easy. It is necessary for the government to impose regulations to

prevent accidents, but it should be understood that this can increase the burden on crew members, and a system that considers this issue, such as reviewing the documents to be submitted, should be designed.

Capital investment is costly; therefore, operators are more proactive in introducing it than owners. However, owners have a close relationship with crew members and are therefore able to introduce equipment in response to their requests. To reduce the crew's workload, systems that provide weather and sea condition information, support systems for night watchkeeping, shore power supply equipment, engines that use diesel oil (ISO standard: Marine Distillate fuel 3 cSt/40℃), and electronic devices such as computers have been introduced. Additionally, it would be desirable to introduce equipment that meets crew requests. While owners are primarily responsible for considering the introduction of such equipment, the cost of the installed equipment must be reflected in freight and charter fees by shippers and operators.

Although all six companies conduct education and training for crew members, allocating time to provide it at sea is difficult, so it is mainly conducted while the vessels are docked. Conversely, companies that allocate time to provide it before boarding or during ship visits station safety staff on shore. As in Company D, training not only conducted one-way by shore staff but also by current or experienced seafarers as instructors would be highly effective. As mentioned above in the section on the manuals, some small companies find it difficult to implement training on their own. In such cases, support may be needed, for example, from business associations or organizations such as the "Ocean Kyoiku Center," who can create educational materials or dispatch instructors.

The effectiveness of collecting and utilizing near misses lies not in compiling reports from crew members and presenting them as numbers, but in carefully examining the content, taking measures to prevent them, and using the information as educational and training material for crew members. Some companies that collect near misses have passive attitudes, with owners saying, "because the operator told us to collect them," and operators saying, "because it was pointed out in the assessment by the government." This may be because the collection and utilization of accident and near- miss information are included in the assessment of companies under the Transportation Safety Management System. First, companies must fully understand why they are collecting near misses and explain this meaning to crew members; otherwise, they will not function as safety measures.

This study clarifies the status of safety measures adopted by Japanese domestic shipping companies and explores the challenges in preventing domestic shipping accidents and improving safety. Interviews with six companies revealed that measures other than traditional ship visits were insufficient. Safety management and manuals, education and training, and the utilization of near misses were imposed on domestic shipping companies when the Transportation Safety Management System was launched. However, implementing these measures is difficult because freight rates, charter fees, and company personnel remain unchanged. Regarding capital investment, equipment cannot be introduced unless the cost is reflected in freight rates and charter fees. Therefore, support from the government and business associations is essential for these measures. Conversely, every time an accident occurs, the government establishes regulations and systems to prevent them, which increase the workload of companies and seafarers. There is concern that this will hinder the original safe operation. In the future, it will be necessary to choose to maintain what is necessary for safety and to abolish what has little effect compared with the effort.

This study summarized the current state of safety measures for only six companies; however, they do not necessarily apply to all companies. Japan's domestic shipping industry has complex and diverse contractual relationships and the details of its safety measures vary accordingly. In the future, it will be necessary to consider specific safety measures for each contractual relationship. Additionally, a questionnaire could be considered a future research method to clarify the measures taken by more companies.

Every company must deal with risks and safely perform its operations. Small and medium-sized companies have limited funds and personnel to spend on safety measures and must ensure safety under these circumstances. This study's results provide insights for small and medium-sized shipping companies and companies in other industries regarding their safety measures. These insights will also help governments understand the current state of safety measures at domestic shipping companies when considering future safety policies.

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UNVEILING MACRO-LOGISTICS COMPETITIVENESS: ANALYSIS OF LOGISTICS COSTS, GDP, AND THE LPI

Paitoon Varadejsatitwong[1], Ruth Banomyong[2], Puthipong Julagasigorn[3], Huay Ling Tay[4], and Siraphob Suwannakes[5]

[1,2]Center of Excellence in Connectivity, Thammasat Business School, Thammasat University, Bangkok, Thailand

[3]Hospitality and Tourism Management Department, International College for Sustainability Studies, Srinakharinwirot University, Bangkok, Thailand

[4]Singapore University of Social Sciences, Singapore

[5]Integrated Engineering Consultants Co., Ltd., Bangkok, Thailand

ABSTRACT

Purpose: This study explores macro-logistics competitiveness by investigating how the ratios of National Logistics Costs (NLC) to Gross Domestic Product (GDP) in countries impact their Logistics Performance Index (LPI) scores. The study defines four logistics cost components: transportation, warehousing, inventory carrying, and administration. Delaney's calculation method is employed to ensure consistency in calculations and to enable a comparative analysis of the ratios across all countries.

Design/methodology/approach: The analysis of logistics efficiency and its economic implications was conducted in two distinct parts: (1) classifying countries into four income categories and (2) conducting a regression analysis to explore the relationship between NLC, expressed as a percentage of GDP, and the LPI. Data were obtained from the National Accounts tables.

Findings: The relationship between NLC, as a percentage of GDP, and the LPI varies significantly across countries at different income levels. The correlation results between the six dimensions of the LPI and NLC for 73 countries showed a moderate negative correlation coefficient across all factors, indicating that improvements in logistics performance are generally associated with lower logistics costs. Thus, countries with higher LPI scores tend to have lower NLC relative to GDP.

Research Limitation/Implications: The study's calculation approach utilizes data from National Accounts, making it cost-effective and time-saving compared to traditional data collection methods. This approach should be valuable for policymakers and academics in the field of macro-logistics, as it can guide their assessment of national macro-logistics competitiveness.

Originality/value: This study employed an identical calculation method and data source, enabling a robust and novel comparison of macro-logistics competitiveness across a broader range of economies. A regression analysis of the ratios of NLC to GDP and the LPI scores identified the factors influencing a country's logistics performance.

Keywords: National logistics cost, Logistics Performance Index

Article classification: research paper

Introduction

National logistics costs (NLC) play a critical role in economic performance and national competitiveness. These costs encompass various expenses related to transportation, warehousing, inventory management, and administration, all of which significantly impact a nation's Gross Domestic Product (GDP) and trade balance. Efficient logistics systems can reduce these costs, thereby enhancing the ability of businesses to compete in global markets by lowering the prices of goods and services. According to the World Bank (2022), countries with lower logistics costs relative to GDP tend to perform better economically and have a more robust trade network, highlighting the importance of continually optimizing logistics operations at the national level.

The Logistics Performance Index (LPI) is a valuable tool that provides a comprehensive measure of a country's logistics efficiency. Published by the World Bank, the LPI evaluates key components of logistics performance, such as customs procedures, infrastructure quality, ease of arranging shipments, and timeliness of deliveries (Arvis et al., 2018). The index allows policymakers and industry leaders to identify strengths and weaknesses within their logistics sectors and develop strategies to improve overall efficiency. Studies have shown a strong correlation between high LPI scores and economic growth, as countries with higher logistics performance are better positioned to participate in international trade and attract foreign investment (Martí et al., 2014). Therefore, understanding and enhancing both national logistics costs and performance through the LPI are essential for fostering economic development and global trade integration.

Literature review

National logistics performance (NLC)

National logistics performance is assessed in the literature from two primary perspectives: logistics performance and trade connectivity, and logistics efficiency as indicated by the ratio of National Logistics Costs (NLC) to Gross Domestic Product (GDP). The first approach predominantly utilizes the World Bank's LPI to gauge a country's trade logistics connectivity, which includes evaluating customs efficiency, infrastructure quality, and other key logistics dimensions (Havenga, 2018). While the LPI provides a comprehensive overview of trade facilitation capabilities and is extensively studied in relation to logistics costs and other performance indicators (Arvis et al., 2010; Ekici et al., 2016; Kinra et al., 2020b), it primarily focuses on international logistics and does not directly measure domestic logistics efficiency. The second perspective focuses on assessing national logistics performance by examining the NLC as a percentage of GDP, which reflects the efficiency of logistics activities within the domestic economy. This approach underscores the impact of logistics costs on a country's overall economic performance (Rantasila and Ojala, 2012; Havenga, 2018). However, there remains a lack of standardization in calculating NLC, presenting challenges in accurately comparing logistics performance across countries (Pishvaee et al., 2009; Pohlen et al., 2009; Rantasila and Ojala, 2012).

Logistics costs significantly influence both firm-level competitiveness and national economic performance by affecting the total cost of goods and services. Effective management of logistics costs requires a holistic approach that minimizes overall costs rather than focusing on individual cost components, as reductions in one area may lead to increases in another (Ballou, 2007). This comprehensive understanding and management of logistics costs—including transportation, warehousing, inventory carrying, and administration—are crucial for improving logistics efficiency and enhancing economic competitiveness (Christopher, 2016). The literature has identified transportation costs as the most significant component of logistics expenses, with trucking alone accounting for a substantial portion in many countries (Cass Logistics Systems Inc., 2023). Other critical components include inventory carrying costs, warehousing costs, and logistics administration costs, all of which contribute to the total logistics expenses (Delaney and Wilson, 2003; Banomyong et al., 2022).

Despite various methodologies developed for calculating NLC, the absence of a standardized approach complicates the assessment and comparison of logistics performance across different national contexts (Banomyong et al., 2022; Heskett et al., 1973). The basic formula for calculating NLC as a percentage of GDP is (Delaney and Wilson, 2003; Banomyong et al., 2022):

NLC as % of GDP = (Total Transport Cost + Total Warehouse Cost + Total Inventory Carrying Cost + Total Logistics Administration Cost) / GDP

Where: Total Logistics Costs represent all expenses associated with the movement, storage, and distribution of goods and services within a country, and
Gross Domestic Product (GDP) is the total economic output of a nation.

The CASS method has become a prevalent tool for assessing logistics costs in various countries, including the United States and Thailand, due to its adaptability to both national and firm-level data (Botes et al., 2006; Havenga, 2010). This method focuses on four primary logistics cost components: transportation-related costs, inventory holding costs, warehouse-related costs, and administration costs (Delaney and Wilson, 2003). The calculation of NLC as a percentage of GDP, often referred to as the logistics cost burden, provides a critical indicator of a country's economic efficiency and competitiveness by quantifying the resources allocated to logistics activities relative to the nation's total economic output. Despite the usefulness of the CASS method, the absence of a standardized calculation methodology for NLC presents challenges, particularly in identifying the relevant logistics cost components and selecting the appropriate calculation method (Banomyong et al., 2022).

Logistics Performance Index (LPI)

The World Bank's LPI is a crucial tool for evaluating the logistics performance of countries worldwide. The LPI assigns scores to each of these dimensions, thereby offering a detailed and comparative analysis of logistics performance across countries. Higher scores reflect superior logistics performance, highlighting areas of strength and identifying opportunities for improvement. Developed to help policymakers and stakeholders understand the challenges and opportunities within their logistics sectors, the LPI provides a comparative analysis of logistics efficiency based on six key dimensions (Ojala and Celebi, 2015): Efficiency of the Customs Clearance Process, Quality of Trade and Transport Infrastructure, Ease of Arranging Competitive Shipments, Competence and Quality of

Logistics Services, Ability to Track and Trace Shipments, and Timeliness of Shipments in Reaching the Destination.

The LPI is derived from surveys conducted with international freight forwarders and express carriers, who provide insights into the logistics environments of the countries they operate in. This approach ensures that the LPI captures real-world perceptions of logistics performance, making it a practical tool for identifying strengths and weaknesses in national logistics systems (Arvis et al., 2018). Research has shown that higher LPI scores are associated with better trade facilitation and economic performance, as efficient logistics systems reduce costs and improve the reliability of supply chains (Ekici et al., 2016). Furthermore, the LPI has been instrumental in guiding policy reforms and investments in infrastructure and services, promoting greater integration into the global economy (World Bank, 2018).

Despite its widespread use, the LPI has also faced criticism, primarily concerning its reliance on perception-based data and its focus on international trade logistics, which may not fully capture domestic logistics performance (Korinek and Sourdin, 2011). However, its strengths in highlighting key areas for improvement and fostering international comparisons make it an indispensable tool for countries seeking to enhance their logistics capabilities. By providing a detailed overview of logistics performance, the LPI enables countries to benchmark their logistics systems against global standards and identify targeted areas for policy intervention and investment.

Research methodology

Analysis methods

The analysis of logistics efficiency and its economic implications were conducted in two distinct parts to provide a thorough understanding of the relationship between NLC and overall logistics performance across different stages of economic development.

In the first part of the analysis, countries were classified into four income categories as defined by the World Bank: low-income, lower-middle-income, upper-middle-income, and high-income. This classification is based on gross national income (GNI) per capita, which serves as a reliable indicator of a country's economic development level (World Bank, 2022). By grouping countries according to these income levels, the study aims to capture the variations in logistics efficiency that correspond with different stages of development. This approach allows for a more granular analysis of logistics performance, recognizing that countries at different economic stages face distinct challenges and opportunities in their logistics sectors. For example, low-income countries may struggle with inadequate infrastructure and inefficient customs procedures, while high-income countries might focus more on optimizing advanced supply chain technologies and reducing logistics costs further (Arvis et al., 2018). The income-based grouping should facilitate a comprehensive understanding of how logistics efficiency evolves as countries progress through different stages of economic development, thereby highlighting the specific needs and priorities of each income group.

The second part of the analysis involves conducting a regression analysis to explore the relationship between NLC, expressed as a percentage of GDP, and the LPI. By examining logistics costs as a proportion of GDP, the study aimed to understand how these costs influence a country's logistics performance as measured by the LPI. This analysis is crucial because high logistics costs can act as a barrier to trade competitiveness and economic growth, particularly in developing countries where logistics inefficiencies are more pronounced (Rantasila and Ojala, 2012). The regression analysis provided empirical evidence on the extent to which NLC impact logistics performance, thereby offering valuable insights for policymakers and industry stakeholders on how to enhance logistics efficiency and drive economic development. Understanding this relationship is essential for formulating targeted policies that can reduce logistics costs, improve supply chain efficiency, and ultimately strengthen a country's competitive position in the global market.

Data used in the analysis

The data for this study were sourced exclusively from the *Key Indicators for Asia and the Pacific 2024: Data for Climate Action* report, published by the ADB. This report provides comprehensive economic data, including the GDP figures at current market prices for 79 member economies in Asia and the Pacific, as well as the GDP data of 21 industrial sectors (Asian Development Bank, 2024).

The transportation and warehousing costs were derived from the GDP value attributed to the Transportation and Storage sector, as indicated in the National Accounts table of the report. For the inventory carrying costs, data were available for specific sectors only, including (1) Mining and Quarrying, (2) Manufacturing, (3) Electricity, Gas, Steam, and Air-conditioning Supply, (4) Water Supply, Sewerage, Waste Management, and Remediation Activities, (5) Construction, and (6) Wholesale and Retail Trade, Repair of Motor Vehicles and Motorcycles (Asian Development Bank, 2024). In sectors such as agriculture, it was assumed that there would be no inventory left, as agricultural commodities are generally harvested and distributed immediately. Similarly, the service sector was assumed to have no inventory costs, given that services are intangible and cannot be stocked. The methodology for calculating these logistics costs is based on these sectoral GDP data and specific assumptions regarding inventory levels across different sectors.

The obtained NLC are considered as a proper indicator indicating a country's past and future performances related to logistics efficiency (Havenga, 2018). It was observed that many developed and developing countries are not only striving to determine their NLCs but they would like to benchmark their logistics performance with other countries (Banomyong et al., 2022). A common way to benchmark logistics efficiency of nations is the LPI.

Findings

Income-based classification of countries

Table 1 shows the LPI scores and NLC per GDP of 73 countries in 2022. The relationship between NLC, expressed as a percentage of GDP, and the LPI varies significantly across countries at different income levels, reflecting the diverse challenges and opportunities they face in optimizing logistics performance. In low-income countries, high logistics costs relative to GDP were found to be associated with lower LPI scores, indicating inefficiencies in logistics systems. These countries typically contend with inadequate infrastructure, limited access to technology, and cumbersome customs procedures, which collectively impede the smooth movement of goods and increase overall logistics costs (Arvis et al., 2018). Any elevated costs in these contexts highlight the pressing need for substantial investments in infrastructure development and capacity building to enhance logistics efficiency and support economic growth (Rantasila and Ojala, 2012).

In contrast, lower-middle-income and upper-middle-income countries were found to exhibit more varied relationships between NLC and the LPI. While some countries in these categories continue to face challenges similar to those of low-income countries, others have made significant strides in improving logistics efficiency. For these nations, reducing logistics costs often correlates with enhanced the LPI, reflecting improvements in infrastructure, regulatory frameworks, and the adoption of modern logistics technologies (World Bank, 2018). High-income countries, on the other hand, were found to demonstrate a strong inverse relationship between NLC and the LPI. These countries benefit from well-developed infrastructure, advanced logistics networks, and efficient customs procedures, which contribute to lower logistics costs as a percentage of GDP and higher LPI scores (Korinek and Sourdin, 2011). The lower logistics costs in high-income countries underscore their ability to maintain a competitive advantage in global trade through the continuous optimization of logistics operations and investments in cutting-edge technologies (Havenga, 2018). This analysis highlights the importance of targeted policy interventions and investments tailored to the specific needs of countries at different stages of economic development to improve logistics performance and reduce costs.

Country	LPI	NLC/GDP	Country	LPI	NLC/GDP	Country	LPI	NLC/GDP
Low income								
Afghanistan	1.9	10.4%						
Lower middle income								
Bangladesh	2.6	12.8%	Micronesia	2.9	13.9%	Sri Lanka	2.8	19.0%
Bhutan	2.5	18.4%	Mongolia	2.5	15.5%	Tajikistan	2.5	19.9%
Cambodia	2.4	15.6%	Myanmar	2.8	27.5%	Timor-Leste	3.5	9.8%
Cook Islands	2.6	10.1%	Nepal	2.9	13.5%	Ukraine	2.7	15.9%
India	3.4	10.2%	Pakistan	3.3	15.4%	Uzbekistan	2.6	21.6%
Indonesia	3.0	13.7%	Papua New Guinea	2.7	8.6%	Vanuatu	2.6	5.3%
Kiribati	2.7	11.5%	Philippines	3.3	8.5%	Viet Nam	2.3	10.1%
Kyrgyz Republic	2.3	16.5%	Samoa	2.8	6.4%			
Lao PDR	2.4	19.6%	Solomon Islands	2.8	12.4%			
Upper middle income								
Armenia	2.5	9.8%	Malaysia	3.6	6.6%	Thailand	3.5	13.7%
Azerbaijan	4.0	20.3%	Maldives	3.6	12.5%	Tonga	2.5	8.9%
China	3.7	7.2%	Marshall Islands	3.3	14.5%	Turkey	3.4	12.4%
Fiji	2.3	9.2%	Palau	3.3	6.6%	Turkmenistan	3.4	21.5%
Georgia	2.7	13.2%	Russia	3.2	16.1%	Tuvalu	3.4	8.5%
Kazakhstan	2.7	17.0%	South Africa	3.7	11.6%			
High income								
Australia	3.7	6.7%	Hong Kong, China	4.0	7.7%	Portugal	3.4	11.2%
Austria	4.0	8.8%	Ireland	3.6	8.6%	Romania	3.2	12.9%
Belgium	4.0	8.3%	Italy	3.7	9.3%	Singapore	4.3	14.1%
Brunei Darussalam	3.2	5.8%	Japan	3.9	5.8%	Spain	3.9	8.9%
Canada	4.0	9.0%	Korea	2.7	9.4%	Sweden	4.0	7.9%
Denmark	4.1	9.2%	Nauru	2.9	20.8%	Switzerland	4.1	8.6%
Finland	4.2	8.8%	Netherlands	4.1	7.8%	Taiwan	2.3	6.2%
France	3.9	9.1%	New Zealand	3.6	7.0%	United Kingdom	3.7	8.6%
Germany	4.1	8.4%	Norway	3.7	9.2%	United States	3.8	8.7%
Greece	3.7	12.9%	Poland	3.6	10.8%			

Table 1: LPI score versus NLC/GDP (2022) (the authors)

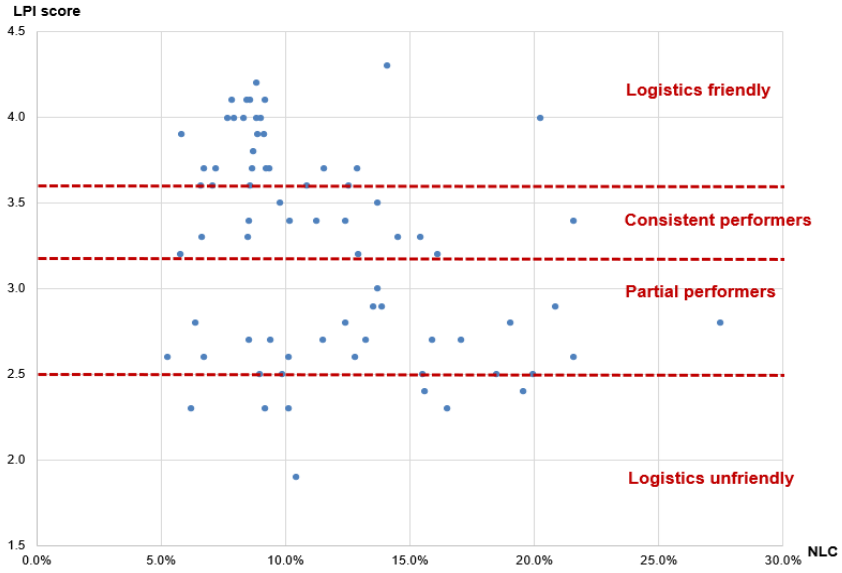

Figure 1: Relationship between NLC and the LPI of 73 countries (the authors)

Figure 1 provides a graphical representation of NLC/GDP and the LPI of 73 countries in 2022. These data can be divided into four zones by dashed red lines, categorizing countries into different performance groups based on their LPI scores: (1) Logistics Friendly: Countries in this category generally have high LPI scores (above 3.5) and relatively lower NLC (often below 10%). These countries are efficient in logistics, with strong infrastructure, streamlined customs processes, and effective logistics services. Most high-income countries fall into this category, demonstrating advanced logistics capabilities. (2) Consistent Performers: Countries in this range have moderate LPI scores. They show consistent logistics performance but have room for improvement. These countries may have moderate NLC and represent middle-income economies that are developing their logistics infrastructure and processes. (3) Partial Performers: Countries within this range have lower LPI scores, indicating average logistics performance with certain inefficiencies. The NLC for these countries are higher, often above 10%, reflecting a higher cost burden for logistics activities. These countries may be in transition, striving to enhance their logistics capabilities. (4) Logistics Unfriendly: Countries in this category have the lowest LPI scores, reflecting significant logistics inefficiencies. The NLC can vary widely, but the high costs typically correspond to poor infrastructure, inadequate logistics services, and inefficient customs processes. These are often low-income countries facing major challenges in their logistics systems.

Relationships between NLC and the LPI

The analysis reveals a correlation between a country's NLC as a percentage of GDP and its LPI score. Generally, countries with higher LPI scores were found to have lower NLC relative to GDP. Such relationship suggests that more efficient logistics systems, which facilitate the quicker and more cost-effective movement of goods and services, are associated with reduced logistics costs as a proportion of economic output.

However, it is crucial to recognize that correlation does not imply causation; the observed association between LPI scores and logistics costs does not necessarily indicate that one directly causes the other (Glymour, 2006). As presented in Table 2, the correlation results between the six dimensions of the LPI and national logistics costs for 73 countries show a moderate negative correlation coefficient across all factors, indicating that improvements in logistics performance are generally associated with lower logistics costs. Both Pearson and Spearman correlation coefficients indicated that countries with lower logistics costs relative to GDP tend to have higher LPI scores, suggesting more efficient logistics performance. Specifically, the Pearson correlation coefficient between NLC/GDP and the overall LPI score is -0.6275, while the Spearman coefficient is -0.6460, both indicating a moderate negative correlation. This suggests that as logistics costs as a percentage of GDP decrease, the overall efficiency and effectiveness of logistics systems, as measured by the LPI, tend to improve. These results indicate that improvements in logistics infrastructure, international shipment handling, timeliness, customs efficiency, service competence, and tracking capabilities are associated with lower national logistics costs relative to GDP.

NLC/GDP with	Peason	Interpretation	Spearman	Interpretation
LPI overall	-0.672301296	Moderate	-0.687015061	Moderate
Infrastructure	-0.658014939	Moderate	-0.683464215	Moderate
International Shipment	-0.65429354	Moderate	-0.665876864	Moderate
Timeliness	-0.639521657	Moderate	-0.648145157	Moderate
Customs	-0.655143865	Moderate	-0.689989785	Moderate
Competency	-0.655652353	Moderate	-0.671528003	Moderate
Track & Trace	-0.662193438	Moderate	-0.673743813	Moderate

Table 2: Correlations between NLC and the LPI (the authors)

Figure 2 offers a graphical representation of the correlation between each dimension of the LPI and NLC for the 73 countries. The correlation analysis between NLC as a percentage of GDP and the various dimensions of the LPI showed a consistent moderate negative relationship across all factors.

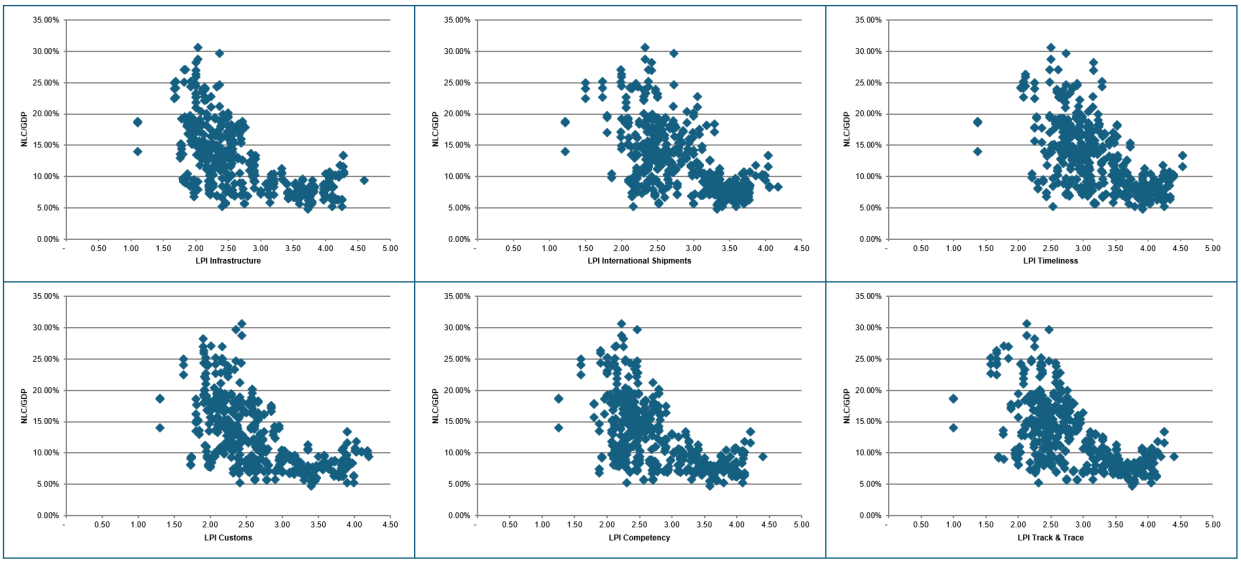

Figure 2: LPI dimensions factor correlation with NLC (the authors)

The findings underscore the importance of enhancing various components of logistics performance to reduce overall logistics costs and improve economic efficiency. The moderate negative correlations suggest that while there is a significant relationship between logistics costs and performance, other factors may also influence logistics efficiency. Moreover, the consistency of the moderate negative correlations across both Pearson and Spearman coefficients highlights the robustness of this relationship, irrespective of the assumptions regarding the distribution of the data (Mukaka, 2012). This analysis provides valuable insights for policymakers and stakeholders aiming to enhance logistics performance by focusing on these key dimensions.

Conclusion

The relationship between National Logistics Costs (NLC) as a percentage of a nation's Gross Domestic Product (GDP) and the Logistics Performance Index (LPI) for 73 countries provide significant implications for economic development and regional integration. Efficient logistics systems are crucial for enhancing country's competitiveness in the global trade arena. Member states should prioritize strategic initiatives aimed at improving logistics performance, including reducing logistics costs and optimizing operational efficiencies. Such improvements are vital for facilitating intra-regional trade and ensuring that country remains a formidable competitor in international markets. Critical steps in this process include harmonizing regulations across member states and streamlining customs procedures, which can significantly reduce trade barriers and improve overall logistics efficiency.

Moreover, achieving lower logistics costs and higher LPI scores can enhance country's attractiveness to foreign direct investment (FDI). To leverage this potential, member states should continue to invest in infrastructure development and regulatory enhancements, fostering a conducive environment for sustainable economic growth. As the region pursues economic development, it is imperative to consider sustainability and resilience within logistics systems. Adopting green logistics practices and enhancing disaster preparedness are essential for building a robust and resilient logistics network capable of withstanding economic shocks and environmental challenges. Collaborative efforts among 73 countries, including regional agreements, joint infrastructure projects, and the sharing of best practices, are crucial for overcoming logistics challenges. Additionally, embracing digital technologies and innovations can lead to significant cost savings and efficiency gains, further bolstering logistics performance. Through these concerted efforts, countries can strengthen their positions, driving sustained growth and prosperity for the region and its member states.

The calculation methodology used in this study presents several limitations that may affect the accuracy and comparability of the results. Firstly, the transportation costs included in the Asian Development Bank's (ADB) national account database encompass both passenger and freight transport. Passenger transportation should be excluded to accurately reflect only freight logistics efficiency. Additionally, the warehousing costs recorded in the national accounts only account for outsourced warehousing activities, omitting expenses associated with in-house warehousing. For a

more comprehensive understanding of logistics costs, both outsourced and in-house warehousing expenses should be considered.

Furthermore, the methodology employed a constant factor of 10% as a proxy to estimate logistics administration costs. This uniform approach does not account for the varying capabilities in logistics management and differing economic conditions across countries, which can significantly influence logistics administration expenses. Lastly, although the LPI provides valuable insights into logistics efficiency, it is based on a perception survey and does not consider logistics costs. This means that a country can achieve a high LPI score despite having elevated logistics costs.

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