The impact of Blockchain technology utilisation on supply chain integration in the maritime industry

By

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ABSTRACT

Purpose: The aim of this thesis is to empirically investigate the Supply Chain Integration (SCI) strategy in the maritime industry and the effectiveness of Blockchain Technology (BCT) introduced to promote SCI. For this purpose, the concept of maritime supply chain and the integration were concretised, and BCT application factors for maritime SCI were identified. Subsequently, the impact of BCT on SCI was incorporated into the research model and subjected to empirical analysis.

Methodology: The blockchain application factors for maritime SCI including domain, benefits and impact were identified using systematic literature review. Based on the finding, the research model to examine the relationship between IT competency, SCI, performance and the moderating role of BCT utilisation (BCU) was developed through Resource-based view (RBV) and value-chain approach. The model was empirically tested using Partial Least Squares – Structural Equation Modelling (PLS-SEM) analysis of 302 questionnaire data samples. Additionally, the study employed Conditional Mediation (CoMe) analysis to verify changes in the relationship between IT competency, SCI, and performance based on the extent of BCT utilisation.

Findings: The application domains of BCT for maritime SCI were identified as document management, transaction management, and cargo/terminal/vessel operations. The research model verified the direct relationship between IT competency, SCI, and performance. The indirect mediation effect of IT competency on performance through SCI was demonstrated showing a significant and positive impact. In addition, the moderating effect of BCU on the relationship between IT competency and SCI was verified to have a significant impact on changes in performance. In other words, this study concludes that the intervention of BCU positively influences the enhancement of SCI by IT competency in maritime organisations, ultimately contributing to the improvement of performance.

Originality and value: This thesis provides two critical insights. Firstly, through the application of the RBV, the research theoretically established and empirically verified the relationship between IT competency and SCI capability in maritime organisations for performance improvement. This offers guidelines for maritime organisations on IT investment and the implementation of SCI strategies in the context of innovative IT adoption. Secondly, the study provides a specific domain, benefits, and impacts of utilising BCT for maritime SCI and verifies its actual effectiveness on maritime SCI. The significant findings advance the academic research on BCT adoption in the maritime sector beyond the previous conceptual stage by providing empirical evidence. Moreover, the validation of a comprehensive research model is expected to serve as key evidence for practitioners considering the adoption and utilisation of BCT.

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LIST OF ABBREVIATIONS

Abbreviations	Full words
ANOVA	Analysis of Variance
AVE	Average Variance Extracted
BCT	Blockchain Technology
BCU	Blockchain Utilisation
C.R	Composite Reliability
CB-SEM	Covariance-Based – SEM
CC	Collaborative Communication
CFA	Confirmatory Factor Analysis
CLM	Council of Logistics Management
CoMe	Conditional Mediation
CSCMP	Council of Supply Chain Management Professionals
DH	Decision Harmonisation
eBL	Electronic Bill of Lading
EDI	Electronic Data Interchange
FITI	Flexible Information Technology Infrastructure
FNP	Financial Performance
GOF	Goodness-of-Fit
GS	Goal Similarity

GSBN	Global Shipping Business Network
HOC	higher Order Construct
HTMT	Heterotrait-Monotrait
ICT	Information and Communication Technology
IoT	Internet of Things
IS	Information System
IS	Information sharing
IT	Information Technology
ITA	IT Assimilation
ITPS	IT Personnel Skills
JPM	Joint Performance measurement
KC	Knowledge Creation
KIFFA	Freight Forwarder Association
KSA	Korea Shipowners Association
M&A	Mergers and Acquisitions
MITK	Managerial IT Knowledge
OPP	Operational Performance
OSL	Ordinary Least Squares
PCS	Port Community System
PLS-SEM	Partial Least Squares – Structural Equation Modelling
PSA	Port of Singapore Authorities
RBV	Resource Based View

ROA	Return on Assets
ROI	Return on Investment
ROS	Return on Sale
SCI	Supply Chain Integration
SCM	Supply Chain Management
SCP	Supply Chain Performance
SD	Standard Deviation
SEM	Structural Equation Modelling
TOC	Terminal Operating Companies
UNCTAD	United Nations Conference on Trade and Development
VIF	Variance Inflated Factor
VRINN	Valuable, Rare, Imperfectly mobile, Not imitable, Not substitutable
WSC	World Shipping Council

Chapter 1 Introduction

In this chapter, an overview of this doctoral study is provided, which investigates the impact of blockchain technology on performance enhancement strategies through supply chain integration based on IT competency within organisations in the maritime and shipping industry. It begins with the research background and motivation. The research objectives and research questions are then presented, followed by an outline of the research.

1.1 Research background

In recent times, the maritime and shipping industry has faced with significant hurdles, including intensified competition, declining profits from freight, and recurrent disruptions in the supply chain, with the COVID-19 pandemic being a notable example (Munim and Schramm 2017; Goulielmos 2020; Notteboom et al. 2021). These challenges have prompted stakeholders within the supply chain to explore innovative strategies for enhancing operational efficiency and generating value (Panayides and Song 2009). The maritime industry has historically developed alongside the acceleration of globalisation and the containerisation of transportation, which has led to the advancement of intermodal systems (Notteboom et al. 2022). As a result, merchant transport holds the largest share of trade volume, accounting for 80% of global trade (UNCTAD 2023). At the same time, as global trade experiences depression, trade tensions arise from unpredictable events, and the economy undergoes fluctuations, the industry has been striving to respond to uncertainty. Shipping companies has considered supply chain integration as a key strategy to efficiently manage the vulnerabilities arising from imbalances in the demand and supply of global trade (Panayides et al. 2012). Supply chain integration (SCI) is a strategic approach to meet customer demand for end-to-end or door-to-door services, bringing the distance between shippers and customers closer together and effectively responding to changing customer expectations in the market (Yuen et al. 2019). The international movement of cargo via container shipping involves complex relationships among various stakeholders within the supply chain, including shippers, carriers, freight forwarders, port terminals, financial organisations, and governmental entities. These processes are often plagued by inefficiencies. This structure leads to delays in delivery, inefficiencies in document exchange, and limits to transparency and traceability, ultimately resulting in increased time and costs. In recent years, the maritime industry has been actively adopting an approach to facilitate SCI strategies, particularly shipping liners are pursuing increased functional integration to manage the maritime supply chain, eliminating intermediate processes and providing integrated logistics services (Paridaens and Notteboom 2022).

Information and Communication Technology (ICT) plays a crucial role in reinforcing SCI. As the global supply chain increasingly focuses on rapid and on-time shipment and delivery, as well as enhanced transparency and traceability of transportation, the importance of ICT is becoming ever more significant (Wang and Sarkis 2021). Progress in ICT has allowed companies to ensure seamless and prompt exchange of information throughout the supply chain, thereby fostering effective collaboration among partners. Sharing real-time or near-real-time data about supply chain operations among partners aids in streamlining supply chain management and boosts overall performance. As advanced ICTs have the potential to cause disruptive impacts on the maritime supply chain, the information technology (IT) competitiveness of shipping organisations has come to be recognised as a crucial capability resource for enhancing productivity, reducing costs, and improving service quality (Bălan 2018). In supply chain management and maritime transport, technologies such as the Internet of Things (IoT), cloud computing, big data analysis, and autonomous vehicle systems are actively being researched and considered for application (Schuelke-Leech 2018). Among these, Blockchain technology (BCT) is garnering attention as a promising technology for achieving successful SCI in maritime and shipping transportation (Shirani 2018; Philipp et al. 2019; Liu et al. 2021).

BCT has recently been recognised as a potential solution for facilitating SCI in the maritime sector and for improving efficiency within maritime logistics (Queiroz et al. 2019). Blockchain is an encrypted distributed ledger database that manages and tracks transaction data. It is Implemented, shared, duplicated, maintained, and synchronised by members of a decentralised network, which is permanent and immutable (Nakamoto 2008). When implemented, BCT possesses characteristics that can promote the integration of maritime supply chain. The inherent features of this innovative technology, such as immutability, decentralisation, trust, transparency, visibility, security, and a global network, serve to bolster trust among maritime supply chain members (Wang et al. 2020a; Wang et al. 2021b). The elements facilitate participation in BCT-based solutions and enable the secure, real-time exchange of various types of information (Wang et al. 2020b).

The complexity of communication within the maritime supply chain is a critical factor that hinders efficient transactions. For instance, a single shipping transaction on a given route can involve up to 28 different parties and include approximately 200 various document exchange, leading to delays in lead times, the occurrence of human errors, and issues with inaccurate communication (Jović et al. 2019). When shared through blockchain, encrypted data becomes accessible to all participants, addressing issues of trust, cargo traceability, process optimisation, and coordination and communication. Balci and Surucu-Balci (2021) expected that a trusted, transparent, and efficient supply chain managed by a BCT solution could reduce international maritime transport costs by up to 15%. Trade-Lens, initially developed by Maersk and IBM, is one notable example of BCT initiative implemented in the container shipping to secure data sharing and foster collaboration (Wee 2022). This solution was launched in 2018, however, despite its potential benefits, it was discontinued the operations in December 2022 due to the economic viability limitations of the opened initiative. Another example is the Global Shipping Business Network (GSBN), a joint venture established by shipping liners such as COSCO and OOCL, along with Hutchison Ports and the Port of Singapore Authorities (PSA) (GSBN 2024).

GSBN currently has over 20,000 users, has expanded its network to 24 ports, and handles half of the world's containers.

The justification for this research is grounded in the acknowledgment of these significant challenges that the maritime industry has faced, as well as the efforts to address them. The first focus of the research is the inherent inefficiencies and intense competition within the maritime supply chain. These challenges have brought SCI strategies to the forefront as a means to streamline the complex structural issues of the supply chain, aiming for a smoother and more efficient flow. The second aspect under scrutiny is the role of ICT as a crucial enabler for effective SCI. In an age where technological innovation is critical, the IT competency of a firm have become increasingly important. The integration of disruptive technologies is revolutionising business processes and providing a competitive advantage to those who can successfully exploit these technological developments. Finally, the research turns its attention to BCT as a potential solution to the challenges mentioned above. As an emergent technology, BCT holds the promise of bringing transparency, security, and efficiency to transactions and record-keeping, which are vital elements of maritime supply chain operations. By synthesising these perspectives, this thesis pertains significance in addressing long-standing issues with contemporary strategies and technologies. The research is the process to explore and investigate the potential impact of the increasingly prominent technology, BCT, to resolve chronic challenges in the maritime supply chain when combined with SCI strategies, in an era where IT competency is a key competitive advantage.

1.2 Research objectives and questions

In the maritime and shipping industry, SCI is being emphasised as a core component of operational strategy, and various innovative IT technologies are being utilised in SCI, with BCT being described as a promising solution. Given the above consideration, this study is designed to comprehensively examine the influence of these phenomena. In light of this background, the research objective of this study is *“to verify the impact of the introduction and utilisation of BCT in the maritime industry on facilitating maritime SCI strategies.”* More specifically, the objective aims to ascertain whether the utilisation of BCT technology, leveraging the IT competencies possessed by maritime organisations, can stimulate the execution of SCI strategies and, consequently, have an empirical influence on performance enhancement. The research is structured to investigate the relationship between SCI and the IT competency of maritime supply chain members, the impact on performance, and ultimately, to validate the effectiveness of BCT.

Research questions have been formulated with the ultimate aim of developing and validating a comprehensive research model, which will be achieved by sequentially addressing these questions. The first step of this argument is to precisely establish the concept of the maritime supply chain and to highlight the need for a clear definition of integration activities. This step solidifies the theoretical and conceptual background of the study and specifies the focus of the research. It also includes the role of an organisation's IT competency, which has a direct relationship with SCI activities. Defining each concept and its role serves as the groundwork for subsequent research hypotheses and the development of models based on these hypotheses. The first research question represents these considerations:

RQ1. *How can the stakeholders, scopes and activities of maritime supply chain integration be clarified and what is the role of IT competency on maritime supply chain integration and performance?*

In addition to the conceptual aspects of maritime SCI and IT competency, the remaining focus of this research is the application of BCT for maritime SCI, which needs to be identified. BCT is an emerging technology that is being developed and launched by maritime organisations, within both the academic field and practical industry. Therefore, exploring and diagnosing the current state-of-the-art of BCT is one of the most significant parts of this research. It is necessary to analyse how BCT technology impacts the integration of the maritime supply chain and in which domains it exerts influence. This argument is represented in the following research question 2:

RQ2. *What are the key domains and application factors to consider when applicating blockchain technology for maritime supply chain integration?*

If Research Questions 1 and 2 focused on the conceptual elements of this study, the subsequent question should aim to identify the mechanisms connecting SCI, IT competency, and performance. In particular, the clearly defined relationship among the variables needs to be provided to validate the impact of IT competency and SCI on performance. IT competency, which represent a company's IT capabilities, must be integrated into the research model as a driver for enhancing SCI. Meanwhile, SCI should be recognised as a direct influencer on performance improvement. When considering the individual relationships, it is hypothesised that IT competency will bolster SCI, and in turn, a strengthened SCI is expected to positively affect performance. Within a composite model, the mediating role of SCI in the indirect relationship between IT competency and performance are established. Based on the structure of the described research model, the current study empirically tests the impact of IT competency on performance via SCI by analysing the data collected from questionnaire survey using Partial Least Squares – Structural Equation Model (PLS-SEM). Research Question 3 has been articulated as follows to regarding this argument:

RQ3. *What is the relationship between IT competency and SCI for performance improvement in the maritime supply chain?*

The final piece of the entire study concerns the empirical evidence of the impact of BCT on integration within the maritime supply chain. Research Questions 1, 2, and 3 are a step-by-step pathway to validate the final objective of present research: 'the influence of BCT on the successful achievement of SCI strategies by maritime organisations.' Once the relationships among IT competency, SCI, and Performance are clarified, the final stage of this research is to determine the impact of BCT intervention on the entire relationship. This process aims to explore changes in the model according to variations in BCT as a moderating variable of utilisation of BCT. The analysis is conducted by applying the Conditional Mediation analysis method in addition to previously validated model using PLS-SEM. This argument leads to the development of Research Question 4:

RQ4. *How does blockchain technology utilisation impact on the process of SCI in maritime organisations?*

By answering these questions, this study will provide a clearer understanding of the SCI integration activities enhanced by IT competency within the precisely identified concept of maritime supply chain. The research will examine how the relationship between IT competency and SCI influence the performance. Furthermore, after exploring the state-of-the-art in the adoption of BCT to achieve SCI, the study will be able to examine the impact of BCT utilisation on the SCI process.

1.3 Structure of the thesis

This research is structured in the following manner to address the proposed research questions in order to achieve the previously discussed research objective. **Chapter 2** explores the literature related to this study using both narrative and systematic approaches. It begins by providing an overview of the relevant literature to understand and establish the scope of maritime SCI. The review focuses on improving the ambiguity with which existing maritime field literature conflates the concepts of maritime logistics and supply chain, and it emphasises clarifying the maritime SCI that is the subject of the current study. This chapter also includes a systematic literature review to investigate the current state of BCT adoption and implementation in the maritime supply chain and its impact on integration. This approach contributes to identifying the domains where BCT is being applied in the maritime industry, determining what benefits are present. The factors identified from the systematic literature review is used for establishing the BCT utilisation (BCU) construct in conducting empirical analyses. Chapter 2 is developed as a process to explore answers to research questions 1 and 2.

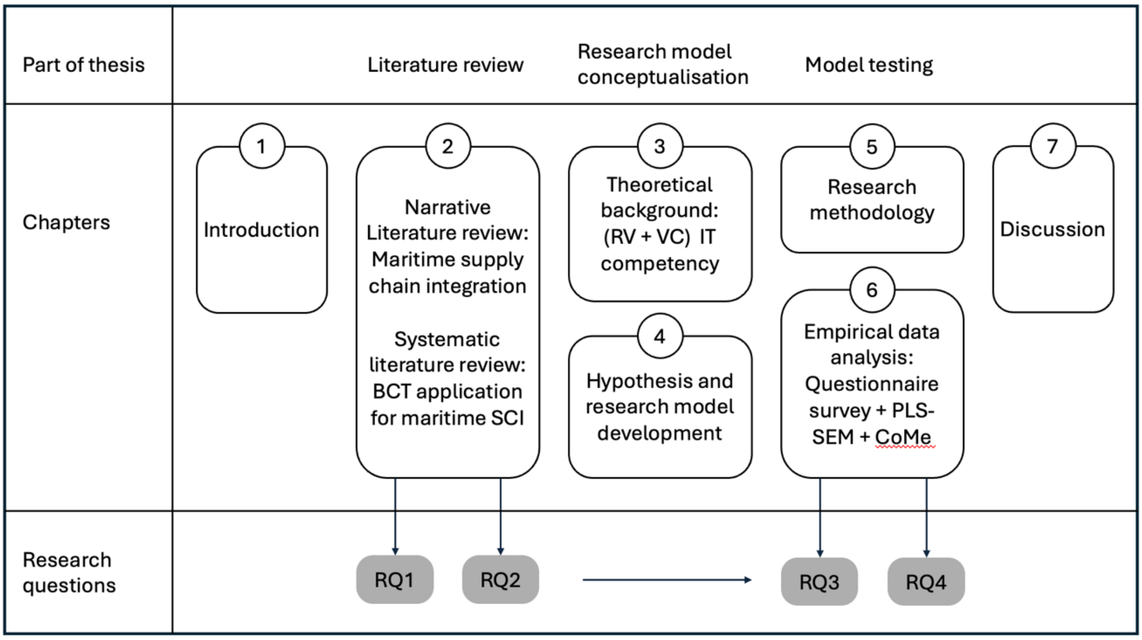
Chapter 3 discusses the process of establishing the relationships between the conceptual constructs identified in this study through a theoretical base. The research adopts a resource-based view (RBV) to elucidate the role of an organisation's IT resources and presents a perspective that views SCI as an organisational capability. Additionally, by utilising the framework of the value chain, the chapter organises the relationships by which IT and SCI-related activities contribute to competitive advantage, thereby serving as the foundation for the development of subsequent research hypothesis and models.

Chapter 4 discusses the development of a research model based on the relationships between the constructs of IT competency, SCI, performance, and BCT investigated in the previous chapters, and presents hypotheses to be tested in the study. This chapter solidifies the concepts of each construct within the research model, expresses the relationships between constructs in the form of hypotheses and models, and includes a discussion on the measurements that comprise each construct of the model.

Chapter 5 addresses issues related to research methodological justifications. It discusses the overall research design, including research philosophy, approach, methodological choice, and strategy. Additionally, the methods for data collection and empirical analysis are described. The study deploys PLS-SEM for analysing structural model and uses Conditional Mediation analysis (CoMe) for testing moderating effects. Justifications for these two analytical methods are discussed in this chapter.

Chapter 6 is composed of three sections detailing the analysis process of the empirical data. The first section presents descriptive statistics for the data collected from the questionnaire survey, which includes the profiles of the participants and the characteristics of the survey data. The second part is a model assessment of the structural model, where the fit of the developed model is examined. In particular, the significance of higher-order constructs composed of IT competency and SCI was assessed. Lastly, empirical data analysis was carried out for the research model that satisfied the model fit criteria. The hypotheses established in the previous chapter were tested using the PLS-SEM method. The validation of the research model includes testing the hypothesised direct relationships between IT competency, SCI, and performance (operational performance and financial performance), as well as the mediated indirect relationship from IT competency to performance through SCI. Furthermore, to examine the influence of BCU as a moderating variable on the structural model, CoMe was conducted.

Chapter 7 closes this study as the conclusion. The final chapter summarises the research process by reviewing the findings of the previous chapters and provides a discussion on the research questions. It also presents the contribution by suggesting academic and practical implications. Then, the current research's limitations are discussed and recommendations for future research reflecting these limitations is provided. Figure 1.1 illustrates the overall structure of current thesis.



Note: SCI: supply chain integration, BCT: blockchain technology, RV: Resource-Based view, VC: value chain, PLS-SEM: Partial Least Square Structural Equation Modelling. CoMe: Conditional Mediation, RQ: Research Question

Figure 1-1Thesis structure with research questions

Source: Author

Chapter 2 Maritime supply chain integration and Blockchain technology

In this chapter, the findings of a literature review that was conducted to explain the motivation for this research is presented. This review explores existing literature to understand how the adoption of blockchain influences and impacts integration within the maritime supply chain. The literature review helps to identify significant theories, concepts, and research methodologies in the research field related to the research topic, and clarifies the relevance and contribution of existing research (Machi and McEvoy 2009). The review supports determination of the directions and scope of the research by setting research questions (Saunders et al. 2019). A critical review should be a constructive analysis that enables the development of a clear argument about what is established and the research gap (Wallace 2021).

This chapter explores two key themes: the application of SCI in the maritime sector and the deployment of BCT within the maritime supply chain. Section 2.2 provides definitions of Supply Chain Management (SCM) and integration concepts, explores current research in the field, and identifies definitions and scopes of maritime SCI which has been previously incomplete. Furthermore, in section 2.3, a systematic literature review was conducted to explore the state-of-the-art BCT applied in the maritime industry, aiming to provide the domains where BCT is utilised in maritime sectors and benefits of technology in the integration of supply chain. Sections 2.4 and 2.5 presents the findings from the literature review to highlight the research gaps that this study aims to fulfil and clarify the direction of current research by synthesising and summarising the literature review.

2.1 Maritime Supply Chain Management and integration

This section clarifies terminology in relation to supply chains and logistics. Then maritime SCI will be defined. Maritime and shipping companies have identified supply chain integration as their primary strategic objective (Paridaens and Notteboom 2022). However, the concepts of supply chains and SCI are predominantly derived from the manufacturing industry, where they are centre around focal companies. This presents challenges when applied to maritime transport, which is just a segment of transportation sector. In maritime and shipping literature that encompasses such as ports, container liners, bulk, and offshore activities, the term 'maritime supply chain' is frequently used but rarely clearly defined and specified. Furthermore, terms that share overlapping concepts, such as maritime logistics, port logistics, and port supply chain, often lead to confusion.

This section will explore the concept and scope of the supply chain, the meaning and purpose of SCM, and the strategic evolution leading to SCI. Subsequently, the associated concepts of SCI are applied to the maritime and shipping industry. Through a review of relevant literature, the maritime SCI strategies will be defined and conceptualised, examining their scope and implications within the industry. This will set the stage for a comprehensive understanding of how integration can be operationalised in a maritime context, ultimately contributing to the advancement of the field.

2.1.1 Maritime logistics

Logistics, as defined by Daskin (1985), refers to "the design and operation of the physical, managerial, and informational systems required to enable goods to transcend time and space". In traditional logistics models, the emphasis is placed on the role of shippers and carriers in moving raw materials to production plants and transporting finished goods from plants to markets and consumers, highlighting the importance of freight transportation (Stevens and Johnson 2016). However, as the market has increasingly emphasised customer satisfaction and with the development of information and management technologies, logistics has evolved into an integrated system (Stenger 1986; Mentzer et al. 2001). This integrated approach not only considers the physical movement of goods but also incorporates the management of information and resources to optimise the entire supply chain, ensuring that customer needs are met efficiently and effectively (Neng Chiu 1995; Lotfi et al. 2013). While efforts to integrate logistics processes within a company have had a positive impact on performance, it is essential to consider independent firms outside the company as involved in the streamline from manufacturing products to reaching the end consumer (Kahn and Mentzer 1996; Agrawal and Narain 2018; Núñez-Merino et al. 2020). In the case of technologically complex products, the supply chain may include a large number of firms. Therefore, an solely-integrated logistics management system is insufficient, and the importance of improving efficiency and effectiveness through externally integrated logistics management across the entire supply chain has been highlighted (Cooper et al. 1997; Lambert et al. 1998; Larson and Halldorsson 2004).

Maritime logistics refers to the integration of logistics concepts within maritime transportation. It involves companies across the entire spectrum of the shipping market applying integrated knowledge to build close cooperative and partnering relationships with customers and suppliers (Panayides 2006). Maritime and shipping companies had begun to embrace logistics concepts in order to bring new opportunities, improve the service quality, achieve cost control, augment potential profit, and establish a competitive advantage (Panayides and Song 2013). Traditionally focused solely on maritime transportation, loading, and discharging of cargo (Gray 1982; D’Este 1996), the maritime and shipping industry has evolved in response to the increasing and diversifying needs of shippers and customers, as well as the changing dynamics within the supply and logistics chain (Brooks 1999; Wagner and Frankel 2000). Exposed to environments emphasising logistics and SCM, global sourcing, intermodal transport, and logistics outsourcing, maritime companies have recognised the necessity to become a critical node in a larger logistics chain and a part of a global distribution channel to fulfil these roles (Heaver 2002; Panayides 2006; Kang and Woo 2017; Koza et al. 2020).

The principles of logistics and SCM, when applied to maritime transport, have transformed shipping networks and maritime transport chains. The evolution of river or ocean transportation of cargo, along with multimodal and intermodal transport, has shifted towards a physical integration of the transport modes, which is exemplified by container inter-modalism (Panayides 2006). This integration facilitates the seamless movement of cargo containers across different modes of transportation, such as ships, trains, and trucks, optimising efficiency and reducing costs throughout the entire supply chain (Panayides et al. 2012). Reflecting the concept of logistics, maritime logistics encompasses the management of physical maritime transport flows, the management of information flows, as well as the management of interfaces between various actors in the maritime supply chain from the manufacturer to the end consumer (Panayides and Song 2013). Maritime logistics deals with maritime transport, which includes shipping and ports, traditional logistics functions such as storage, warehousing, and distribution centre services, as well as integrated logistics activities that provide value-added services like labelling, assembly, and repairing (Nam and Song 2011; Jiang et al. 2021). The core players in maritime logistics consist of shipping companies, port operators, and freight forwarders, along with port authorities that supports process within the port operation (Lee and Song 2010; Meersman et al. 2010; Panayides and Song 2013). Manufacturing firms seek for providers who can offer value-added services as part of an integrated package, which often involves vertical integration along the supply chain. Key players in maritime logistics collaborate to provide a comprehensive transport package service and to ensure swift door-to-door delivery (Marlow and Casaca 2003; Gülmez et al. 2023).

This idea of logistics management posited that the flow of materials throughout the entire organisations within the supply chain could be managed in an organic and systematic manner, leading to significant enhancements in both the operation's efficiency and effectiveness (La Londe and Masters 1994; Palmieri et al. 2019). Adopting this comprehensive perspective enables an organisation to balance trade-offs among procurement expenses, transportation costs, and the costs associated with inventory and warehousing. Close co-ordination of these processes can yield superior service levels and operational performance while minimising overall expenses (Zhou et al. 2018).

2.1.2 Maritime supply chain management

The concept of logistics integration has been expanded into the realm of supply chain management and has also been adopted within the maritime and shipping field, leading to the establishment of maritime supply chain management.

2.1.2.1 Supply chain management

This strategy of applying integrated logistics management to all elements of a supply chain is referred to as "supply chain management (Lambert and Cooper 2000; Stevens and Johnson 2016)". The supply chain encompasses a network of interconnected activities focused on the strategic planning, coordination, and management of materials, components, and finished products from the origin of supply to the end consumer (Stevens 1989). Mentzer et al. (2001) defined the supply chain as *“A set of three or more entities (organisations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer.”* The concept extends from the mere physical transportation of materials, to including broader aspects such as managing suppliers, procurement, manufacturing process, planning of facilities, providing customer services, and managing the flow of information along with the transportation and distribution of goods. However, the different definitions and meanings of supply chain and SCM across numerous research have been found (Larson and Rogers 1998; Shukla et al. 2011; Stadtler 2014). These analyses are considered incomplete due to the risk of omitting important definitions or concepts.

Council of Supply Chain Management Professionals (CSCMP 2024), previously named as the Council of Logistics Management (CLM), provided a solid distinguishable definition between logistics management and SCM. Logistics management is a subset of SCM, focusing on the efficient and effective movement and storage of products, services, and information within the cargo flow, including transportation, warehousing, and inventory management, and it coordinates with other business functions such as marketing, sales, and finance. SCM is a broader discipline that involves the planning, management, and coordination of all activities related to sourcing, procurement, conversion, and logistics, as well as collaboration with partners across the entire supply chain. SCM aims to integrate supply and demand management both within and across companies, linking major business functions to create a cohesive and high-performing business model. Cooper et al. (1997) also emphasised that the integration of logistics activities has become a strategic role in the integration of business processes, which constitutes an area within the domain of SCM for sustainable competitive advantage. However, Mentzer et al. (2008) highlighted the anecdotal interpretations held by academics and practitioners, therefore, consolidated these perspectives to present a comprehensive framework for SCM. As illustrated in Figure 2-1, logistics is identified as a functional area within SCM. Specifically, logistics includes transportation management and load consolidation, with an emphasis on the role of enhanced transportation utilisation and service performance. This focus on transportation and service is crucial for the overall operational design both within a firm and across the entities in the supply chain.

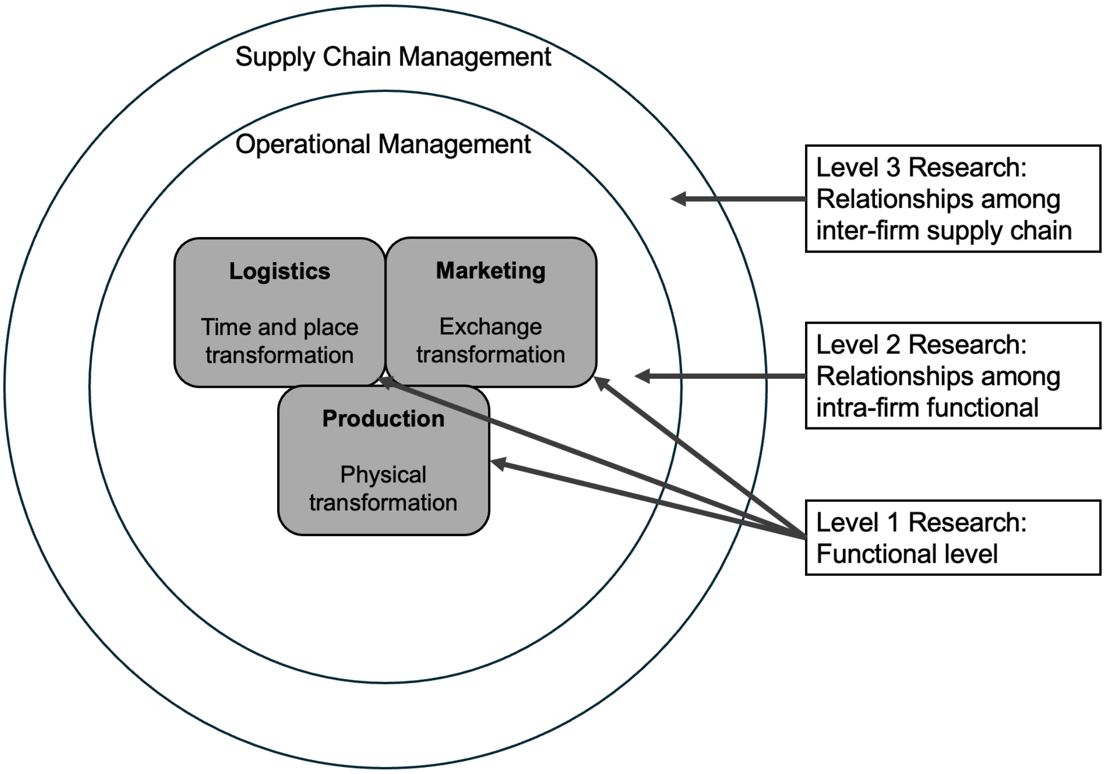


Figure 2-1 Supply chain management framework
Source: Mentzer et al. (2008)

Stock and Boyer (2009) also made an effort to propose the consensus SCM definition based on a large number of literature review: "The management of a network relationships within a firm and between interdependent organisations and business units consisting of materials suppliers, purchasing, production facilities, logistics, marketing, and related systems that facilitate the forward and reverse flow of materials, services, finance and information from the original producer to final customer with the benefits of adding value, maximising profitability through efficiencies, and achieving customer satisfaction". In their research, logistics is described as a sector that plays a partial role within the overarching domain of SCM. This characterisation aligns with the unionist perspective in the research by Larson and Halldorsson (2004), which is an approach that has gained widespread acceptance and complements previous definitions (Larson et al. 2007).

2.1.2.2 Service supply chain

However, the concept of the supply chain, traditionally applied to manufacturing, has its limitations when applied to the service industry (Nie and Kellogg 1999). Armistead and Clark (1993) and Youngdahl and Loomba (2000) emphasised the need for research on the supply chain in the service industry and contributed to the development of the service supply chain. Ellram et al. (2004) presented a critical view of the traditional perspective that primarily considers manufacturing companies as the focal company, by introducing the concept of the service supply chain (Roh et al. 2011). In consideration of the management of professionalised outsourcing services, they defined service SCM from a perspective centred on the production and procurement of services by service providers, distinct from a product-centric viewpoint: "The management of information, processes, capacity, service performance, and funds from the earliest supplier to the ultimate customer." The key processes and flows of service SCM were identified as information flow, capacity and skills management, demand management, customer relationship management, supplier relationship management, service delivery management, and cash flow (Ellram et al. 2004). Lin et al. (2010) categorised the main partners in the service supply chain as suppliers, service providers, customers, and other service partners. They defined service supply chain as a network that transfers resources into services or service products to be delivered and received by customers (Baltacioglu et al. 2007). Service SCM is the efficient management of information, processes, and resources along the service supply chain. The ultimate and most important member would be service provider who serves as the core unit of service supply chain and service provider plays similar role as the focal company in a traditional manufacturing supply chain (Mohan and Zailani 2011).

Logistics services are a series of management activities provided by logistics service provider in order to fulfil customer's requirement whereas logistics service effectiveness is referring to the logistics process that create value added benefits for customer and customer satisfaction (Panayides 2007). The studies by Lai et al. (2002) and Lai (2009) positioned the transport logistics service provider as the focal company in the supply chain, with suppliers designated as shippers and customers as consignees. When service providers deliver services, product suppliers participate in the supply chain by providing a part of the service that is delivered to the customer. Zhang and Wang (2019) presented a structure model for the service supply chain. Their research categorised the participants into modular service providers that offer standardised forms of services, service integrators that integrate these modules through highly efficient information processes and strong service design capabilities, and customers. The conceptual model has been applied to port logistics, where service modules such as transport, warehousing, and customs clearance are provided by service providers and are delivered to individual customers through the integrated service process of port enterprises (Zhang et al. 2009). Kim and Ha (2022) also proposed a generalised service supply chain model through an exploratory review of literature related to the service supply chain. In this model, the service is at the centre of the supply chain, with products and other services positioned upstream, and manufacturing or service enterprises positioned downstream. Notably, this study asserted that the customer can be placed simultaneously in both directions, upstream and downstream.

2.1.2.3 Maritime supply chain

The study by Lam (2011) defines the maritime supply chain from a service SCM perspective. The study illustrates how maritime logistics are applied within the context of container shipping. It describes the actors involved and the connected series of activities related to maritime transportation and shipping services. These activities include planning, coordinating, and controlling the movement of cargoes, whether containerised or not, from the point of origin to the destination (Carlan et al. 2018; Vanelslander and Sys 2020). The chains of shippers, shipping lines, ports terminal, and other maritime logistics providers (e.g. freight forward) are vertically connected by customer-supplier relationships. These participants can each be perceived as a focal company that constitutes the maritime supply chain when applied the perspective of service SCM. Figure 2-2 represents the structure of maritime supply chain illustrating the flow of physical cargoes and information within the chain (Meersman et al. 2010). A shipper selects a particular carrier directly or through the mediation of a freight forwarder or logistics service provider. A carrier decides on the port of call and terminal operator, potentially with the help of an agent. Furthermore, when dealing with customs procedures, the goods' owner might engage a customs broker (Carlan et al. 2018; Shin et al. 2023). Table 2-1 shows the main and supportive logistics functions offered by maritime operators (Lee and Song 2010).

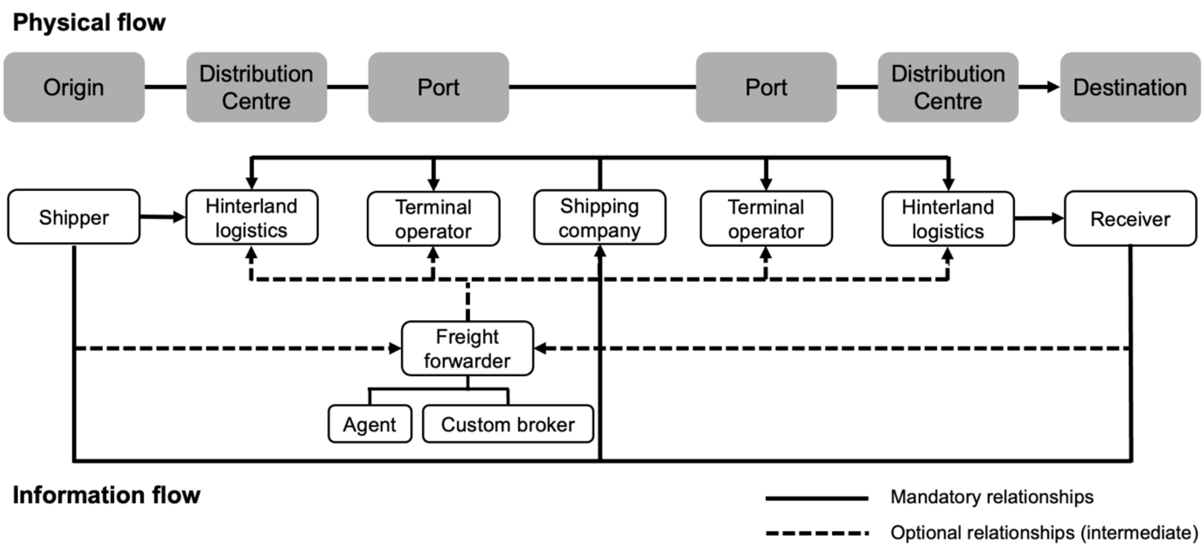


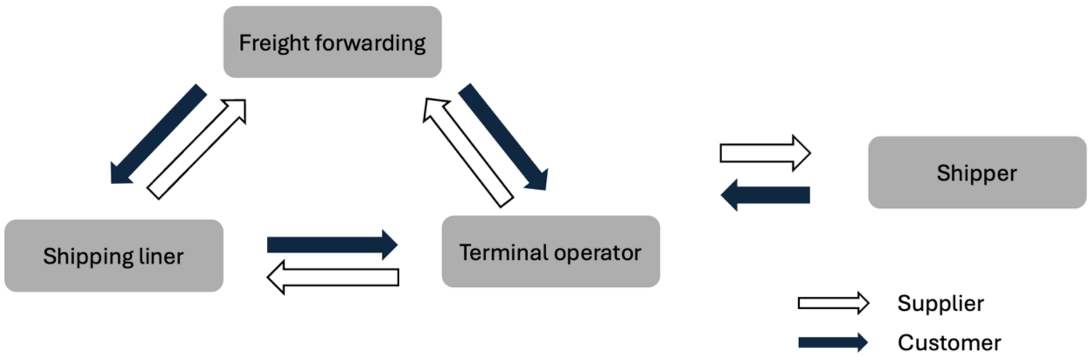
Figure 2-2 Maritime supply chain
Source: Meersman et al. (2010); Shin et al. (2023)

	Shipping	Port/terminal operating	Freight forwarding
Main function	Moving cargoes between ports	Shipping reception; loading/unloading; and connecting to inland transportation	Booking vessels; and preparing for requisite documents for ocean carriage and trade, on behalf of shippers
Supportive logistics activities	Documentation relating sea trade; container tracking and information; and intermodal service	Warehousing; offering a distribution centre; resting; assembly; repairing; and inland connection	Inventory management; packaging; and warehousing

Table 2-1 The functions of maritime operators
Source: Lee and Song (2010)

Previous research in the discipline of maritime logistics and SCM has highlighted the role of ports as central (Robinson 2002; Carbone and Martino 2003; Marlow and Casaca 2003; Robinson 2006; Panayides and Song 2008; Song and Panayides 2008; Tongzon et al. 2009; Woo et al. 2011; Stevens and Vis 2016). Ports, beyond their traditional roles in loading and discharging, have evolved as critical nodes in maritime supply chains which enhance supply chain effectiveness and efficiency through value-added services, cost and cycle time reductions, and improvements in productivity and delivery quality (Notteboom and Rodrigue 2005; Ascencio et al. 2014b). Port-centric supply chains consider ports as the focal company, with Terminal Operating Companies (TOCs) at the centre, and include suppliers and customers across the range of services provided by the port (Woo 2010). On the other hand, research on the high level of integration of liner shipping in maritime logistics has been consistently conducted (Heaver 2002; Notteboom and Merckx 2006; Panayides et al. 2012; Lam 2013; Tseng and Liao 2015; Koza et al. 2020). As demand for integrated door-to-door services has grown, shipping companies have evolved from mere cargo carriers to strategic distribution partners, providing visibility and connectivity within the maritime supply chain (Lam and Van De Voorde 2011; Yuen et al. 2019). The expanded role and scope of shipping companies, now acting as supply chain integrators and information disseminators, has become essential for supply chain service performance (Evangelista and Morvillo 1999; Wagner and Wiśnicki 2019). The conceptual shift from logistics management to SCM has spurred research into the role of freight forwarding as a key supply chain operator rather than merely a service contractor (Sandra et al. 2002; Lai et al. 2004; Frémont 2009; Skiba and Karaś 2022). Research on freight forwarding is not limited to the maritime supply chain alone, as freight forwarders connect shippers and shipping companies but also provide a variety of logistics services (Lee and Song 2018). As their importance grows from being logistic providers to supply chain integrators, their role is becoming more emphasised (Stojanović and Veličković 2019).

Woo (2010) provided a perspective for identifying the roles of the actors within the maritime supply chain from the perspective of the service supply chain. In his study, within the seaport supply chain, terminal operating companies were set as the focal company. Suppliers were defined as partners providing resources necessary for delivering port services, such as auxiliary service providers, casual labour suppliers, equipment leaser, and materials providers. Customers were identified as partners receiving port services, including shipping companies and inland transport providers. In the study by Lee and Song (2010), it is stated that maritime operators are inter-linked with each other as suppliers or customers within the maritime supply chain. For example, as indicated at Table 2-2, shipping liners are customers of terminal operators, freight forwarders are customers of shipping lines. In the case of shipping liners, the shippers and freight forwarding can be considered as the customers of cargo transportation services, while other service providers (such as port service suppliers) which offer supportive services for integrated logistics services can be considered as suppliers. When interpreting the supply chain from the perspective of a shipping liner as the focal company, terminal operators act as service suppliers, providing sea access services such as the loading and unloading of cargo at ports. In this scenario, freight forwarders represent the position of customers, as they advocate on behalf of the end customers, coordinating the receipt and delivery of cargo through the services provided by the shipping liners. Conversely, when considering terminal operators as the focal company, both shipping liners and freight forwarders assume the role of customers. Shipping liners require the terminal services for their vessels, while freight forwarders need these services to manage the movement of cargo for their clients. It is important to note that, although not displayed in Table 2-2, enterprises that provide assets, labour, and tools for terminal services are considered as service suppliers within this framework. This mechanism applies equally to freight forwarders, who also rely on various suppliers such as terminal operators and shipping liners to fulfil their role in the supply chain. Adopting this perspective, this thesis defines and investigates the maritime supply chain as the relationship between each of the maritime service providers (i.e. shipping liners, ports, freight forwarding), suppliers who provide contributory services, and the customers who purchase and receive their services. Deploying a service supply chain perspective to restructure the maritime supply chain represents a reconseptualisation process that provides the foundation for defining maritime SCI. This approach transcends the mere description of stakeholders based on the flows of cargo, and instead interprets the relationships among stakeholders through the lens of traditional SCM theory. Consequently, it successfully adapts and configures the concept of SCI to capture the integration processes within the maritime supply chain.



Operators	Terminal operator		Shipping line		Freight forwarding		Shipper
Position in SCM	Focal	←	Customer	←	Customer	←	Customer
	Supplier	→	Focal	←	Customer	←	Customer
	Supplier	→	Supplier	→	Focal	←	Customer

Table 2-2 Relationship between maritime supply chain operators
Source: Author

In summary, logistics management is identified as a subset of SCM, focusing on the functional area related to the movement of products, whereas SCM encompasses a broader scope, including all business functions related to the production and procurement of products. However, it has been observed that both SCM and logistics management emphasise the integration, collaboration, and cooperation of a series of activities, processes, and functions for optimisation. Moreover, if the concept is applied from the perspective of the service supply chain, an understanding of the maritime and shipping supply chain from the standpoint of service providers offering logistics services is supported. The previous studies mentioned in the topic of maritime SCM focus on integration, which is elaborated in the following section. Next, the concept of SCI and related studies will be discussed to outline the research gaps and direction of this thesis.

2.1.3 Maritime supply chain integration

The management of logistics and supply chains can be achieved through efficient and effective integration. Advancements in IT have enabled the facilitation of traditional SCI activities.

2.1.3.1 Supply chain integration

Through the definitions presented earlier, it is possible to discern the distinctions between SCM and logistics management, as both concepts have historically emphasised the integration and collaboration, or cooperation, of a series of related activities, processes, and functions for optimisation. The various definitions of SCM consistently highlighted the concept of integration, as evidenced by the terms "Integrated management" by Stein and Voehl (1997), "integration of business processes" by Lambert et al. (1998), "coordination of activities" by Stank et al. (2001), “coordination and integration of all activities” by Cooper et al. (1997). Kahn and Mentzer (1996) identified characteristics of integration within SCM, portraying SCI as essential necessities to manage the supply chain. Just as the definitions of SCM vary in focus across different studies, there is also a diversity of opinions regarding the scope, definition, and objectives of SCI (Pagell 2004; Fabbe-Costes and Jahre 2008). However, related research commonly corroborates that integration is associated with enhanced efficiency and productivity, which means highly integrated firms outperform those with lower levels of integration. Various terms are employed to characterise the diverse types and degrees of SCI. The approach to integration has evolved in a manner similar to SCM, with an emphasis on the perspective of logistics integration (Lee 2005). Gustin et al. (1995) suggested the concept of integrated logistics management which is the seamless connection of activities, processes, and information involving purchasing of raw material, manufacturing of products, and distribution to customer. Integrated concept must recognise the need for coordinating distribution activities and taking a systems approach. This highlights the need for logistics functions that are traditionally integrated within a company to be connected with external suppliers and customers, and third-party providers. Kahn and Mentzer (1996) identified interaction and collaboration as key characteristics of logistics and interdepartmental integration. They defined interaction as the communication and information flow necessary to unite different departments, while collaboration refers to the collective work between departments to achieve common goals.

Companies aim to achieve the primary goal of SCM, which is the integration of the supply chain, to enhance the value provided to the end customer. This entails not only fulfilling orders but also simultaneously meeting all customer expectations such as delivering the exact items and quantities ordered, ensuring on-time and damage-free delivery, and providing error-free invoicing, all while maintaining profitability and minimising costs (Stank et al. 2001). Flynn et al. (2010) made an effort to define SCI by considering its strategic nature. They described SCI as "the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organisation processes." The objective of SCI is to ensure effective and efficient flows of products and services, information, money, and decisions, in order to deliver maximum value to the customer at low cost and with high speed.

Four-stage model of increasing integration was presented by Stevens (1989) and Stevens and Johnson (2016) in Figure 2-3, each characterised by its approach to managing the flow of goods and information. From stage 1 to 4, independent and often incompatible control systems and procedures evolve progressively into functional integration, internal integration, and external integration, thereby forming an integrated supply chain based on long-term relationships. The outcomes are high-quality products, timely service, shared technology, and a long-term commitment that often leads to the elimination of multiple sourcing. As many companies move beyond the stage of cross-functional coordination, Hewitt (1994) proposed a fifth stage to the progression, which involves integrated intracompany and inter-company supply chain process management characterised by an integration level that aims to maximise total business process efficiency and effectiveness.

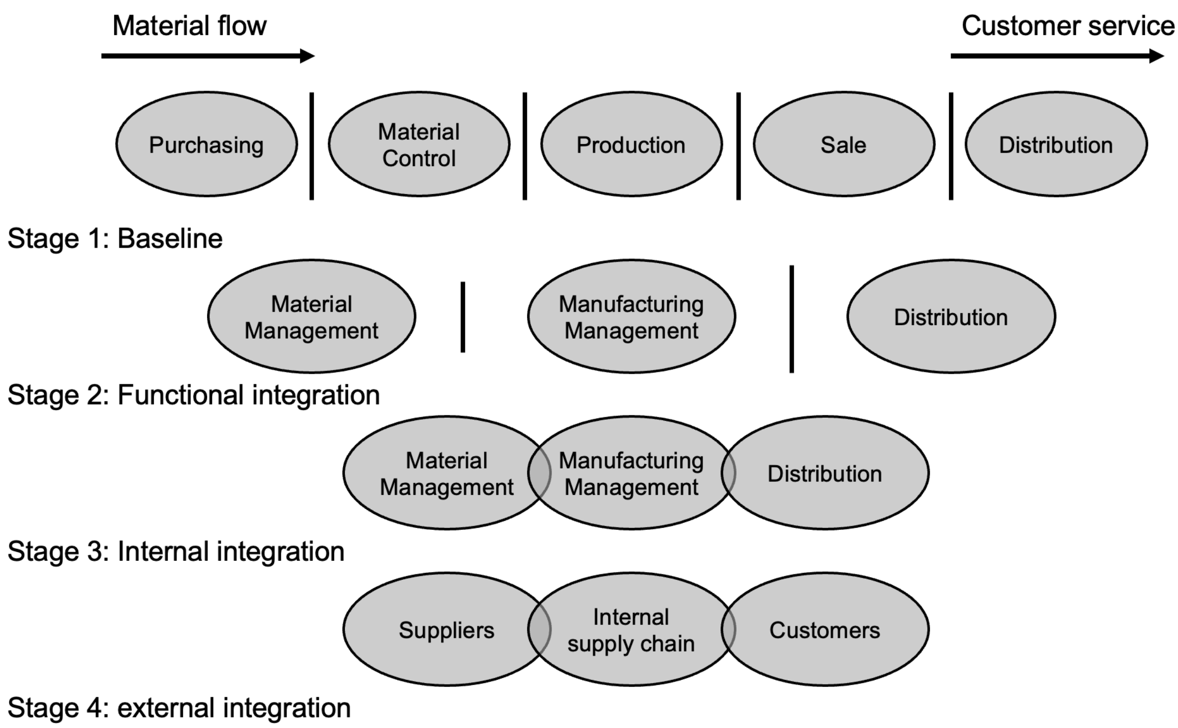


Figure 2-3 The stages of supply chain integration
Source: Stevens (1989) and Stevens and Johnson (2016)

Other studies classified SCI into two types: internal and external (Stock et al. 2000; Stank et al. 2001; Chen and Paulraj 2004; Yuen and Thai 2017c). Internal integration represents the interrelationships and trade-offs within a firm, while external integration refers to functional integration that encompasses integration with customers, material, and service suppliers (Gustin et al. 1995). Flynn et al. (2010) further developed a conceptual model by proposing three dimensions of SCI: customer integration, supplier integration, and internal integration. They divided external integration into customer integration and supplier integration. Customer integration is characterised by the essential competency gained through collaboration with key customers, whereas supplier integration pertains to the core competency associated with collaborating with important suppliers. Internal integration refers to organising focal company's (manufacturer's) strategies, practices, and processes into collaborative, synchronised processes in order to satisfy its customers' requirements and efficiently communicate with its suppliers (Flynn et al. 2010). The systematic analysis of literature by Fabbe-Costes and Jahre (2008) presented the definition of layers and scope of SCI, specifically focusing on external integration (Table 2-3). It was observed that this work contributed to theory building by enhancing the understanding of SCI and was developed and utilised as a measurement tool for research in the field.

Layers	Scope
Integration of flows (physical, information and financial)	Limited dyadic downstream: focal company – customers
Integration of processes and activities	Limited dyadic upstream: focal company – suppliers
Integration of technologies and systems	Limited dyadic: customer – focal company / focal company – suppliers (both up and downstream but separately)
	Limited triadic: customer – focal company – suppliers (without differentiating)

Integration of actors	Extended: integration between more than three parties

Table 2-3 Layers and scope of supply chain integration
Source: Fabbe-Costes and Jahre (2008)

2.1.3.2 Antecedents of Supply chain integration

Mentzer et al. (2001) suggested viewing SCM as a management philosophy characterised by three main features: systemic perspective that considers the supply chain as a single entity; synchronised internal and external operational and strategic capabilities; and customer-centric approach to generate value for customers. Furthermore, Mentzer et al. (2001) identified seven key activities of SCM, which are: the mutual information sharing; integrated behaviour; shared risks and benefits; cooperation; process integration; long-term partnerships; and a dedication to customer satisfaction. SCM and SCI have been explored as two distinct philosophies where SCI is portrayed as an essential component of SCM having characteristics of SCM being directly applied but focusing on the integration of processes, information, and relationships among supply chain partners to ensure that the entire supply chain operates cohesively and effectively (Kahn and Mentzer 1996; Khanuja and Jain 2020). Zhao et al. (2011) argued that the three major aspects of internal integration—information sharing, collaboration, and interaction—influence the expansion into external integration. The antecedents of SCI have been identified in previous literatures. The multidimensional systematic review analysis by Jayaram et al. (2010) also pinpointed information sharing, inter-organisational decision-making, and proactive planning with supply chain members as critical elements of SCI. Liu et al. (2013a) observed two main dimensions of SCI: information sharing and operational coordination. Both Frohlich and Westbrook (2001) also identified delivery integration and information integration as integral components of effective supply chain integration. Khanuja and Jain (2020) conducted a comprehensive systematic literature review on the enablers, dimensions, and performance of SCI and identified three key elements as representative characteristics of SCI: information sharing, operational coordination, and strategic alliance. Cao and Zhang (2011) identified information sharing, goal congruence, decision synchronisation, incentive alignment, resource sharing, collaborative communication, and joint knowledge creation as interconnected components of SCI through a synthesis of the literature.

Information sharing and communication are one of the major prerequisites for SCI (Barratt 2004; Chen and Paulraj 2004). Zhao et al. (2011) mentioned that an internal information sharing system must be in place for a firm to be able to share data and information with external supply chain partners. Correct information sharing with the whole supply chain and partners contributes to the smooth operation of the supply chain by providing accurate demand forecasting and stock management, thereby reducing the bullwhip effect in the supply chain (Zhao et al. 2011). Operational and tactical information, when shared, enables the collaborative management of the flow of decision-based activities by coordinating allocated resources, activities, and roles across the supply chain and partners (Wu et al. 2014). Beyond the mere movement of information, strategic information sharing involves the exchange of data that supports long-term plans and objectives, enhancing flexibility and responsiveness to market changes, and ultimately leading to improved competitiveness (Gunasekaran and Ngai 2004). Cheng et al. (2014) highlighted that communication with advanced technology is transforming the traditional methods of communication, allowing for synchronisation with external partners to enhance efficiency and competitive ability in SCI. On the other hand, Jayaram et al. (2010) contended that alongside formal information sharing and communication, the concurrent use of informal forms and channels can enable supply chain partners to align on future strategic direction and requirements. This approach can reduce uncertainty and the frequency of changes in SCM, and improve stability in scheduling and planning. Furthermore, continuous and frequent communication with supply chain members ensures appropriate intervention and corrective actions, ultimately enhancing system visibility, which is beneficial for SCI (Ahmad and Buttle 2001; Simchi-Levi et al. 2004; Yeh 2005).

Operational coordination refers to the sharing and exchange of decisions, knowledge, and resources across the supply chain in supply chain activities (Liu et al. 2013a). This includes coordination and collaboration among supply chain members in inventory planning, demand forecasting, order scheduling, and customer management. Operational coordination entails collaborative efforts by companies to derive knowledge from shared information and adapt their business procedures as necessary. Chen et al. (2009) stated that the integration of the operation process involves collaboratively managing a company's operational activities through a structured approach. By effectively coordinating business processes across the supply chain, both transactional and relational structures can be optimised for greater efficiency and effectiveness. Lau et al. (2010) argued that coordination of operations also encompasses business decisions, as well as the joint assessment and design of business systems. They claimed that joint system development and shared decision-making with supply chain members enhance the sharing of risks and resources, which in turn leads to reduced costs and time, and improved performance. Joint decision-making enhance mutual understanding and communication among supply chain partners, leading to stronger relationships (Pradabwong et al. 2017). In integrated supply chain operations, working collaboratively enables the development of a deeper understanding of and response to the market and environment. Cao and Zhang (2011) identified this process as joint knowledge creation.

Strategic alliances, as emphasised by Zhao et al. (2011), underscore the consistency of objectives and practices through interaction with different business partners. Activities such as communication, information sharing, and cross-functional teamwork are crucial for establishing and maintaining the company's alliance with chain members. Sharing of a common goal among supply chain partners in a collaborative relationship as a key element of operational integration

(Cao and Zhang 2011). By accomplishing their supply chain objectives through joint learning, members can attain mutual benefits. In a strategic relationship aimed at a common goal, synchronised decision-making orchestrates the supply chain planning to optimise operation (Simatupang and Sridharan 2002). Simatupang and Sridharan (2005a) asserted that for an integrated supply chain oriented towards a similar goal, there must be an agreement on metrics for key performance. Performance metrics should be integrated to measure the overall supply chain performance rather than the performance of individual members (Simatupang and Sridharan 2002).

2.1.3.3 Integrated container maritime supply chain

SCI has emerged as a key strategy not only in various industries but also within the maritime and shipping industry, where it is being studied by maritime researchers (Lam 2013; Tseng and Liao 2015; Yuen and Thai 2017a; Yuen et al. 2019). Several studies have used the term "orientation" or “collaboration” to describe the relationship between integrative functions and performance within the supply chain (Martin and Grbac 2003; Tongzon et al. 2009). A preference for door-to-door services on time and at reasonable costs has pushed maritime supply chain parties to provide integrated logistics services and enhanced SCM functions (Lam and Zhang 2014). Ferrari and Benacchio (2002) stated that collaboration among the various entities involved in transport chain enhances logistical efficiency, encourages focused business practices, and promotes cost savings through better infrastructure use and economies of scale. Notteboom and Rodrigue (2005) asserted that for the enhancement of supply chain operations, logistics decisions and actions of chain members should be aligned with the development of integrated freight distribution, information systems, and inter-modality. Given the complexities of the maritime supply chain, maritime SCI aims to achieve a high level of supply chain performance through smooth cargo movement and information flow especially in container shipping (Cao and Zhang 2011; Lee et al. 2016). Applying the concept of integration within the maritime supply chain to the SCI framework reveals that maritime supply chain is focusing on external integration among the stakeholders who are presented in the previous section, rather than internal integration. Panayides and Song (2009) defined the SCI of seaport container terminals as “the extent to which the terminal establishes systems and processes undertake functions relevant to becoming an integral part of the supply chain as opposed to being an isolated node that provides basic ship-shore operations.” In terms of scope, this includes suppliers and customers centred around the focal company, with the potential to extend to multiple parties, depending on the environment (Fabbe-Costes and Jahre 2008). In the actual industry, major shipping line companies or maritime groups owning shipping lines are increasingly implementing strategies to set up logistics subsidiaries, focusing on areas such as terminals, freight forwarders, and inland distribution providers (Frémont 2009; Paridaens and Notteboom 2022).

Research on the integration in the maritime supply chain has taken various directions. Traditionally, the integration of shipping lines has focused on horizontal integration through mergers and acquisitions (M&A) or the formation of strategic alliances (Evangelista and Morvillo 1999; Slack et al. 2002). Strategic alliances among container carriers which are designed to take advantage of vessel sharing arrangement, aims to attain optimal size and benefit from the scale and scope of economies derived from increased scale (Álvarez-SanJaime et al. 2013). These alliances enhance joint efficiencies by spreading the variable cost across all members, yielding a reduced marginal cost (Quartieri 2017). Horizontal integration enhances efficiency by consolidating assets, however, it also promotes collective decision-making among stakeholders by reducing the number of competitors (Crotti et al. 2020). The study by Notteboom and Rodrigue (2008) emphasised with an analytical approach to optimise the velocity of freight for improving the productivity performance of shipping lines, highlighting the need for connectivity with other shipping lines and port terminals for an integrated schedule. Research has also been discovered that employs mathematical and statistical methods to analyse the performance of integrated service networks, including form of alliances, with a focus on scheduling and route optimisation (Ting and Tzeng 2003; Kang and Woo 2017; Koza et al. 2020; Yichao et al. 2024).

On the other hand, in response to customer demand for door-to-door and one-stop shopping logistics services, there have been attempts to extend and integrate the reach of shipping lines into other parts of supply chain activities over recent decades (Notteboom et al. 2022). This integration has taken the form of M&A, subsidiaries, and dedications among maritime supply chain partners to control costs and operational performance, and to improve profitability. As indicated in Table 2-4, major shipping companies aim for SCI by owning subsidiaries, while other parties in the chain are strengthening network integration through strategical or ad hoc coordination with independent operators (Notteboom et al. 2022). Numerous studies have investigated the essential elements that strengthen vertical integration across external maritime supply chain partners. Traditional studies, such as the work of Evangelista and Morvillo (1999), have analysed the scope of functional areas within maritime SCI. They categorised the stages of integration of shipping alliances into waterborne transport, port terminal, inland transport, and logistics services for measurement. Notteboom and Merckx (2006) proposed indicators for identifying levels of freight integration in liner shipping. The list includes slot capacity ranking, terminal ownership, focus on commodities/cargo flows, type of service provider, geographic coverage of liner shipping services, relevance as a market participant in the field of intermodal transport, commitment to inter-modality, knowledge and experience in logistics, and global cooperation and partnerships. Panayides et al. (2012) identified four key elements to consider in the strategy of integration through the acquisition of subsidiaries by shipping liners, namely, alliances and coalitions, chain structures and value chain constellations, market settings, and policy settings. More recently, there has been an increasing interest in identifying the essential elements that enhance SCI. For instance, Yang et al. (2015) identified top management support, internal integration, information technology, commitment sharing, and long-term relationship are influencing to enhance integration. Furthermore, Yuen et al. (2019) proposed critical factors which are significant for maritime SCI in container shipping, including relationship management, information management, organisational commitment, strategic alignment and performance management.

Group	Shipping activities	Terminal activities	Logistics
AP Moller China	Maersk Line	APM terminals	DAMCO
COSCO Group	COSCO & OOCL	COSCO Ports	COSCO Logistics
NYK Group	Ocean Network Express (ONE)		Yusen Logistics
MSC	MSC	Terminal Investment Limited (TIL)	MEDLOG
CMA CGM	CMA CGM	Terminal Link – CMA Terminals	CEVA Logistics

Table 2-4 Vertical integration in the maritime industry
Source: Notteboom et al. (2022)

Yuen and Thai (2017a) summarised the benefits of SCI in maritime logistics into several themes: demand complementarity, operational synergies, business diversification, reduced transaction costs, access to new markets, and enhanced service quality. Vertically integrated supply chain generates growth in the demand for other logistics services linked to maritime transport such as inland distribution, consolidation, and cargo handling, and can also create opportunities for innovative technology and synergies in operation (Heaver 2002; Lam and Zhang 2014; Yuen and Thai 2017b; Guo and Yang 2019). Additionally, organisations can spread and diversify investment risks such as declining freight rates, overcapacity, and trade imbalances across other supply chain operators having a diversified service portfolio (Frémont 2009; Panayides et al. 2012). The SCI also reduces costs used in searching, identifying, negotiating, and performing inter-firm transactions (Fawcett et al. 2007; Williamson 2008). Collaborative operation among alliance partners enables new market operations through the joint development of assets and knowledge by extending network externality (Bergantino and Veenstra 2002). Lastly, by fostering closer connections and contact with end shippers and customers, all members gain a better understanding of their needs, which in turn enhances the overall quality of logistics services (Yuen and Thai 2017b). Calatayud et al. (2016) also highlighted benefits of enhanced integration across the supply chain, including improved inventory control and visibility, reduced order fulfilment lead time and cycle, more effective monitoring of customer behaviour, increased capacity for designing, monitoring, and implementing logistics plans, and greater logistics flexibility along with improved performance of delivery and logistics assets.

2.1.3.4 Digitalisation of maritime supply chain integration

Sharing information that is accurate, relevant, complete, and confidential in a timely manner with supply chain partners, mentioned in the previous section, has been cited by numerous studies as an essential requirement for achieving competitive advantage and SCI (Li and Lin 2006; Jayaram et al. 2010; Cao and Zhang 2011; Zhang and Chen 2013; Lu et al. 2018; Yuen et al. 2019; Sundram et al. 2020). The IT technologies that enable information sharing are part of the trend towards digitalisation, which transforms key business operations, as well as organisational structures and management concepts (Matt et al. 2015). Carlan et al. (2017) referred digital innovation of maritime supply chain as “new ICT development and more specifically to communication platforms that facilitate the exchange and management of information, IT developments that helps the cargo flow, and technological advancements that monitor the equipment or cargo”. They proposed the three applications of information and communication technology (ICT) in the port sector: electronic data interchange (EDI), vehicle and cargo monitoring, and systems that support cargo flow, all of which are typically initiated by port or terminal operators (Carlan et al. 2017). Tijan et al. (2021a) suggested that the concept of digitalisation encompasses process automation, operations automation, and the processing of information to facilitate business improvements or to innovate the business model in strategic, tactical, and operational perspective. Digital technology also provides advanced connectivity and visibility to supply chain processes, thereby facilitating more effective management of increasingly intricate global supply chains (Wu et al. 2016). Carlan et al. (2018) demonstrated that the enhanced visibility strengthens the linkage among partners with data on processes and products, in turn enabling integration and flexibility of supply chain by multiple case studies of innovation and technology adoption in maritime industry. As ICT platforms replace traditional business models, strong cooperation between multiple stakeholders has been recognised as an essential prerequisite for ICT developments. Van de Voorde and Vanelslander (2014) emphasised the importance of communication through ICT between actors involved in the same supply chain for efficient vertical integration. Calatayud et al. (2016) also argued that the implementation of information technologies and the establishment of information connectivity are essential for facilitate integration across the supply chain.

The complexity of maritime supply chain has a wide range of challenges to information exchange. According to Carlan et al. (2020), existing maritime stakeholders have faced challenges pertaining to data retrieval, which results in inefficiencies such as fragmented information, limited data access, cyber risk, lack of visibility, and increased costs. To address these issues, the introduction and implementation of advanced technological solutions relevant to information and document flow are being considered and implemented. Carlan et al. (2020) also identified barriers to the adoption of ICT technologies, which include technological elements such as incompatibility of operating and strategic goals, lack of tools for new technology implementation in sustainable supply chains, and security challenges. Furthermore, they presented cultural and managerial factors that hinder integrated solutions among maritime supply chain members, such as lack of trust between partners, resistance to change, lack of awareness and tendency about new technologies, hesitation to convert to new systems, and lack of management commitment (Song and Panayides 2008; Carlan et al. 2020). On the other hand, Tijan et al. (2021a) identified success factors for digital transformation in maritime transport through a literature review. From an intra-organisational perspective, key factors include shaping of future strategy towards new business models, the IT knowledge and skills of employees and managers, and dynamic capabilities and readiness for change. In terms of technological aspect, the factors highlighted are digital security and compliance, alignment of business strategies and processes with new technologies, compatibility, interoperability and integration of existing systems with new technology and multiple information platforms, and the development of standards. Lastly, the external environmental factors identified encompass mutual trust between supply chain partners, collaboration and engagement with partners, inter-organisational data and knowledge exchange, and the provision of adequate regulation and support by policymakers. Vanelslander et al. (2016) presented factors for the successful implementation of ICT, including infrastructure for functioning information technologies, ability of transition to emerging technology, adaptability, institutional support for new applications, closely interconnected network among stakeholders, and capability to rapidly and effectively learn new technologies and business patterns. Panayides and Song (2008) pinpointed three key enablers for efficient information exchange among supply chain participants from a port-centric viewpoint: the adoption of electronic data interchange for interaction with partners, the integration of IT platforms for data sharing, and the implementation of advanced logistics service systems for collaboration with other stakeholders.

2.2 Blockchain application in maritime SCI

The maritime industry is undergoing a process of improving global trade processes through the digital transformation of advanced ICT systems, including the integration of the Internet of Things (IoT), big data analysis, cloud computing, and autonomous vessels (Bălan 2018; Shin and Shin 2022). BCT has been viewed as a key digitalisation tool to facilitate the integration of the maritime supply chain. The actual application of BCT in the maritime and shipping industry began to be developed in recent years, and related research has also flourished following this trend (Shin et al. 2023). TradeLens, a BCT-based digital platform developed collaboratively by Maersk, a shipping liner, and IBM, a software company, is a notable example, following this, maritime supply chain operators have been developing various BCT solutions and conducting pilot tests even forming consortia. This section identify what BCT is and consolidates evidence from academia and practice to analyse how it influences maritime SCI, investigating its impacts through a systematic analysis.

2.2.1 Blockchain technology and Supply chain

Blockchain is a distributed ledger database that manages and tracks transaction data that has been Implemented, shared, duplicated, maintained, and synchronised by members of a decentralised network, which is permanent and immutable (Nakamoto 2008). The definition of Blockchain varies among different authors therefore, there is no single and universally agreed-upon definition (Zīle and Strazdiņa 2018). Yaga et al. (2019) described the blockchain by explaining the mechanism of blockchain in terms of a distributed ledger: *"…. distributed digital ledgers of cryptographically signed transactions that are grouped into blocks. Each block is cryptographically linked to the previous one (making it tamper evident) after validation and undergoing a consensus decision. As new blocks are added, older blocks become more difficult to modify (creating tamper resistance). New blocks are replicated across copies of the ledger within the network, and any conflicts are resolved automatically using established rules."* The data in a blockchain is managed by the participating entities without the involvement of central authorities (Scott et al. 2017). Each block within the blockchain is connected through cryptographic hashes of the preceding blocks, and every node possesses an identical copy of hashes of previous blocks (Figure 2-4). Once the involved parties in the blockchain network have verified and validated the blocks, they become immutable. These characteristics ensures transparency and the ability to track transactions, simultaneously improving security and trust over the peer-to peer networks linked by cryptographic hashes (Irannezhad 2020).

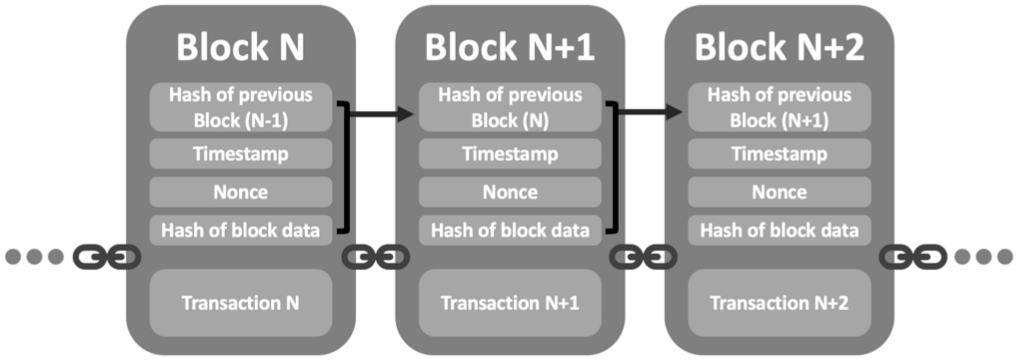


Figure 2-4 Structure of Blockchain overview
Source: Yaga et al. (2019); Shin et al. (2023)

Based on who can access the data in a blockchain, blockchain can be classified as permissioned or permissionless. In a permissionless blockchain network, the system is open and accessible to everyone. Individuals can read the blockchain and issue transactions without approval from a centralised authority. However, maintaining such a network requires considerable resources (Blossey et al. 2019). On the other hand, in a private blockchain, participants must receive an invitation for authorisation or permission to join the network in order to create blocks, which ensures their identifiability by a consortium of members or by single entity. Identified users within the network are able to establish a robust trust relationship each other (Wang et al. 2018; Yaga et al. 2019). A regulatory authority can determine the degree of participation according to the level of trust with users. Given that each connected member contributes to maintaining the blockchain in a decentralised manner, the network does not require the extensive resource expenditure and maintenance that a public network requires (Cole et al. 2019).

Considering these characteristics, a permissioned blockchain is typically established by business organisations. In a decentralised system, data can be accessed, observed, stored, and updated by various participants, leading to the elimination of intermediaries and full visibility of transactions for members of the supply chain (De Giovanni 2020).

The consensus mechanism in a blockchain is a set of cryptographic rules and processes that allows all the nodes (participants) in the network to agree on the state of the blockchain's ledger in time sequence chains (Hald and Kinra 2019). When a new block of transactions is created, it must be validated and agreed by the participants. Since blockchains operate in a decentralised manner without a central authority, consensus mechanisms are crucial for maintaining the integrity and security of the data. These mechanisms are designed to prevent fraudulent transactions and ensure that all participants have a consistent view of the ledger, which is key to the trust nature of blockchain technology.

BCT also enhances the ability to trace events and activities in the network such as supply chain. It offers real-time verification of a product's proof of provenance and authenticity to all parties involved in the transactions (Chang et al. 2020). With the dissemination of shared data, blockchain not only increases the visibility of tracking details related to product logistics as captured by IoT sensors, but it also secures the accuracy of the recorded transaction data (Blossey et al. 2019). Such capabilities have the potential to improve efficiency in the maritime and shipping industries. Wang et al. (2020b) summarised the attributes that BCT can provide when applied to the supply chain as follows: Immutability, decentralisation, trust, transparency and visibility, security, and a global network. According to Wang et al. (2019), BCT is expected to penetrate supply chain areas such as extended visibility and traceability, simplification, trust building, and disintermediation.

Blockchain technology, an advanced and encrypted database technology, is at the forefront of digital transformation and integration within the maritime supply chain. Blockchain technology, with its decentralised network, ensures transparency, traceability, security, and trust by maintaining immutable transaction data that all participants can access and verify (Yang 2019). This results in the elimination of intermediaries and full visibility of transactions for supply chain members. Additionally, BCT bolsters trust among supply chain partners through its mechanism, which validates transactions via the consensus of participants. It also enhances traceability within the supply chain network by providing real-time proof of product origin and authenticity (Wang et al. 2021a). With the shared information, these features ensure not only visibility through tracking information but also the integrity of transaction information. Such benefits promote SCI in the maritime and shipping sectors, contributing to performance improvement.

2.2.2 A systematic literature review regarding blockchain technology applied for maritime supply chain integration

The current study conducted a systematic literature review to understand the current state of academic interest in BCT application in the maritime supply chain. However, due to the relatively recent emergence of the topic and to bridge the gap with industry practices, the study progressed by consolidating evidence from practical sources (Rowley and Slack 2004). A systematic literature review is a methodical approach that enhances replicability, scientific rigor, and transparency by conducting thorough literature searches to minimise bias (Petticrew and Roberts 2008). This method differs from traditional narrative reviews by systematically compiling and analysing extensive information to provide an objective assessment in response to a specific research question. The systematic literature review in this study was conducted to achieve the following objectives: to identify the current application domains of BCT in the maritime supply chain and to understand the key influences of BCT on maritime SCI. Based on the results of this review, the findings will be utilised to develop variable constructs for future empirical research.

Elements of the systematic literature review for this research were published in an academic journal and the findings have been restructured here to align with the thesis' objectives (Shin et al. 2023). This is included in Appendix A, where the entire process and results are presented. Through an initial search using keyword selection, a total of 183 academic articles were identified from Scopus, and 170 practical sources from Lloyd's List published from 2016 to 2021 were identified (Ducruet et al. 2015; Davarzani et al. 2016; Shanshan et al. 2019). Following a thorough full-reading process based on inclusion and exclusion criteria, the final number of sources was reduced to 73 academic and 75 practical evidence, respectively (Lim et al. 2019).

The systematic review provided a descriptive overview of information regarding studies on the application of BCT in the maritime supply chain. It covered the areas or sectors focused on, related benefits and challenges factors, as well as data utilised, methodologies employed, and findings from the research. Table 2-5 represents the theoretical approach and research method of collected academic literatures. As the results indicate, research on BCT in the maritime supply chain sector is concentrated on the analytical approach, with conceptual and review research occupying the largest proportion as methods. In contrast, studies that have chosen the empirical approach are in the minority, with case studies being the primary method adopted. These findings suggest that BCT research in the current maritime supply chain discipline is in its nascent stage, focusing on establishing a theoretical foundation. Additionally, through the review of practical articles, not only information on the development and utilisation of BCT in the maritime and shipping industry, but also the objectives and functions of its applications, was provided from a practical perspective. The analysis focused on identifying the characteristic elements through which BCT can contribute to the maritime SCI, and on classifying the domains where BCT is being applied within the maritime supply chain. This was achieved by consolidating and categorising the results from review analysis from academic articles and case studies gathered from practical articles. The findings present the domains where BCT applications are being utilised, the functions they serve within those domains, and the effects they have on the SCI.

Theoretical building		**No.**	**Research method**	**No.**
Analytical		31	Conceptual research	21
	Analytical conceptual	30	Review	12
	Analytical mathematical	4	Content analysis	1
Empirical		15	Case study	9
	Empirical statistical	13	survey	2
	Empirical case study	5	Interview	3
			Observation	1
			Quantitative empirical	4
			Math modelling	3
Other			Design	11

Table 2-5 Distribution of theoretical approach and research method
Source: Shin et al. (2023)

2.2.2.1 Blockchain application domains and benefits

The research focus of the reviewed papers encompasses various areas within the maritime supply chain. BCT use cases have been categorised into different types of organisations such as shipping liners, ports, software companies, insurance firms, and banks, according to the results of the review analysis from practical sources. During this period, a total of 20 BCT solutions, projects, and pilot tests of various scales were developed and implemented by a range of leading companies. The result of case study is organised in Table 2-5. Seven BCT solutions and pilot tests developed primarily by shipping liners, while three have been developed by port authorities or terminal operators. Eight solutions have been developed for supply by software companies, and financial organisations such as insurance companies or banks have invested in the development of two solutions. Their common aim is to digitise paperwork and connect related stakeholders along the supply chain on a standardised platform that enables real-time and seamless information sharing with enhanced transparency, visibility, and security while reducing costs and saving time. The case study results revealed that various projects based on BCT have been implemented, however, as time passed, this trend has concentrated into two main BCT consortia, namely TradeLens led by Maersk and IBM, and the Global Shipping Business Network (GSBN) led by COSCO. Participants in the maritime supply chain joined these consortia with the goal of integrating processes such as document exchange, cargo booking, and tracking through BCT solutions. Nevertheless, TradeLens decided to cease operations after 2023 due to limitations in achieving global integration as an open and neutral platform, which was more to do with the business case rather than the technology itself (Wee 2022). On the other hand, GSBN continues to collaborate with carriers, terminals, and financial partners, including Japanese liner operator Ocean Network Express (ONE), Hapag-Lloyd, PSA, Hutchison Ports, OOCL, CMA-CGM, MSC, and others. GSBN is expanding the application of BCT not only in maritime operations such as issuing electronic Bills of Lading (eBL), cargo release, and trade finance but also in sustainability areas such as safe transportation and decarbonisation (GSBN 2024). This indicates that while some blockchain initiatives in the maritime supply chain face challenges, others are finding ways to continue and even expand their applications, demonstrating the potential for BCT to integrate maritime supply chain.

Company types	Lead company	Name of project	Main partners	Participating members	Year	Role and aim
Shipping liner	MOL		NYK Kawasaki, and NTT Data	14 members	2017	Trade data sharing platform to streamline procedure and reduce costs
	Hyundai Merchant Marine		Oracle, Samsung SDS, IBM Korea, Busan Port authority	38 members	2017	Blockchain consortium for shipment booking and cargo delivery
	APL		Kuehne+Nagel, InBev, Accenture,		2018	Solution to eliminate shipping documents and save logistics costs
	Pacific International Lines		PSA International and IBM Singapore		2018	Blockchain-based electronic bill of lading to cut the traditional paper trail and streamline the process
	Maersk	TradeLens	IBM	300 members	2018	Open and standardised platform for interaction through real-time access to shipping data and shipping document, including IoT and sensor data
	Ocean Alliance carriers	GSBN (Cargo Release)	Bank of China, DBS Bank, HSBC		2019	Blockchain-based open platform to connect stakeholders and allow them to digitise and organise dangerous goods documentation
	China Merchants Energy Shipping	Britc	China Merchants group		2021	Reliable platform for a shipping service platform, a documentation and contract system, as well as an information-sharing centre in dry bulker and tanker industry

	Authorities at the Port of Antwerp		T-mining, PortXL programme		2017	Platform to optimise efficiency in the container handling logistics chain by eliminating physical paperwork
Port	ABU Dhabi Ports unit Maqta Gateway	Sisal	Maritime SC		2018	Blockchain system providing seamless and secure link between stakeholders across the trade community with encrypted documentation
	Port of Rotterdam Authority		Samsung logistics and ABN Amro		2018	Open, independent and global platform for paperless integration of physical, administrative and financial streams within international chain
	Marine Transport International		Solas VGM		2017	Programme leveraging the legal requirements
	ShipNext		300 cubits		2018	Selling digital token for secured and reliable transactions in cryptocurrencies
Software companies	300 Cubits		Westports, LPR		2018	Deposit system using BCT and TEU token to address the problem of cargo 'no-shows' and 'rollovers'
	EY and Guardtime	INSURWAVE		4 members	2018	Digital platform for marine hull insurance
	CARGOSMART		Oracle		2018	Solution for supply chain parties to auto-fill repeated and verified information
	CargoX				2018	Blockchain-based electronic bill of lading
	Wave BL		Hapag-Lloyd, Zim, MSC		2020	Blockchain-based electronic bill of lading

	BunkerChain	TrustTrade	Singapore’s Infocomm Media Development Authority		2021	Real time visibility and control of the physical bunkering process with full audit trail
Insurance	LLOYD’S Register Foundation	MBL consortium	Blockchain Labs for Open Collaboration (BLOC)	8 members	2018	Tracking the risks and challenges associated with the declaration and handling of dangerous goods
Bank	BNP Paribas and HSBC Singapore				2018	Digitised letter of credit transaction and digitalisation of trade finance

Table 2-6 The cases of blockchain application in the maritime industry

Source: Shin et al. (2023)

When it comes to academic sources, the majority of the articles did not focus on a specific supply chain sector or operator, but rather provided conceptual frameworks that provide a holistic view of BCT adoption across the entire supply chain (Lambourdiere and Corbin 2020b; Pu and Lam 2020; Liu et al. 2021). Tsiulin et al. (2020b) and Bavassano et al. (2020) identified significant factors in the implementation of BCT in the maritime sector. Meanwhile, Nguyen et al. (2020) and Balci and Surucu-Balci (2021) focused on identifying the risks and barriers to BCT adoption in the maritime supply chain and validated causal relationships between them. Li and Zhou (2020) investigated how BCT is implemented in the process of movement of cargo, document exchange, and contact execution among supply chain operators, such as shipping liners, ports, and forwarding companies. More specific research field of BCT application include port logistics and terminal operation (Henesey et al. 2019; Liu and Wu 2020; Ahmad et al. 2021), transaction and documentation in smart contract (Todd 2019; Wunderlich and Saive 2019; Narayanam et al. 2020), financial sector (Philipp et al. 2019; Pečarić et al. 2020), vessel operation (Perera and Czachorowski 2019; Petković and Vujović 2019). Due to the nascent stage of BCT application in the maritime supply chain, the reviewed articles have shown a tendency for over half to adopt an analytical rather than an empirical approach from theoretical lens, with conceptual research and review analysis being the predominant methodological approaches.

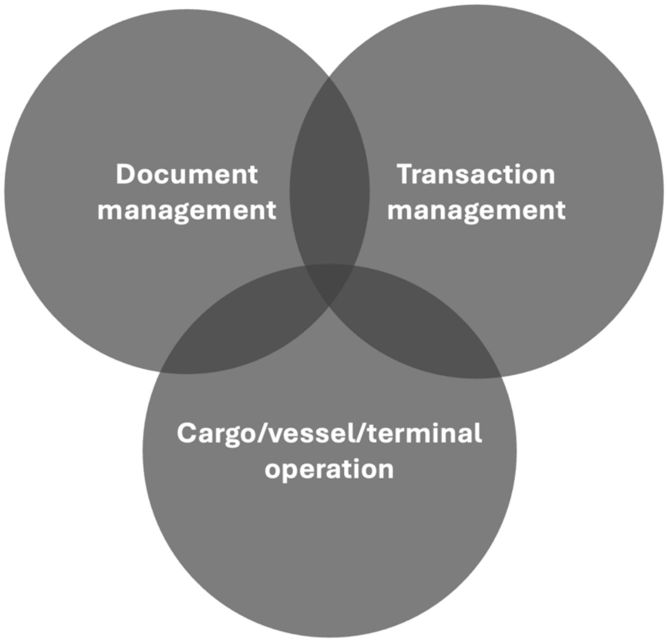


Figure 2-5 Blockchain application domains in the maritime supply chain
Source: Author

The BCT domain in the maritime supply chain can be divided into three main categories by functionality: document management, transaction management, and cargo/vessel/terminal operation. As presented in Figure 2-5, firstly, the document management domain includes significant changes in the processes of document digitalisation, real-time information exchange and accessibility, data management, and document unification. Maritime organisations can shorten process by digitising documents, thereby improving efficiency and reducing the cost and time spent on paperwork (Nærland et al. 2017; Gausdal et al. 2018; Jabbar and Bjørn 2018; Jensen et al. 2019; Jović et al. 2019; Wunderlich and Saive 2019; Yang 2019; Li and Zhou 2020; Pečarić et al. 2020; Perkušić et al. 2020; Peronja et al. 2020; Pu and Lam 2020; Tsiulin and Reinau 2021). Additionally, BCT systems enable smoother and seamless access to and exchange of information about documents, shipments, and transactions in real time, enhancing flexibility (Lambourdiere and Corbin 2020b; Pranav et al. 2020; Tsiulin et al. 2020b; Ahmad et al. 2021; Bae 2021; Liu et al. 2021; Sangeerth and

Lakshmy 2021). Data managed on a distributed ledger in an encrypted form is immutable to modifications or changes, and traceable and trackable, which reduces the risk of fraud and attacks (Petković and Vujović 2019; Ho and Hsu 2020; Irannezhad 2020; Tan and Sundarakani 2020; Ahmad et al. 2021). Finally, a shared BCT system using standardised document formats resolves the issue of duplication that can occur in document exchange among multiple stakeholders, ultimately improving transaction speed and efficiency (Jović et al. 2019; Pu and Lam 2020; Tsiulin et al. 2020b).

Secondly, the adoption of BCT solutions is expected to address the issues of complexity and inefficiency in the existing transaction systems within the maritime supply chain through the transition to smart contracts. BCT factors applied to transaction management include the decentralisation of the supply chain, a consensus mechanism for transactions, automated transactions, data management, and platform standardisation. In a decentralised BCT system, instead of a central authority or intermediary traditionally responsible for storing and managing data, the data is spread across all parties. This prevents the monopoly of data and minimises peer-to-peer communication, thereby simplifying transactions and accelerating the speed of execution of trade contracts (Gausdal et al. 2018; Petković and Vujović 2019; Philipp et al. 2019; Li and Zhou 2020; Papathanasiou et al. 2020; Pečarić et al. 2020; Perkušić et al. 2020; Pranav et al. 2020; Tan and Sundarakani 2020; Tsiulin et al. 2020a). Transactions are only proceeded with the consent of the participants through a consensus mechanism, ensuring trust and coordination among supply chain operators (Lambourdiere and Corbin 2020b; Peronja et al. 2020; Sampath et al. 2020; Sangeerth and Lakshmy 2021). A BCT system combined with a smart contract algorithm automates and simplifies the necessary certifications for transactions, such as payment approval, transaction reporting, document passing, and freight rates (Nærland et al. 2017; Jugović et al. 2019; Philipp et al. 2019; Segers et al. 2019; Pečarić et al. 2020; Tan and Sundarakani 2020; Irannezhad and Faroqi 2021; Zhong et al. 2021). As documents are managed, transaction data is also managed in an encrypted form, ensuring security and privacy, while the authority to access transaction history and conditions in real time ensures visibility and traceability (Philipp et al. 2019; Liu and Wu 2020; Pu and Lam 2020). Transactions with these features are managed on a standardised platform, contributes to the ease of access and data management (Jensen et al. 2019; Jović et al. 2019; Jugović et al. 2019; Yang 2019).

The last application domain is the role of BCT systems as a bridge to data associated with the physical level. This area includes cargo management, terminal operation optimisation, connectivity with IoT, and vessel data management. Cargo tracking information, which includes location and condition, is recorded on the blockchain at each point of the entire delivery process and verified in real-time by all participants (Xu et al. 2018; Jugović et al. 2019; Yang 2019; Liu and Wu 2020; Narayanam et al. 2020; Papathanasiou et al. 2020; Peronja et al. 2020; Ahmad et al. 2021). As cargo moves, smart contracts automatically validate the authenticity based on consensus mechanism (Hasan et al. 2019; Pang et al. 2020; Pu and Lam 2020; Tan and Sundarakani 2020; Alkhoori et al. 2021; Munim et al. 2021; Zhong et al. 2021). This assists each operator in facilitating efficient planning of operations. The real-time sharing of exact information on the arrival time and location of cargo contributes to terminal operators' ability to prepare optimal stowage planning (Hasan et al. 2019; Henesey et al. 2019; Jović et al. 2019; Liu and Wu 2020; Ahmad et al. 2021; Tsiulin and Reinau 2021; Wang et al. 2021a). This leads to potential congestion reduction within ports and terminals, labour cost reduction, improved time management for organising cargo, decreased lead times resulting in enhanced cycle times, and ultimately, improved environmental sustainability (Vujičić et al. 2020). BCT provides the secure storage and sharing of data collected from IoT devices such as RFID and GPS attached to containers, equipment in terminals, and vessels (Allen et al. 2019; Perera and Czachorowski 2019; Philipp et al. 2019; Pang et al. 2020; Tan and Sundarakani 2020; Tsiulin et al. 2020b; Ahmad et al. 2021; Irannezhad and Faroqi 2021; Munim et al. 2021). The integration of data related to vessel operations with BCT systems with the previously described features, has the potential to be used in autonomous ship control (Petković and

Vujović 2019). The application domains of BCT, the application factors within each domain, and the benefits are presented in Table 2-6, as the finding of the systematic literature review.

Blockchain domain	Application factors (Number of papers/cases)	Benefit factors
Document management	Document digitalisation (13/11) Real time information (9/5) Data management (16/4) Document unification (3/1)	Improved efficiency Traceability and trackability Real-time access and sharing Visibility and transparency Cost reduction Immutability Sustainability
Transaction management	Decentralisation (14/3) Consensus mechanism (8/3) Automated transaction (8/2) Data management (4/4) Platform standardisation (4/6)	Improved efficiency Simplification Real-time access and sharing Visibility and transparency Trust Standardisation
Cargo /vessel /terminal operation	Cargo management (16/4) Terminal operation optimisation (8/1) Connectivity with IoT (9/0) Vessel data management (2/0)	Improved efficiency Traceability and trackability Cost reduction Immutability Sustainability Compatibility with other technology

Table 2-7 Blockchain application factors

Source: Author

2.2.2.2 Impact of blockchain technology on maritime supply chain integration

The systematic literature review has confirmed a growing academic and practical interest in the application of BCT within the maritime supply chain. The findings, derived from the analysis of content from published articles and industrial cases, have identified the domains where BCT is applied in the maritime supply chain, as well as the roles and benefits of BCT within each domain. The objective of BCT solutions, projects, or consortia is to maximise the efficiency of the flow of documents, transactions, and physical information related to cargo, terminal, vessel operation exchanged within the maritime supply chain. In each domain, the core function of BCT is the ability to manage and share information in real-time, quickly, securely, and transparently. This aims to achieve the integration of a digitalised maritime supply chain, ultimately enhancing the performance of supply chain operations.

Previous studies have also implied that the characteristics of BCT systems are suitable for enhancing SCI. Korpela et al. (2017) conducted a focus group study that demonstrated the potential of BCT to support the integration of digital supply chains. However, they emphasised that while data integration can be achieved within a blockchain system, a standardised data model is necessary to integrate supply chain systems effectively. Wang et al. (2020b) argued that BCT can significantly impact SCI because of the similarity of characteristics between blockchain and supply chain networks in terms of comprised structure, decentralised decision-making, and reliance on the connection among nodes or partners, which requires a certain level of integration and collaboration. Wang et al. (2020a)'s pilot study concluded that the features of BCT such as information sharing, trust, and traceability strengthen SCI elements like visibility, agility, and flexibility. Li et al. (2021) provided evidence that for BCT to impact performance, it must be supported by SCI. Tan et al. (2023) demonstrated that the visibility characteristic of BCT networks supports SCI, thereby impacting performance improvement in manufacturing supply chain. Kamble et al. (2023) also highlighted the positive relationship between blockchain and SCI in the automotive industry. The previous three studies analysed the mediating impact of SCI in the direct relationship between BCT and performance. While numerous studies utilising empirical data support the argument that BCT facilitates SCI, this perspective is on the general supply chains, and there is a shortage of evidence for the maritime supply chain. To provide evidence for this, this study conducts an analysis through the process of hypothesis and conceptual model development that reflects a theoretical perspective to verify the relationships between the previously established maritime SCI, the organisation's IT competency, and the BCT applied to the maritime supply chain, and finally, the performance improvements that can be achieved through the relationship.

2.3 Research gap

Numerous studies have contributed to research on the concepts of SCM and SCI within the maritime field. Although the maritime industry's integration strategies, particularly with the advent of advanced technologies, are gaining interest, related research remains comparatively limited. By conducting a comprehensive review of the existing literature, this study has identified research gaps that need to be addressed, which are summarised below.

Research gap 1. There is lack of understanding of maritime supply chain because of confusion between the concept of maritime logistics and supply chain.

Through a comprehensive literature review, it was confirmed that the integration of supply chains is a central element SCM. This trend is also evident in the maritime supply chain sector. The concept of SCI has been predominantly focused on integrating the entire process from production to delivery of products, from the perspective of manufacturers, suppliers, and customers. The systematic literature review by Fabbe-Costes and Jahre (2008) has presented evidence that validated SCI practices enhance the strategic relationships between supply chain partners and positively influence the flow of products and information, leading to more effective and efficient performance improvements. This finding is corroborated by Khanuja and Jain (2020), whose research spans various sectors including manufacturing, electricity, retail, healthcare, and hospitals. Despite these insights, research on SCI within the maritime sector tends to be narrowly focused on specific areas such as ports, with a shortage of studies addressing the broader concept of maritime logistics integration.

The literature review concerning maritime SCI indicates that the existing concepts of SCM have not been adequately adapted to the maritime sector. This reflects a shortfall in readiness for research into the efficiencies of maritime processes that could be achieved through vertical integration. For instance, research by Yuen and Thai (2017a) and Yuen et al. (2019) explored barriers and critical success factors within maritime SCI in the container shipping industry. However, these studies applied traditional SCI concepts from the perspective of manufacturing domain without fully incorporating the service-centric perspective of maritime logistics or the distinct features of maritime operators. This suggests that research in maritime SCI might face difficulties in obtaining results that are distinct from traditional SCM concepts. Consequently, this study seeks to redefine the concept of the maritime supply chain as a service supply chain through a review of the literature. It aims to provide empirical evidence of its specialised relationships, using a theoretical framework specifically developed for the maritime supply chain context.

Research gap 2. There is a deficiency in empirical evidence to determine the impact of blockchain utilisation on the integration of maritime supply chain.

As explored in Section 2.3 through a systematic literature review, BCT is being actively adopted as a means of integrating the maritime supply chain.

Furthermore, various reviews and conceptual literature have established that BCT is expected to positively affect multiple aspects of maritime SCI. However, empirical evidence validating the impact of BCT on maritime SCI and performance is scarce (Shin et al. 2023). Given that the application domains and the role of BCT have been identified through a systematic literature review, the next step is to empirically verify the influence of BCT adoption within the industry to confirm its effects. Therefore, this study focuses on statistical analysis to validate the enhancement of SCI through the adoption of BCT in the maritime sector, employing research models and empirical data. Ultimately, it aims to present the outcomes of BCT's impact on performance and provide a rationale for its adoption.

Research gap 3. The need to examine the impact of BCT adoption and utilisation in maritime supply chain with empirical analysis evidence through theoretical approach.

The application of BCT for the integration of the maritime supply chain is considered a subject that needs to be validated. However, in order to investigate the technological integration, it is essential to establish a theoretical foundation that facilitates an understanding of the various factors influencing the adoption and use of technology. These theories provide a conceptual and theoretical framework that explains how users accept and utilise new technologies, and the advantages they acquire from them (Salahshour Rad et al. 2018). Due to the limitations of merely analysing BCT's role in the different SCI strategies of various organisations, this research aims to examine how organisations leverage IT resources to gain competitive advantage by applying Resource-Based approach.

Researchers with a focus on operations management, and particularly on SCM, have not extensively utilised the theory (Zhang and Dhaliwal 2009). There are substantial opportunities to merge insights from organisational theory with SCM to develop an understanding of the reasons why certain operational strategies (such as those related to the development and leveraging of IT competencies) may confer a long-term competitive advantage to supply chains. Additionally, it is important to explore how companies strive to find a balance between adhering to industry best practices and maintaining their unique operational characteristics. In this perspective, this study introduces the concept of IT competency, representing the IT resources and utilisation of them by the maritime operators, to demonstrate the role of BCT according to the condition of the organisation's IT competency and different SCI strategies.

2.4 Summary

This chapter has primarily focused on reviewing literatures related to the topic of maritime SCI and BCT. The outcomes of this review have established a foundation for the theoretical framework and conceptual model of this thesis.

Section 2.1 established the concepts related to maritime SCI by reviewing literature on maritime logistics and the maritime supply chain, aiming to identify definitions, scopes, and key elements. Initially, the section examined explored literature on SCM and service supply chain to adopt these concepts to the maritime supply chain, which has unique characteristics distinct from other industry. Since the traditional supply chain are mainly manufacturer-centric, the concept of service supply chain which is centred from perspective of service providers was deployed for the reinterpretation of the maritime supply chain. Through this analytical process, it was possible to conceptualise the supplier-customer relationships among major maritime operators—such as shipping liners, port terminals, and freight forwarders. By clearly defining the participants, scope, and relationships within the maritime supply chain, the section provides theoretical foundation necessary for developing current research models and the selection appropriate targets for data collection.

Subsequently, the studies to elaborate the layers, scope and dimensions of SCI were analysed. Relevant research supported identifying antecedents of SCI such as information and communication, operational coordination, and strategic alliances, which will serve as components of the research model for SCI. Focusing on these characteristics, the analysis examined how integration had occurred within the maritime industry, particularly in container shipping. The findings suggested that a strategic shift from horizontal integration to vertical integration is a key strategy in contemporary maritime SCM, aiming to achieve a complete door-to-door service. In addition, innovative ICT are being utilised to facilitate frequent integrative activities among partners, aligning with the trend of digitalisation in the maritime industry. In accordance with this, the role of technologies in integrating the supply chain and the benefits were elaborated.

Finally, for the comprehensive understanding of the adoption of BCT as a key technology for SCI within the maritime supply chain, a systematic literature review was conducted. BCT has emerged as solutions being demonstrated under the leadership of various maritime stakeholders. These solutions are being directly implemented in three main domains: document management, transaction management, and the operations of cargo, vessels, and terminals. While the literature suggests that the characteristics of BCT strengthen SCI and, consequently, have a positive impact on performance, it also indicated a lack of empirical research in the field of the maritime supply chain.

As a result of literature review of this chapter, the research has clarified the concept and elements of maritime SCI and identified the domains and characteristics of BCT adoption that facilitate integration in the maritime industry. Building on this, the next chapter aims to discuss the theoretical background that will be the foundation for establishing a model to verify the relationship between maritime SCI and BCT.

Chapter 3 Theoretical background

Chapter 2 dedicated to exploring the previous literatures and identifying research gaps to justify this study. This chapter addresses the theoretical background that form the basis for the development of a research model and the establishment of hypotheses prior to conducting empirical analysis. The first section of this chapter delves into the Resource-based View (RBV), discussing how organisations perceive and utilise their resources to secure a competitive advantage. This research deployss a RBV to interpret, from a theoretical perspective, the role and interrelationship of two key organisational resources: the capability to efficiently integrate and operate the supply chain and the ability to possess and utilise BCT as an IT resource, as explored in Chapter 2. In this research, it is hypothesised that the way firms perceive and employ IT resources, specifically blockchain technology, plays a critical role in the successful execution of SCI strategies. Therefore, after exploring the background of the RBV, discussion of the way an organisation acknowledges IT as resources in order to leverage them as a competency is followed. The second section of the chapter includes Porter's value-chain concept, examining the processes and activities that form an organisation's value stream. It further extends to link the organisational resources and capabilities identified through the RBV with corresponding activities in the value chain. This discussion lays a comprehensive theoretical background, elucidating how organisations generate value internally and leverage their resources and capabilities, particularly in the realm of IT and supply chain management, to gain a competitive advantage.

3.1 Resource-Based View

Resource-based view (RBV) originated from the discipline of strategic management, which suggests the performance of a firm is determined by the uniqueness and variety of its resources and capabilities (Wernerfelt 1984; Barney 1991; Mata et al. 1995). From the RBV perspective, a company's ability to gain a competitive advantage and improve its performance hinges on the strategic utilisation of its unique resources, which are characterised by their value, rarity, irreplaceability, and difficulty to imitate (Rumelt 1984; Barney 1991). The characteristics of resource heterogeneity and immobility are deeply connected to sustained competitive advantage (Mata et al. 1995). If a company possesses a resource or capability that other companies also possess, it cannot be recognized as a competitive advantage. Conversely, even if a company possesses a resource or capability that other companies do not have, it must not be easily replicable by others to ensure the sustainability of the competitive advantage. These features are organised into the model presented in Figure 3-1.

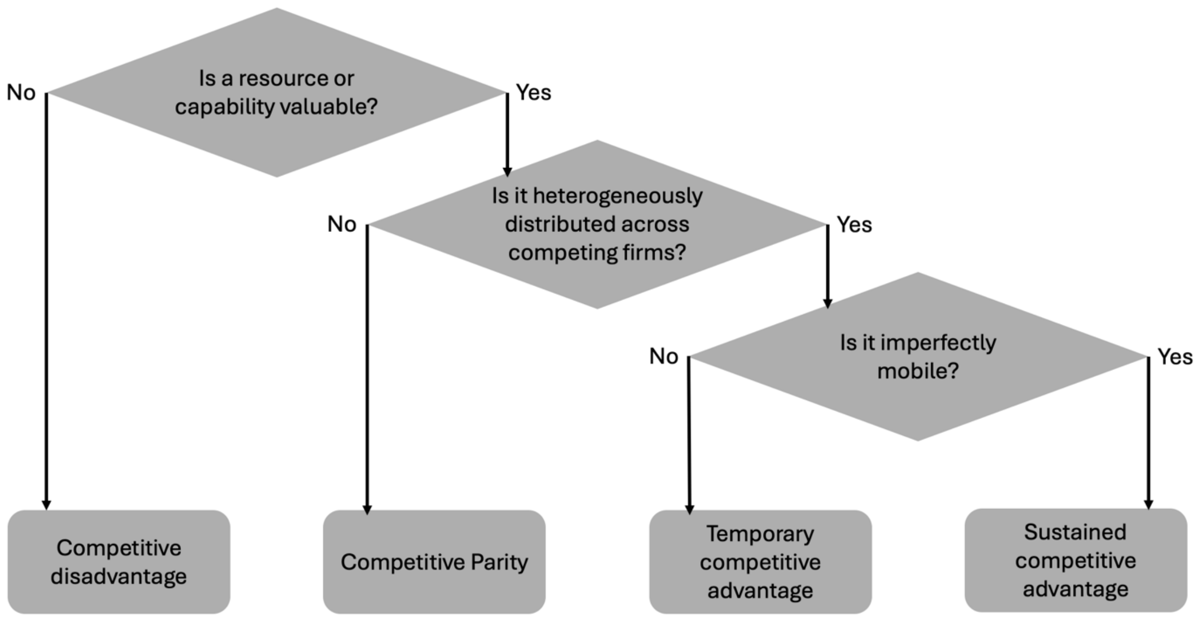


Figure 3-1 A Resource-Based Model of Competitive Advantage
Source: Mata et al. (1995)

Specifically, resources encompass a wide range of assets, organisational processes, knowledge, firm attributes, information, capabilities, and other potential factors that can provide a competitive advantage, which are owned or controlled by the central firm (Barney 1991). However, Grant (1991) argued that resources are the source of a firm's capabilities, and capabilities, in turn, are the source of competitive advantage, emphasising a distinction in meaning between the two. He suggested six major categories of resources: financial resources, physical resources, human resources, technological resources, reputation, and organisational resources. Wade and Hulland (2004) described a resource as any asset or capability that a firm can use effectively to recognise and capitalise on market opportunities or to mitigate market threats. In this context, Barney (1991) proposed three classification of resources: physical capital resources, human capital resources, and organisational capital resource. Fahy (2000) expanded and clarified the categories into tangible assets, intangible assets, and capabilities in a more comprehensive and precise manner.

Tangible assets refer to fixed physical assets and financial capital that a company owns with a fixed long-run capacity. These include capital assets such as factories, equipment, and land, as well as produced goods, stocks, financial debtors, and bank deposits (Grant 1991; Fahy 2000). Intangible assets refer to knowledge assets that include not only intellectual property such as reputation, brand image, and product quality but also human-based resources including technical skills and know-how, as well as dimensions such as culture, training, and loyalty (Bharadwaj 2000; Hall 2009). Teece (1998) noted that intangible assets contribute to the ability to respond to the expansion and transformation of industries, going beyond cost reduction and the point of profitable reinvestment in a firm's market. Lastly, capabilities refer to a firm’s ability to deploy resources, usually a combination of organisational, functional, and technological skills, in a manner that effectively and efficiently executes strategies to achieve competitive advantage and adapt to changing market conditions (Amit and Schoemaker 1993; Teece et al. 1997). Due to these characteristics, capabilities are often classified separately from resources when defining assets, distinguishing between tangible and intangible assets. Capabilities play a crucial role in applying, integrating, and reconfiguring both internal and external resources, thereby making a more critical contribution to a firm's success than both tangible and intangible assets

(Galbreath 2005; Mikalef and Pateli 2017). Huo et al. (2016) clearly differentiated between resources and capabilities in the context of the mechanisms for achieving competitive advantage. Resources are defined as the inputs that an organisation owns or controls, while capability is the ability to deploy resources using organisational processes in order to achieve competitive advantage (Amit and Schoemaker 1993). For instance, the study by Ravichandran et al. (2005) distinguished between resources as the source of capability and capabilities as the source of competitive advantage, examining the direct relationship between them on competitive advantage. The utilisation of these assets and capabilities serves as a source of sustainable competitive advantage in achieving a firm's strategy and enables business processes to be operated more efficiently and effectively (Wernerfelt 1984; Barney 1991; Ray et al. 2004). The RBV enables organisations to identify their strengths and weaknesses, address the issues associated with their weaknesses, and enhance their strengths as part of their strategic development (Barney 2001). Organisations can forge a sustainable competitive advantage that is challenging for competitors to replicate by concentrating resources (Miller 2003). Therefore, the RBV offers an all-encompassing framework for evaluating an organisation's competitive position and developing potent long-term strategies, which assists in benchmarking their unique resources and capabilities against industry standards (Malhotra et al. 2024). This approach aids to understand resource gaps compared to the best performance and supports the strategic planning process to develop and acquire critical resources required for competitive advantage (Peteraf 1993).

In the realm of operations management, organisational capability is recognised as a means to intended or realised competitive performance or operational robustness (Peng et al. 2008). Various types of organisational capabilities have been identified, with core or local capabilities being described as unique sets of competencies found within individual units that operate in comparatively stable environment (Kusunoki et al. 1998; Wade and Hulland 2004). On the other hand, capabilities known as dynamic, architectural, and process capabilities refer to the capacity to integrate, develop, structure, and reconfigure both internal and external competencies in order to create a series of sustained competitive advantages in unstable and changeable environments (Schreyögg and Kliesch-Eberl 2007; Huh et al. 2008). Core dynamic capabilities can represent an organisation's capability to integrate internally and externally within the supply chain. Key capabilities include information technology, information systems, human resources, information sharing, communication, inter-firm relationships, and network collaboration (Grant 1996; Teece et al. 1997; Kusunoki et al. 1998; Bharadwaj 2000; Aral and Weill 2007; Huo 2012).

The RBV has been adopted in the SCM research to explore how firms gain a sustainable competitive advantage. Rungtusanatham et al. (2003) considered integrated linkage between supply chain partners as a key factor of SCM (Armstrong and Shimizu 2007; Newbert 2007). They suggested the two perspectives on how the ability to manage the supply chain enhances operational performance: one views SCI as a resource that provides operational performance benefits to a firm, and the other sees it as a capability to acquire resources that yield benefits to the firm's operations. The first approach views SCI itself as a resource that is valuable to the firm, rare to come by, imperfectly mobile, not imitable by competitors, and not substitutable (VRINN). It guarantees the flow and quality of material and information, thereby creating an operational performance advantage for the firm. The second perspective views SCI as a connection between the focal firms and its supply chain partners that allows the firm to acquire a VRINN resource (Huo 2012; Xu et al. 2014). This means that SCI is a capability that supports the acquisition of VRINN resources, which take the form of explicit and tacit knowledge, thereby enabling better management of the flow and quality of materials and information (Grant 1996; Lee and Whang 2000; Rungtusanatham et al. 2003). The research concluded that if SCI is represented as a resource, it has a direct effect on performance, whereas if it is represented as a capability, it has an indirect effect on performance. As a result, preserving the VRINN properties of SCI, a firm can enjoy sustainable operational performance benefits. This research adopts the perspective of the RBV to establish an understanding of integration and IT competency within the supply chain. SCI is considered as an organisational capability that contributes to the improvement of supply chain operations performance. Meanwhile, IT competency is recognised a critical resource that can have a positive impact on firm performance. These concepts will be further elaborated in the subsequent section.

3.1.1 IT competency from the RBV perspective

Innovation can be seen as an evolutionary process when an organisation adopts new devices, systems, processes, policies, or services (Damanpour 1987). To achieve this, organisations must possess the capability to deploy their resources in order to develop new competencies that generate value. In other words, innovative capability denotes an organisation's capacity to consistently convert knowledge and ideas into new products, processes, and systems (Yang et al. 2009). Traditionally, new technologies, products, and services are classified as technological innovation, while new procedures, policies, and organisational structures are categorised as administrative innovation (Stoel and Muhanna 2009). In the realm of technological innovation, IT is not merely a collection of hardware, but a socially constructed concept. This underscores the importance of considering how technology is embedded and utilised within society. The use of IT extends beyond simple technological advancement, influencing economic value creation through social interaction and other impacts. From this perspective, Salomon et al. (1999) defined IT as "a family of technologies used to process, store, and disseminate information, facilitating the performance of information-related human activities, provided by, and serving both the public at-large as well as the institutional and business sectors."

With the increasing technical and social importance of IT, along with its growing significance as a tool for both internal and external communication, IT capability has risen to prominence as a critical resource that companies must effectively manage (Saraf et al. 2007). To achieve this, companies should implement IT systems in conjunction with their unique strategies, such that competitors would face significant disadvantages if they attempted to replicate (Ross et al. 1996). Investment in IT is also a part of these efforts, as the activities associated with the application of IT can lead to competitive advantages, helping firms to address both external and internal challenges (Li and Ye 1999). Top managers' increasing deliberation on methodologies and techniques for the strategic utilisation of IT to support business strategies and create strategic options has enriched related research activities, leading to the development of rich models and frameworks for theory-building (Earl 1989; Moynihan 1990). A well-designed plan for the use of IT resources is intended to coordinate IT investments with corporate objectives, leverage IT to gain a competitive advantage, guide the efficient and effective management of information system assets, and establish technology strategies and frameworks (Earl 1993). In the field of IT-related research, such as Information Systems (IS) or Information and Communication Technology (ICT), studies adopting the RBV theoretically explore the relationship between IT, organisational strategy, and performance (Wade and Hulland 2004). As mentioned in the earlier section, from the perspective of the RBV, to serve as a source of competitive advantage, resources and capability must be strategically valuable and challenging for competitors to imitate. Implementing IT-dependent strategic initiatives such as business process reengineering, fostering customer intimacy, promoting organisational learning, and driving organisational transformations makes IT capability valuable and essential for achieving organisational goals.

As the impact of IT resources and assets on innovative companies has grown, the facilitation of IT leads to a wide range of applications and penetration into various aspects of industrial and personal life, while increasing the market share of new devices or equipment and simultaneously reducing costs (Salomon et al. 1999). From the perspective of the RBV, organisations have invested in developing IT resources that provide competitive advantages. Previous studies have applied the RBV to consider IT-related capabilities as resources that provide a unique competitive advantage to firms (Li and Ye 1999). IT capability is often referred to as the ability to utilise IT-based resources in combination with other resources or capabilities (Bharadwaj 2000). It is also described as a complex bundle comprised of IT resources, skills, and knowledge that enables the coordination of activities by making use of IT assets (Stoel and Muhanna 2009). Applying the traditional approach to organisational capabilities from the perspective of IT, IT competency is recognised as a higher level of capability that enables the achievement of organisational goals encompassing the concept of IT resources and the capability to utilise them, preferably in a way that surpasses competitors' capability (Grant 1996). In this context, IT competency reflects the characteristics of VRINN resources and capabilities, which leads to the observation of similarities in the typologies of IT resources, capabilities, and IT competency as used in related studies (Mao et al. 2016; Jalilvand et al. 2019; Mao et al. 2021). Tippins and Sohi (2003) conceptualised IT competency as "the extent to which a firm is knowledgeable about and effectively utilises IT to manage information within the firm." Tippins and Sohi (2003) posits that companies achieved high level of competence in managing information through effective tools and processes are superior positioned to achieve market leadership. IT can potentially have a direct impact on reducing costs and increasing revenue, however, this does not necessarily mean it will become a source of sustained competitive advantage for an organisation (Mata et al. 1995). To ensure that IT resources do not merely provide a temporary competitive advantage, they must be managed as assets that are not easily emulated by competitors. The IT resources support the firm's IT competency by exhibiting characteristics of complementarity, which enhances the interaction between other resources (Powell and Dent-Micallef 1997), and co-specialisation, which exist when the multiple resources significantly increase their collective value (Clemons and Row 1991).

3.1.1.1 Classification of IT competency

This recognition prompted research that defined IT as a resource and applied the previously mentioned categories to differentiate IT resources (Duncan 1995; Mata et al. 1995; Ross et al. 1996; Ravichandran and Lertwongsatien 2002; Wade and Hulland 2004; Aral and Weill 2007). These studies attempted to classify IT resources (also referred to as assets, capabilities, and competencies) in various ways to support the creation of sustainable competitive advantage for firms. Mata et al. (1995) based their research on the RBV and identified four possible sources of sustained competitive advantage from IT. The first is accessibility to capital, which enables investment in IT. Companies that can bear the risk and uncertainty of IT investments may gain a competitive edge over their competitors. However, such investments need to be coordinated with the necessary skills and required capital to be effective. The second source is proprietary technology. While technology can be protected by patents, IT applications are often vulnerable to imitation. Organisations can secure a competitive advantage from other companies by keeping their proprietary technology secrets. The third source is technical skills, which refer to the know-how that allows the building and operation of IT applications. This includes knowledge of programming systems, understanding of communication protocols, and experience with operating systems. Lastly, managerial IT skills refer to the ability of management to ensure that IT applications support and enhance other business functions. For this, managers need to understand and collaborate with the needs of other functional managers, suppliers, and customers.

Ross et al. (1996) categorised IT assets contributing to business value as IT processes into three types: Human assets, Technology assets, and Relationship assets. 1) Human assets comprise the technical skills that reflect the capabilities of IT staff, which managers can leverage when introducing new IT systems and technologies, the business understanding that results from interactions with clients, and a problem-solving orientation empowered by team learning and communication between IT and business staff. 2) Technology assets consist of sharable technical platforms and databases. These technical assets enable system integration and yield cost-effective benefits for IT applications. If the technology architecture is well-defined, it enables the appropriate allocation of hardware, software, and support where they are needed. This specifies the rules that determine what data the organisation should share and store. Additionally, data and platform standards simplify system integration, which ensures faster processes, reduced costs, and maintained quality. Technology assets are crucial in supporting knowledge and decision-making regarding IT development at the team or managerial level. Otherwise, there is a risk of incurring costs from external resources. Lastly, 3) the relationship asset emphasises the importance of the ability to communicate, coordinate, or negotiate through IT, with shared risk and responsibility. It highlights the significance of top managers' capabilities in managing information sharing across business units. Furthermore, it involves establishing IT priorities to ensure the efficient and wise investment of limited resources (Ross et al. 1996).

Bharadwaj (2000) applied Grant (1991)'s classification framework to categorise IT-based resources into three distinct groups. These include tangible resources, human IT skills, and intangible IT-enabled resources. 1) Tangible resources encompass the components of physical IT infrastructure. Flexible IT infrastructure is adaptable and scalable, allowing for new applications to be launched rapidly. This flexibility means that the company can quickly capitalise on new opportunities or respond to threats in the market by deploying technology solutions in a very short time frame. 2) Human IT skills involve technical and managerial IT expertise. Skilled IT workforce can understand the strategic implications of market changes and competitor actions. This skilled workforce can execute the development and deployment of critical applications swiftly. 3) Intangible IT-enabled resources consist of knowledge assets, customer orientation, and synergy. This orientation is supported and enabled by the robustness of their IT infrastructure and the expertise of their IT personnel. A strong customer orientation means that the company prioritises the needs and preferences of customers, which can lead to higher levels of customer satisfaction and loyalty. It is suggested that these elements work together to create a comprehensive IT capability that can contribute to a firm's performance.

Wade and Hulland (2004) proposed a categorisation of IT competency for achieving sustained competitive advantage as inside-out, outside-in, and spanning IT capabilities. In the categorisation, resources that can be oriented within an organisation to manifest as capabilities include IS infrastructure, IT technical skills, IS development, and cost-effective IS operations. Additionally, as resources that can bridge the internal and external facets of an organisation, IS-business partnerships and IS planning and change management are identified.

Prominently, the most frequently cited framework by Tippins and Sohi (2003) represents IT competency in terms of capabilities based on the established distinctions within IT resources. Tippins and Sohi (2003) conceptualised IT competency into three components: IT knowledge, IT operation, and IT object. 1) IT knowledge is a more specific subset of the general concept of knowledge, which involves applying the right actions and appropriate rules in specific situations to lead to predictable outcomes (Taylor 1971; Capon and Glazer 1987). This represents the extent to which a company possesses technical knowledge about its IT systems in the context of IT. 2) IT operations are composed of various steps within methods, skills, and processes that leverage IT knowledge to accomplish specific goal (Granstrand 1982). Essentially, this involves the capacity to apply IT knowledge to create new value. The concept of IT operations reflects the extent to which an organisation effectively utilises its IT resources to manage and make use of market and customer information. 3) IT objects serve as resources encompassing hardware, software, and support personnel, as tools that facilitate the production, processing, storage, and use of dissemination of information.

While traditional studies focused on the definition and categorisation of IT resources, other research has emphasised the importance of IT capability (Chen et al. 2014; Yu et al. 2017). Lu and Ramamurthy (2011) conceptualised IT capability as consisting of three constructs: IT infrastructure capability, IT business spanning capability, and IT proactive stance. Ravichandran et al. (2005) argued that IT capability acts as complementarities, playing a role in achieving competitive advantage through IT resources. Classification frameworks for IT competency, as established by traditional studies, have provided a solid theoretical foundation for a variety of subsequent research, and these frameworks have been utilised in successive research following the IT revolution and the continuous changes in the business environment (Alalie et al. 2018). Wang et al. (2012) demonstrated that existing IT resources can be transformed by organisational process into IT competencies, which are composed of IT strategic planning, IT development, IT use, and IT management. Mikalef and Pateli (2017) explained that while IT resources are a necessary condition for achieving sustainable competitive advantage, the causal mechanism by which this advantage is realised is through capabilities. Additionally, other studies have asserted that IT competency exerts an interaction effect when integrated with other capabilities of the organisation such as marketing (Song et al. 2007; Yu et al. 2017). For instance, Mao et al. (2016) showed that knowledge management capability acts as a mediator in the role that IT resources play in gaining competitive advantage (Jalilvand et al. 2019). Furthermore, other studies have introduced a contingency perspective to consider the influence of the external environment in order to address the issue of the absence of desirable evidence between IT capability and performance (Wiengarten et al. 2013; Chen and Ong 2016; Lioukas et al. 2016; Mao et al. 2016). This reflects the perspective that different resources have different impacts on organisational capability, and the utilisation of resources must be aligned with and match the strategy design (Lyu et al. 2019). For instance, Gupta et al. (2018) introduced the concept of contingent RBV, suggesting that IT resources influence performance contingent upon the situation and must reflect the complexity of the supply chain. The study by Liu et al. (2016) applied the contingency and configuration approach to examine the fit between IT competency and the extent of SCI, in order to verify their relationship with performance.

Overall, the RBV explains how organisations achieve competitive advantage and improve performance through the resources they possess and the capabilities to effectively utilise them. This thesis conceptualises SCI as a supply chain capability, and interprets the organisation's IT competency in utilising BCT as an IT capability that encompasses relevant IT resources.

3.2 Value chain

According to Porter (1980), organisations attain a competitive advantage, allowing them to generate higher profits or achieve superiority over competitors, through cost leadership and differentiation. Sustainable competitive advantage is a key element for companies to continuously conduct successful business (Porter 1985a). Previously, it was stated that a competitive advantage can be achieved through the strategic utilisation of resources and capabilities that are differentiated from competitors. The concept of the value chain is presented by Porter (2001) to understand the source of differentiation for performing strategic activities to obtain a sustained competitive advantage. He stated that in the supply chain, value is transformed through additional activities as products move through channels from suppliers to customers. An understanding of both the value system and the value chain is the ultimate basis for differentiation to gain a sustained competitive advantage. To represent the collection of activities within a firm, Porter and Millar (1985) introduced the concept of the generic value chain, as depicted in Figure 3-2.

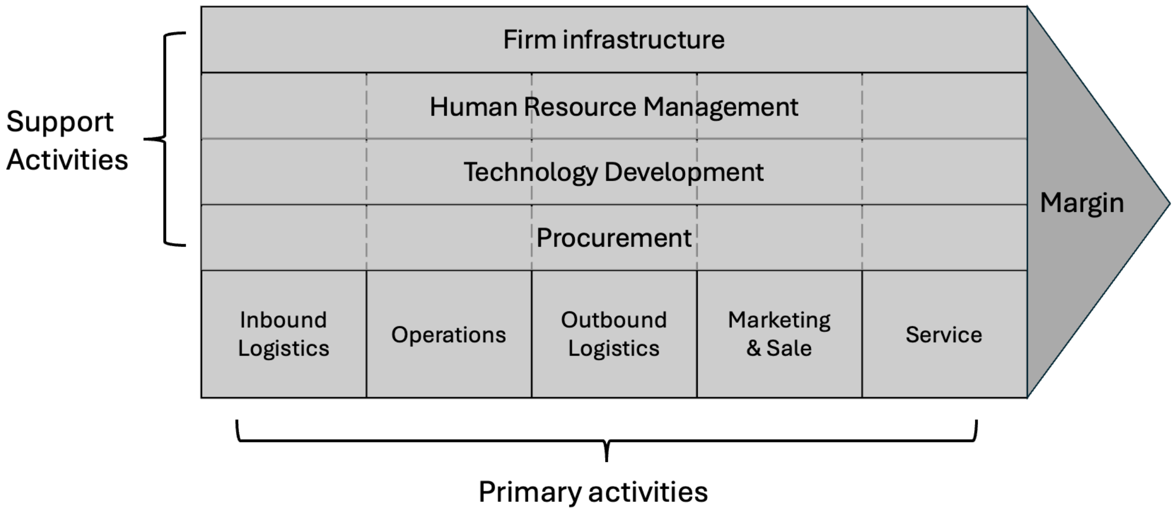


Figure 3-2 Value-Chain

Source: Porter and Millar (1985)

Value activities are the physically and technologically distinct activities a firm performs to create a product valuable to the buyer. Value activities consist of primary activities, which are physically and directly linked to the production and sale of products and services, and support activities, which support the primary activities. Primary activities include inbound logistics, which are activities related to receiving, storing, and distributing inputs internally; operations, which are activities that transform inputs into the final product form; outbound logistics, which are activities required to get the finished product to the customers; marketing and sales, which are activities associated with getting buyers to purchase the product; and service, which are activities that maintain and enhance the product's value. While, Support activities include firm infrastructure activities such as general management, planning, finance, accounting, legal support, and government relations that support the entire value chain; human resource management activities involved in the recruiting, hiring, training, development, and compensation of personnel; technology development activities related to the development of technologies that can be used in the firm's primary activities; and procurement activities involved in the purchasing of goods, services, and materials necessary for the company to operate (Porter 2001).

In the value chain model, IT is mainly represented as a support activity under technology development. Traditionally, IT encompasses activities related to research and development (R&D), process automation, software development and implementation, and data management systems, all of which are used to support a company's primary activities (Porter 1985b; Porter and Millar 1985,2009). As illustrated in Figure 3-2, IT spans across all primary activities and has the potential to change the way a company operates, thereby serving as a crucial means for gaining a competitive advantage (Powell and Dent-Micallef 1997). Consequently, IT can make each activity in the value chain more effective and efficient, ultimately enhancing the overall performance of the company (Breznik 2012). These supportive activities of IT have been focused on aiding in the reduction of coordination costs with suppliers within the supply chain, lowering distribution costs, and decreasing channel management costs (Chou and Shao 2023). IT-enabled Just-in-Time (JIT) inventory management, automated manufacturing and assembly processes, and communication IT infrastructure are examples of IT enablement that help firms gain a competitive advantage. Astuti and Rahayu (2018) verified that the competency of IT systems contributes more to improving performance by aiding the organisation's operational processes rather than having a direct impact on financial performance. In addition, information integration through technology is recognised as a source that facilitates the re-engineering of business processes (Emmelhainz 1992).

The expansion of IT-related activities has evolved from playing a supportive role in primary activities to serving as a key driver of performance improvement and competitive advantages, as highlighted in numerous studies. Al-Surmi et al. (2020) emphasised that IT strategy should support business strategy over the long term by facilitating communication that links suppliers and customers, and it should be aligned with business strategy. Particularly, this perspective adopts the view of the RBV, referring to IT resources and the capability to utilise these resources. For instance, the study by Irfan et al. (2020) demonstrated how Porter's value chain concept aligns with business mechanisms to enhance supply chain performance, identifying IT as a foundational capability that enables sustainable supply chain activities (Radhakrishnan et al. 2018). In their research, IT capabilities derived from IT resources act as enablers of business operations, including quality management, plant capacity, sourcing, and product design. Singh and Teng (2016) confirmed that supply chain outcomes are positively impacted by IT integration, which serves a complementary role in supply chain governance activities. This integration reduces uncertainty and strengthens process capability, thereby aiding in cost reduction and performance enhancement. Luo et al. (2012) study, drawing on the RBV, highlights that IT capability, can evolve into a strategic driver of value chain performance. Specifically, IT is shown to directly enhance operational capabilities, supply chain coordination, and innovation potentials, thus exerting a driving influence over primary activities (Liu et al. 2013b; Chou and Shao 2023). The influence of IT extends to small-scale enterprises as well, supporting supplier, customer, and internal related value-chain activities, which in turn impacts profit increase and cost reduction (Sianjase and Libati 2016).

On the other hand, when it comes to supply chain context, the distinction between the value chain and the general supply chain concepts lies in their focus and scope. While the value chain is centred on creating a firm-level competitive advantage, the general supply chain encompasses a broader range of entities from supplier to customer (Walters and Lancaster 2000; Al-Mudimigh et al. 2004). However, at the firm level, ability to integrate their supply chain is a critical organisational capability that facilitates the smooth flow of materials and information from suppliers to customers, serving as an integral part of the primary activities necessary for building efficient and responsive supply chain networks, as demonstrated by empirical studies (Hock Soon and Mohamed Udin 2011; Golini et al. 2016). In this context, the argument that IT-related activities act as enablers supporting the enhancement of SCI and thereby improving performance has been verified by various studies (Afshan et al. 2018; Sundram et al. 2020). Rasheed and Rasheed (2015) emphasised that the evolution of internet-based IT plays a crucial role in value creation by fostering integration in supply chain activities, as it spans the boundaries of IT firms and industries. Rashid et al. (2023)

examined the role of technologies capability that enables effective SCI by facilitating communication and real-time information sharing among supply chain partners for purchases, inventory, project orders, and demand forecasting. In the domain of SCI research, there are studies that have applied the RBV to validate the relationship between IT and SCI. These studies indicate that IT competency, formed from IT resources and capabilities, lead to an increase in performance by integrating inbound and outbound processes and achieving SCI (Ganbold et al. 2020; Yu et al. 2021). Building on this, it can be deduced that IT acts as supportive activities that enhance the core activity and capability of SCI, thereby improving performance (Marinagi et al. 2014). This relationship between IT, SCI, and performance has been corroborated by various studies (Sanders and Premus 2005; Sanders 2007; Vijayasarathy 2010; Zhang et al. 2016; Kim 2017; Sundram et al. 2020).

3.3 Summary

This chapter explores the theoretical background to logically link the variables, namely SCI and BCT, explored in Chapter 2 for developing a conceptual research model and hypotheses. Firstly, the Resource-Based View (RBV) categorises resources that a firm can utilise into tangible, intangible, and capabilities to obtain a competitive advantage. Notably, the ability to achieve SCI is recognised as organisational capabilities, contributing to a sustainable competitive advantage, as evidenced in operations management papers. This suggests that SCI strategies can serve as a theoretical foundation, implying that they are recognised as key resources for firms to achieve enhanced performance and can have a positive link.

Additionally, the current study applies BCT as a key technology for successfully achieving SCI. Reflecting this approach, the research explores the conditional impact of firms' IT competency levels on the extent of SCI and the utilisation of BCT, borrowing from the RBV to examine firms' perception and utilisation of IT resources. IT is also recognised as a key resource for firms, and various studies have been reviewed to understand how IT is classified as a resource and utilised to contribute to the acquisition of firm competency.

Lastly, this research employs the value-chain theory which categorise the necessary activities for achieving a supply chain strategy into support activities and primary activities. The value-chain perspective asserts that IT elements serve as supportive activities to aid primary activities such as integrated logistics operations for performance enhancement. By understanding this theory, the research will be able to clearly comprehend and delineate the roles and relationships of IT competency, SCI, performance, and BCT variables in the following chapter.

Chapter 4 Hypotheses and conceptual model

Chapter 4 aims to develop hypotheses and a conceptual model based on the knowledge of SCI and BCT explored in Chapter 2, and the theoretical background investigated in Chapter 3. Section 4.1 will clearly redefine the concepts used in the model as variables for empirical analysis. In Section 4.2, the relationships between variables will be articulated as hypotheses, supported by theoretical evidence and related studies. Finally, Section 4.3 will provide definitions for the components that are used to measure the variables.

4.1 Definition of Key construct

The concepts explored in Chapters 2 and 3 have been redefined as constructs for the research model to be used in empirical analysis, with reference to precedents established in previous research.

4.1.1 Maritime supply chain integration measurement components

Empirical studies focusing on maritime SCI have endeavoured to develop suitable measurement instruments. These instruments are tailored to assess the degree of SCI, taking into account the unique characteristics of the maritime supply chain. In this context, Panayides and Song (2009) proposed a measurement tool specifically for evaluating port terminal integration, which consists of four key components: information and communication systems, value-added services, multimodal systems and operations, and SCI practices. This second-order model was validated using a sample obtained from international container terminal workers through confirmatory factor analysis (CFA) (Panayides and Song 2008). In addition, research by Song and Panayides (2008) incorporated three additional variables: the use of information and communication technology, the relationship with shipping lines, and the relationship with land transportation operators, to analyse their impact on performance. Drawing on previous studies, Tongzon et al. (2009), Woo et al. (2013) and Hussein and Song (2024) included long-term relationships as a key variable alongside the original four variables, to validate their relationship with performance. The study by Simatupang and Sridharan (2002) presented mutual objectives, integrated policies, appropriate performance measures, decision-making domains, information sharing, and incentive alignment as means for interventions to achieve successful collaborative supply chains. Cao and Zhang (2011) developed this construct and identified the elements that constitute SCI for a partnership process in which supply chain members collaborate closely to plan and execute operations. These elements consist of information sharing, goal congruence, decision synchronisation, incentive alignment, resource sharing, collaborative communication, and joint knowledge creation. The study by Seo et al. (2015) also developed an instrument tool for assessing maritime SCI. Their research focused on the role of intermediary supply chain processes in container maritime logistics and empirically validated SCI measurements conceptualised by a multidimensional construct which is developed through in-depth discussion with experts. Maritime SCI involves the management of multiple collaboration through Information sharing (IS), Knowledge creation (KC), Collaborative communication (CC), Goal similarity (GS), decision harmonisation (DH), and Joint supply chain performance measurement (JPM). The instrument was also validated for second-order dimensionality through CFA, and the relationship between collaborative advantage and performance was analysed (Cao and Zhang 2011; Seo et al. 2016). This construct can cover both upstream and downstream and is capable of representing the synergies arising from SCI practices as a single variable (Danese et al. 2020). Table 4-1 presents the diverse aspects of maritime supply chain integration examined in prior research, detailing their respective components, constructs, analytical methods, and detailed descriptions.

References	Focus	Components/constructs	Method	Model details
Panayides and Song (2008) Panayides and Song (2009)	Port supply chain	Information and communication systems Value added services Multimodal systems and operations Supply chain integration practice	CFA	Develop parameters and measurement dimensions for assessing terminal supply chain integration
Song and Panayides (2008)	Port supply chain	Use of information and communication technology Relationship with shipping line Value added service Integration of transport modes Relationship with inland transport operation	CFA Multiple regression	Supply chain integration -> competency
Tongzon et al. (2009)	Port supply chain	Relationship with users Value added services Inter-modal infrastructure Channel integration practices	CFA	Measurement model assessment and importance wight measurement

Woo et al. (2013)	Port supply chain	Information and communication systems Long-term relationship Value-added logistics services Inter-modal transport services Supply chain integration practices	CFA CB SEM	Supply chain orientation -> supply chain integration -> performance
Seo et al. (2015)	Maritime supply chain	Information sharing Knowledge creation Goal similarity Decision harmonisation Joint supply chain performance measurement	CFA	Develop parameters and measurement dimensions for assessing maritime supply chain integration
Yang et al. (2015)	Container shipping supply chain	Top management support Internal integration Information technology Commitment Sharing	EFA CB SEM	Intra-organisational integration, extra-organisational integration -> supply chain logistics integration

		Long-term relationship		
Seo et al. (2016)	Maritime supply chain	Information sharing Knowledge creation Collaborative communication Goal similarity Decision harmonisation Joint supply chain performance measurement	CFA CB SEM	Supply chain integration -> collaborative advantage -> performance
Yuen et al. (2019)	Container shipping supply chain	Relationship management Information management Organisational commitment Strategic alignment Performance management	CFA CB SEM	Critical success factors -> internal integration, external integration -> supply chain performance
Hussein and Song (2024)	Port supply chain	Communication technology and information system Long-term relationships Value-added logistics services	EFA CFA CB SEM	Supply chain integration -> economic sustainability, environmental sustainability

	Inter-modal transport services
	Supply chain integration practices

Table 4-1 Empirical research of supply chain integration

Source: Author

In this thesis, the measurement instrument developed by Seo et al. (2016) has been carefully considered for model development and variable measurement (Seo et al. 2015,2016). The measurement offers the most comprehensive conceptualisation by presenting a framework accounts for the multidimensional nature of SCI (Cao and Zhang 2011). Unlike other studies, their research expanded the scope of supply chain focus to include the entire maritime supply chain and encompassed entire maritime supply chain operators, such as shipping liners, terminal operators, freight forwarders, inland transport companies, ship management companies, and third-party logistics providers as its subjects. This approach distinguishes itself from studies that analyse SCI from the perspective of specific stakeholders. The six SCI measurement constructs borrowed from their research are: Information Sharing (IS), Knowledge Creation (KC), Collaborative Communication (CC), Goal Similarity (GS), Decision Harmonisation (DH), and Joint Performance Measurement (JPM). Although the causal model in their research was validated for its impact on port performance, the integration measurement model was deemed suitable for this thesis, which targets the entire maritime supply chain. Consequently, it was further refined through specific modifications to the questionnaire items. The six constructs from their research will be more explored in later chapter for conceptual model. In Seo et al. (2016)'s research, the term collaboration is used to describe the close cooperation among business partners which emphasises a joint relationship between autonomous supply chain partners. Supply chain collaboration highlights the joint relationship between autonomous supply chain partners more than integration (Cao and Zhang 2011). However, supply chain collaboration often interchangeably used with integration in other studies (Michalski et al. 2018; Mofokeng and Chinomona 2019). Notably, in the study by Simatupang and Sridharan (2005b), supply chain collaboration is referred to as an integrated supply chain process, and the components of collaboration include integrated activities and processes. The SCI defined in the previous section is based on strategic collaboration and management with supply chain partners to deliver integrated logistics services, the term 'integration' is more commonly employed in a general approach (Flynn et al. 2010).

4.1.2 IT competency measurement components

As shown in Table 4-2, IT competency, identified by prominent prior research as a capability or resource depending on the research objectives, has been developed into a measurement tool for empirical analysis within research relevant to IT-related topics (Lu and Ramamurthy 2011). Previous research consistently have identified IT infrastructure as a core element of IT competency, while technical and managerial IT skills are also recognised as essential components. Additionally, the relationship between IT units and business units, as well as partnerships with external partners, has often been utilised as components of IT competency. This aligns with the findings from Piccoli and Ives (2005)'s review analysis, which shows that infrastructure, technical skills, and management skills are the most frequently referenced components of IT resources.

Reference	Resource	Components
Mata et al. (1995)	IT competitive advantage	Access to capital: ability for IT investment
		Proprietary technology: ability to protect technology
		Technical IT skills: knowledge of programming, experience with operating systems, understanding of communication protocols and products
		Managerial IT skills: managerial skills (conceive of, develop, and exploit IT applications)
Ross et al. (1996)	IT assets	Human asset: technical skills, business understanding, problem-solving
		Technology asset: well-defined technology architecture, data and platform standards
		Relationship asset: business partner ownership of IT projects, top management leadership in IT priorities establishment
Bharadwaj (2000)	IT capacities	Tangible resource: physical IT infrastructure
		Human IT resources: technical and managerial IT kills
		Intangible IT-enabled resources: knowledge assets, customer orientation, and synergy
Ravichandran and Lertwongsatien (2002)	IT capabilities	IS human capital: IS personnel skill, IS human resource specificity

Ravichandran et al. (2005)		IT infrastructure sophistication: network and platform sophistication, data and applications sophistication IS partnership quality: internal partnership quality, external partnership quality
Tippins and Sohi (2003) Pérez-López and Alegre (2012) Turulja and Bajgoric (2018) Cai et al. (2019) Mao et al. (2021)	IT competency	IT knowledge: technical know-how IT operations: technical methods, skills, and process IT objectives: hardware, software, support personnel
Dehning and Stratopoulos (2003) Wang et al. (2012)	IT resources	Managerial IT skills: managerial skills (conceive of, develop, and exploit IT applications) Technical IT skills: expertise to build and use IT applications IT infrastructure
Wade and Hulland (2004) Cai et al. (2016)	IT resources	Outside-in: external relationship management, market responsiveness Spanning: IS business partnerships, IS planning and change management Inside-out: IS infrastructure, IS technical skills, IS development, cost effective IS operations
Menville and Kraemer (2004)	IT resources	Technological IT resources: infrastructure, business applications

			Human IT resource: technical skills, managerial skills
Bhatt and Grover (2005)	IT capabilities		IT infrastructure: compatibility, modularity, scalability, IT standards
			IT business experience: IT groups understand business
			Relationship infrastructure: positive relationship between IT and business managers
Piccoli and Ives (2005)	IT resource	IT assets	IT infrastructure: foundation of shared IT services
			information repositories: collection of logically related data, structured form
		IT capabilities	Technical skills: ability to design and develop effective information system
			IT management skills: ability to provide leadership for the IS function, manage IT project, evaluate technology options
			Relationship assets: mutual respect between IS function and business
Aral and Weill (2007)	IT resource	IT assets	Infrastructure: foundation of shared IT services
			Transactional: automate process, cut costs
			Informational: information managing, accounting, reporting, planning, analysis, data mining
			Strategic: new market, new product, new service
		IT capability	Competency: IT skills, IT management quality

		Practice: IT use intensity, digital transaction intensity, internet architecture
Zhang et al. (2008)	IT capacity	IT infrastructure
Chen et al. (2014)		IT business partnership
		Business IT strategic thinking
		IT business process integration
		IT management
		External IT linkage
Liang et al. (2010)	IT resources	Technology resource: IT investment, IT infrastructure, IT assets, software, system application
		Organisational resource: knowledge resource, human resource, financial resource
Lu and Ramamurthy (2011)	IT capabilities	IT infrastructure: technological foundation
		IT business spanning: business-IT strategic thinking and partnership
		IT proactive stance: opportunity orientation
Chakravarty et al. (2013)	IT competency	IT infrastructure: physical assets, hardware platforms, software applications, data repositories, networking, objective-based technologies, updates of IT related asset stocks
		IT capabilities: technical skills, management skills, IT practices

Liu et al. (2013b) Liu et al. (2016)	IT competency	Flexible IT infrastructure: shared set of technological resources with connectivity, compatibility, modularity IT assimilation: ability to diffuse and routinise IT application in supporting, and enabling its business strategies and value chain activities Managerial IT knowledge: necessary business acumen and technical skills to foresee the value and potential of IT of top managers
Liu et al. (2015)	IT capabilities	IT operational capability: ability to provide reliable and consistent It support to current business IT transformational capability: ability to use IT applications to transform to new business opportunities
Mao et al. (2016)	IT resources	IT infrastructure: technological foundation IT human: technical and managerial IT skills IT relationship: relationship between IT and business units
Irfan et al. (2020)	IT capabilities	Flexible IT resources: tools of IT, inter organisational communication network IT assimilation: capability to embed information resources technically and use Inter-organisation Information system integration: capability to coordinate, align, configure and integrate IS within supply chain
Zeng and Lu (2021)	IT capabilities	IT talent capabilities

		IT infrastructure capabilities
		IT internal communication
		IT external communication
Al-Shami et al. (2022)	IT competency	IT infrastructure flexibility
		IT integration
		IT alignment
		IT management

Table 4-2 Components of IT related resources

Source: Author

Among the various definition and classification, the three elements presented by Tippins and Sohi (2003)—IT knowledge, IT operations, and IT object—have been adapted by other studies to measure IT competency. The study by Pérez-López and Alegre (2012), Cai et al. (2019) and Mao et al. (2021) measured IT competency using IT knowledge, IT operation, and IT infrastructure. Liu et al. (2016) stated that typical typologies are initially defined from the perspective of the IT unit (Stoel and Muhanna 2009), whereas Tippins and Sohi (2003)'s typologies broaden to the firm management level through a process of complementary and co-specialisation. Liu et al. (2016) defined IT competency as the comprehensive technological capability that organisations leverage to utilise IT resources effectively, thereby contributing to the achievement of sustained competitive advantage (Liu et al. 2016). They conceptualised the existing three elements to flexible IT infrastructure, IT assimilation, and managerial IT knowledge. Therefore, this thesis establishes flexible IT infrastructure, IT assimilation, and managerial IT knowledge as potential components for measuring IT competency, taking into account the subject relevance with the study by Liu et al. (2016), which researched the relationship between IT competency, SCI, and performance. However, since the skill of IT personnel as a human resource, which was emphasised in the previously reviewed literature, was not considered, this construct is added to propose four components as potential components.

4.1.3 Maritime supply chain integration performance

The integration of supply chains for efficient and effective management strategies has been consistently highlighted. Precise assessment of performance is crucial in SCM because it (1) lays the foundation for comprehending the system, (2) affects the behaviour across the systems, and (3) offers information about the outcomes of the system's effort to members of the supply chain and external stakeholders (Chen and Paulraj 2004). However, evaluating the performance is not an easy task. Previous literature has continued efforts to accurately assess the influence of SCM and SCI on performance. One of the main difficulties in measuring Supply Chain Performance (SCP) is the challenge of evaluating common activity performance across the entire supply chain due to the intertwined different interests of various parties (Cooper et al. 1997). To overcome this issue, organisations need to have a comprehensive understanding of their supply chain and consider the overall impact of their performance on partners within the supply chain (Lai et al. 2002).

Traditionally, financial measures of business performance have been the dominant indicators in empirical strategy research, serving as the primary yardstick for the majority of stakeholders. (Yamin et al. 1999; Chen and Paulraj 2004; Petersen et al. 2005). Financial performance is assessed by determining costs of the total logistics, which means an organisation can measure and evaluate its profitability and efficiency by efficiently managing expenses incurred at various stages of the supply chain (Cavinato 1992). Vickery et al. (1997) asserted six common financial measures related to Return on assets (ROA), return on investment (ROI), return on sale (ROS) (Handfield and Pannesi 1992). Gunasekaran et al. (2001) also argued that increased sales leading to enhanced profit, and subsequently, a higher ROI as a measure of financial performance that can be achieved based on business investment, and cash flow as a key indicator that can determine the level of ROI. These indicators can be based on actual values extracted from released information from an objective perspective, while they can be subjectively assessed and measured by respondents in research (Vickery et al. 1997). In the study by Droge et al. (2004), it was demonstrated that the strengthening of the SCI reflects the ability to attract and retain customers, thereby identifying market share as a key performance indicator. The mentioned indicators have been utilised in studies verifying the relationship between SCI and performance. Notably, Narasimhan and Kim (2002) researched the impact of SCI on performance by measuring sales growth and market share growth using actual data, while profitability growth, ROI, ROA, revenue growth, financial liquidity, and net profit were based on respondents' responses. Iyer et al. (2009) categorised ROI, average profit, and profit growth as financial performance, and market share and sales growth as market performance for their measurements. Flynn et al. (2010) referred to their metrics as business performance indicators, measuring growth in sales, return on sales, growth in return on sales, growth in profit, growth in market share, ROI, and growth in ROI using a Likert scale. Cao and Zhang (2011) used the term 'firm performance' and measured items such as growth of sales, ROI, growth in ROI, and profit margin on sales based on respondents' responses (Afshan et al. 2018; Ruzo-Sanmartín et al. 2024).

However, the literature has pointed out that relying solely on financial performance measures is inadequate, as it tends to offer only a simplistic summary of information, which can lead to a limited and potentially misleading picture of an organisation's performance (Johnson and Kaplan 1987; Eccles and Pyburn 1992; Tarr 1995; Huo 2012). Arzu Akyuz and Erman Erkan (2010) argued that it is challenging to represent financial and operational performance with balanced indicators through a literature review of the SCM discipline. Therefore, this research aims to employ instruments that measure not only financial performance but also operational performance as indicators of the efficiency and effectiveness of the SCM in the maritime.

In terms of operational performance, Arzu Akyuz and Erman Erkan (2010) pointed out that there is a need to move away from traditional performance measures, which focus on specific figures, to more innovative measurements that offer a comprehensive view. This transition is characterised by features such as being value-based, having compatible performance metrics, being customer-oriented, focusing on long-term outcomes, emphasising team metrics, incorporating cross-functional metrics, monitoring improvements, and aiming at evaluation and involvement, as identified through their systematic review of SCP measurement analysis. The research conducted by Gunasekaran et al. (2001) and Gunasekaran et al. (2004) developed a framework that allows for the evaluation of SCP from various perspectives, such as strategic planning, order planning, production level, delivery level, and customer satisfaction. Within this framework, important indicators at the overall supply chain level included the reduction of cycle and lead times, as well as the reduction of cost.

Lai et al. (2002) noted the importance of operational efficiency for transport logistics service providers in SCM performance within transportation logistics. They highlighted the efficiency of a transport logistics service provider in using resources to perform its service activities and proposed indicators related to cost and assets. The study by Sodhi and Son (2009), in the context of SCM, underscored the significance of lead time, responsiveness, and cost reduction as performance indicators in the relationships between SCM partners. Lam and Zhang (2014) presented research on performance evaluation criteria for service providers, identifying key variables such as cost control, reliability, responsiveness, public image, and value-added services. Cost, quality, Inventory, customer service, response time and delivery are criteria for performance metrics commonly observed in other studies (Mofokeng and Chinomona 2019; Ganbold et al. 2020; Gu et al. 2021; Feng and Sheng 2023). Dependability and flexibility have been mentioned as additional performance evaluation factors (Lambourdiere and Corbin 2020a). As measurement tools for port supply chain performance, Song and Panayides (2008) identified cost, quality, reliability, customisation, and responsiveness as key performance indicators. Seo et al. (2016) highlighted connectivity, value-added service, safety and security, efficient operation, cost efficiency, reliability, and convenience of port users as important metrics to assess the performance of port supply chains. Han (2018) included cost, quality, and responsiveness as items for measuring the competitive performance of a port's terminal. On the other hand, Shin et al. (2018) solely reflected financial performance in maritime logistics, considering ROI, ROA, port throughput, market share, and sales.

These indicators are essential for evaluating how well ports and their supply chains are managed and how effectively they meet the needs of their users and stakeholders.

The components used to measure the performance of supply chain operations have been synthesised from previous studies. Established potential financial performance items include return on investment, return on sales, market share, and net income. Additionally, this thesis incorporates measurement tools from research in transport logistics and maritime supply chains, identifying speed, cost, service quality, responsiveness, and lead time as potential evaluative items.

4.2 Structuring the research model: Hypothesis development

The purpose of this study is to explore the potential relationship among three variables: IT competency, SCI, and performance (both financial and operational) within the context of the containerised maritime supply chain. Additionally, the study aims to verify the impact of blockchain utilisation (BCU) on these relationships. Figure 4-1 represents the conceptual research model of this study. As discussed in the section 4.1, IT competency is depicted as the extent to which identified IT resources are utilised within an organisation, while SCI is expressed as the degree of collaboration among maritime supply chain partners. Furthermore, BCU is measured the extent to which BCT is being utilised within the based on its role across three domains identified through a systematic literature review. The research model presumes that IT competency has a positive impact on SCI and financial and operational performance, while the impact of SCI on both performance is also positively significant, acting as a mediating effect. Additionally, BCU is expected to exert a moderating effect, strengthening the relationship between IT competency and SCI, and subsequently influencing performance.

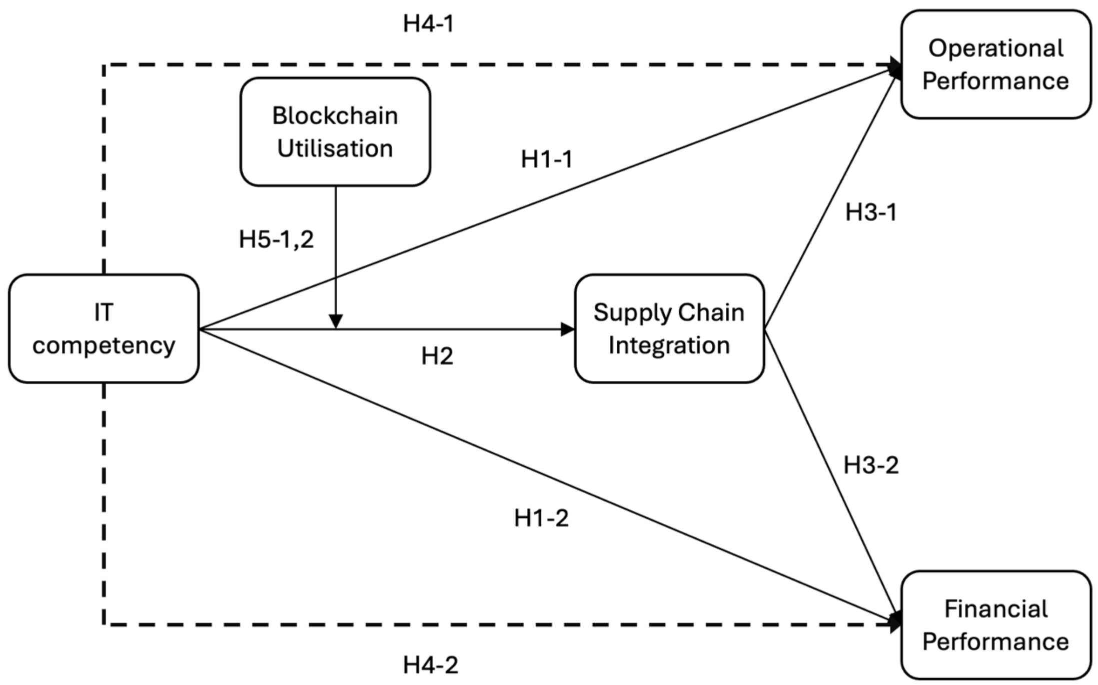


Figure 4-1 Conceptual model
Source: Author

4.2.1 The impact of IT competency on SCI and performance

One of the key objectives of investing in IT is to enhance a company's performance. However, traditional research has predominantly concentrated on the relationship between IT investment and financial performance, often analysing it through accounting metrics. Despite this focus, these studies have failed to produce consistent results, with findings varying from positive to negative, or even showing no significant impact of IT investments on financial outcomes (Weill 1992a; Gu et al. 2008; Lim et al. 2011). Previous studies have shown results regarding the relationship between IT investment and performance, with some research verifying a positive link (Bender 1986; Harris and Katz 1988; Banker et al. 1990)), while others have concluded that there is no relationship

(Lucas 1975b,a; Turner 1983; Roach 1988). The phenomenon where the impact of IT on productivity has not been conclusively proven in an apparent manner is often referred to as the 'productivity paradox' (Strassmann 1990; Brynjolfsson 1993; Sabherwal and Jeyaraj 2015). This is due to the lack of a uniform conceptualisation of IT investment and the absence of appropriate identification of performance measures (Rai et al. 1997). Moreover, as the economic environment has changed, so has the value of IT outputs, and most of research have failed to accurately reflect these environmental conditions. In addition, when new IT is introduced as a result of IT investments, qualitative payoffs may emerge after the initial stages of learning, adjustment, and restructuring of the organisational environment (Lim et al. 2004). Weill (1992a) also explained that not all IT investments lead directly to performance improvements because the impact of IT investment depends on a firm's ability to leverage IT resources for competitive advantage. It is because all organisations invest in different types of technology with various goals. Therefore, it is essential to appropriately design the conceptualisation of IT and its relative performance effect (Aral and Weill 2007). For example, Lim et al. (2011)'s meta-analysis discovered that studies employing market measures of performance found a marginally, but significantly stronger link when examining the impact of IT investment on performance. Nonetheless, when financial measures are applied at the process level, a substantial relationship between IT investment and performance is revealed. Moreover, when IT investment is quantified based on the level of IT spending, it exhibits a strong correlation with accounting measures. Conversely, when IT investment is assessed in terms of its contribution to enhancing IT strategy, it demonstrates a strong correlation with market measures (Lim et al. 2004). These research findings highlight the complexity of the relationship between IT and a firm's performance, suggesting the need for a strategic IT approach that takes into account a company's unique capabilities and environmental elements. Building on the above discussion, it is illustrated that hypotheses 1-1 (H1-1) and 1-2 (H1-2) aim to verify whether IT competency has a positive impact on both financial and operational performance.

As discussed in the chapter 2, the digitalisation of the maritime supply chain is anticipated to positively impact SCI by facilitating information sharing and communication between supply chain partners. IT acts as a crucial facilitator for SCI by acquiring, structuring, and disseminating essential data about core business operations, transcending the internal and external boundary of an organisation (Rutner et al. 2003; Li et al. 2009). It is expected that maritime organisations will support SCI by acquiring IT resources and developing IT competencies, which in turn will maximise the use of ITC. Successful integration hinges on the fluent exchange of precise and timely information among partners within the supply chain. The study by Angeles (2009) indicated that well-established organisation's IT infrastructure strengthen the integration of supply chain processes concerning flow of information, physical, and finances. Li et al. (2009) reported that IT implementation has a direct effect on SCI. They emphasised that IT should be used as a separate variable to enhance SCI, highlighting that IT and SCI are not synonymous. Seo et al. (2014) also presented research findings indicating that technology-driven innovation SCI, thereby enhancing SCP. Additionally, the research by Bruque-Cámara et al. (2016) examined the impact of applying community-related technologies on facilitating real-time data integration and its subsequent effect on SCI. Based on these research findings, Hypothesis 2 (H2) was designed with the premise that IT competency has a positive impact on SCI, as shown in Figure 4-2.

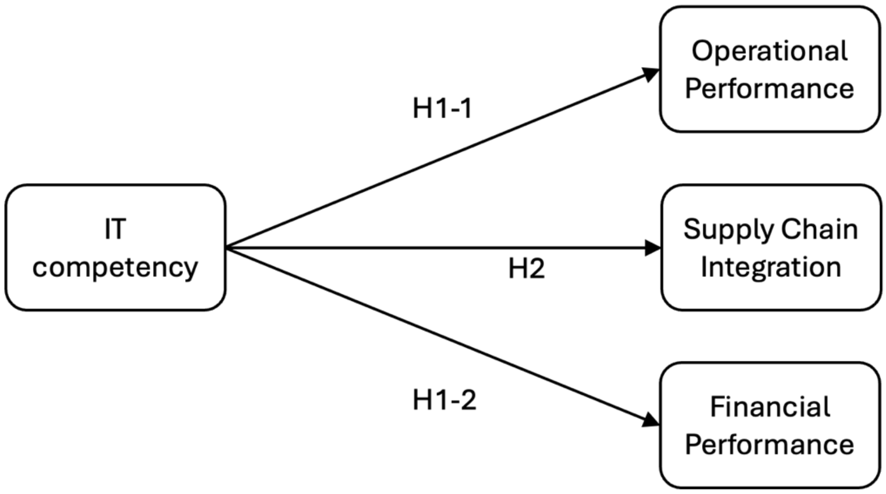


Figure 4-2 Conceptual model for H1 and H2
Source: Author

H1-1: IT competency positively influences operational performance.

H1-2: IT competency positively influences financial performance.

H2: IT competency positively influences supply chain integration.

4.2.2 The impact of SCI on performance

The following premise concerns the influence of SCI on performance. In maritime SCI studies, it has been consistently verified that SCI positively affects performance. As explored in the chapter 2, SCI brings various benefits to supply chain operations. Maintaining close relationships among partners within the supply chain channel has been proven as essential for effective management of supply chain due to the fact that performance can be improved through an integrated process among these partners and stakeholders (Pagell 2004). It is well-documented through several review papers that SCI has a significant and positive influence on performance. The antecedents identified a positive influence of SCI on performance-related factors such as process flexibility, cost, delivery reliability, product quality and lead time. Song and Panayides (2008) demonstrated that the SCI of seaports has a positive impact on operation-related measures such as service quality, customisation, and responsiveness, rather than on traditional measures like cargo throughput. Similarly, the research by Woo et al. (2013) also confirmed that SCI positively influences the efficiency and effectiveness of port performance. In addition, Seo et al. (2016) validated the significant relationship between SCI and port performance in the context of maritime logistics. De Martino and Morvillo (2008) posited that the higher level of inter-firm cooperation within an integrated supply chain, which is based on mutual trust and shared strategic objectives, leads to greater benefits and value. Sheu et al. (2006) also supported these findings by identifying that integration is a critical factor for organisational performance, emphasising the importance of long-term relationships. These findings led to the establishment of Hypothesis 3 (H3), which posits that maritime SCI influences operational and financial performance, as illustrated in Figure 4-3.

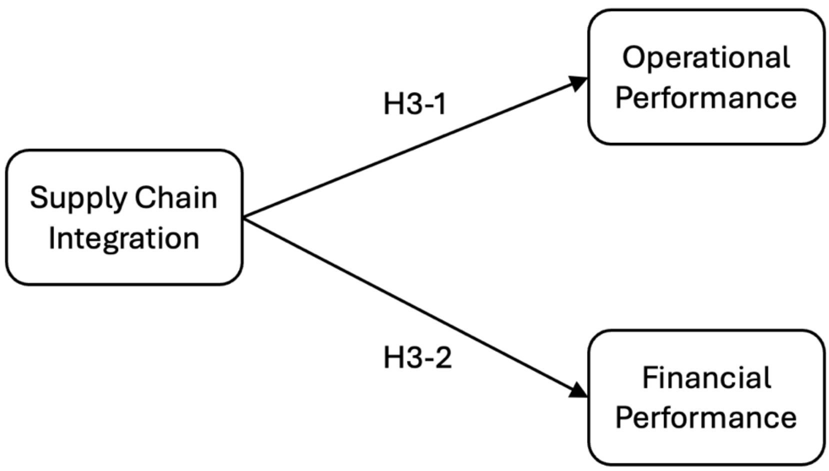


Figure 4-3 Conceptual model for H3
Source: Author

H3-1: supply chain integration positively influences operational performance.

H3-2: supply chain integration positively influences financial performance.

4.2.3 The impact of IT competency on performance through the mediation effect of SCI

A proper conceptualisation is also needed regarding the impact of IT competency on performance in the SCM area. With the introduction of computers and information systems, their impact on logistics management and performance in terms of functionality has been a focal point of traditional studies in logistics management (Ballou and Pazer 1985; Stenger 1986; Mentzer et al. 1990). However, Porter and Millar (1985) and Earl (1989) highlighted the value-adding activities of IT and stated that the utilisation of IT plays a role in transforming the existing value chain into a new value chain, thereby contributing to the creation and maintenance of a company's competitiveness. As the implementation of IT provides timely, accurate, and reliable information, enables real-time integration of supply chain partners, offers forward visibility, and improves planning, more and more research is being devoted to investigating the influence of IT on SCP (Li et al. 2009). Bryan Jean et al. (2008) argued that in empirical studies, IT has an indirect mediating effect on SCP by enhancing specific business processes, capabilities, or structures, rather than a direct impact. This perspective aligns with the RBV in that it suggests IT itself does not directly enhance performance, however rather contributes indirectly to performance by improving an organisation's core competencies or business processes (Melville et al. 2004; Wade and Hulland 2004). Furthermore, this approach can be related to Porter's generic value chain model, where technology is considered one of the support activities that indirectly contributes to competitive advantage and value creation indirectly by supporting primary activities (Porter 2001). Wu et al. (2006) examined the indirect effects of IT on performance by incorporating supply chain capability as a mediating variable in the IT-performance relationship. Within the context of SCI research, many studies have recognised SCI as a form of supply chain capability, which serves as a mediating factor when assessing the impact of IT on performance (Sanders and Premus 2005; Devaraj et al. 2007; Sanders 2007; Prajogo and Olhager 2012; Liu et al. 2016; Zhang et al. 2016; Kim 2017). Building on the theoretical approaches of these studies, this thesis also aims to examine the relationship between IT competency, maritime SCI, and performance.

Other studies have adopted organisational capabilities as a third construct to mediate or moderate the impact of IT on performance, in order to overcome the ambiguity and verify its indirect impact rather than focusing on one-dimensional relationship (Bryan Jean et al. 2008; Liang et al. 2010; Zhang et al. 2011; De Vass et al. 2018; Asamoah et al. 2021). Organisational capabilities refer to the ability of an organisation to respond to external environmental changes and risks. When it comes to SCM approach, the organisational capacity in supply chain is related to activities involved in the supply chain process with partners (Wu et al. 2006). Given that, SCI is a core objective of SCM, and the extent of supply chain capabilities depends on how well an organisation integrates its supply chain (Lambert and Cooper 2000). The perspective of setting SCI as a mediator between IT competency and performance aligns with the definition of the IT system in Porter's value chain framework. In this framework, IT is viewed as a supporting activity that enhances performance by improving the functioning of the value-added process (Porter 1985a; Porter and Millar 1985; Sanders and Premus 2002). In the value chain, the IT utilisation strategy for SCI goes beyond simply enhancing the efficiency of the physical aspect. IT systems are necessary components in establishing a total supply chain network to achieve integrated SCM (Narasimhan and Kim 2001). It involves building and optimising the structural connection among supply chain activities (Porter and Millar 1985; Earl 1989). Kim and Narasimhan (2002) demonstrated the increasing importance of IT's value creation as SCI expands from internal strategies to external connections. Paulraj and Chen (2007) also showed that IT has a positive impact on SCI by increasing the volume and complexity of information through communication with trading partners, providing real-time information for managing and controlling supply chain activities, and allowing for better coordination between partners to facilitate the alignment of operations. Sanders (2007) examined the impact of e-business technology on performance, both directly and indirectly, mediated by organisational collaboration. Prajogo and Olhager (2012) validated the sequential positive effects among IT factors, logistics integration, and performance. Liu et al. (2013b) emphasised the mediating role of SCI elements in the impact of IT capabilities on performance. There are also studies showing the role of IT as a moderating effect rather than a mediating effect (Zhang et al. 2016). Furthermore, Seo et al. (2014) demonstrated that supply chain performance is enhanced by advanced technologies, including internet-based ordering and integrated communication networks, which foster knowledge and relationships through consistent integration among supply chain partners.

In summary, for an efficient and improved SCM, it is essential to strengthen the SCI with competitive IT. The enhanced SCI will, in turn, have a positive impact on performance. Therefore, Hypothesis 4 (H4) presents that SCI serves as a mediator in the relationship between IT competency and performance, bridging the indirect relationship as represented in Figure 4-4.

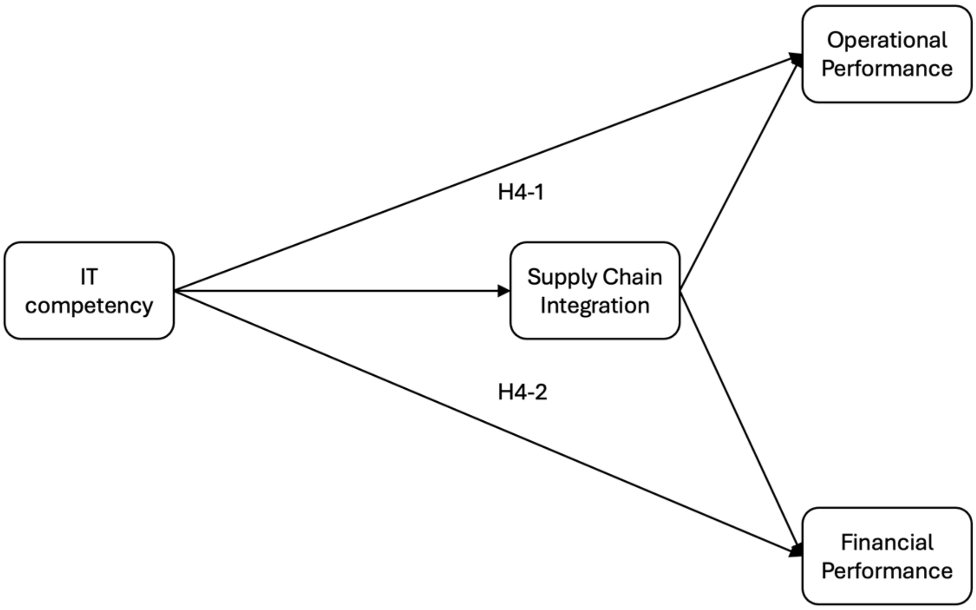


Figure 4-4 Conceptual model for H4
Source: Author

H4-1: IT competency indirectly influences operational performance through supply chain integration.

H4-2: IT competency indirectly influences financial performance through supply chain integration.

4.2.4 The moderating effect of BCU on the model

BCT, as an innovative database technology, is being applied in various fields for advanced information sharing, management and storage, and studies are being conducted on its effects. It has been spotlighted as the base technology for the platform of document sharing, transactions and communication between partners in SCM (Dutta et al. 2020) including in maritime supply chain (Yang 2019; Liu et al. 2021). BCT is expected to contribute to improving supply chain visibility, ensuring secure information sharing and building trust, and allowing for operational improvements in the supply chain (Wang et al. 2019). Given the relatively recent implementation of BCT, it is dominated by theoretical and conceptual research, with a relative scarcity of empirical studies. Tan et al. (2023) examined the impact of BCT's dimensions on performance through SCI. This aligns with the assertion made by Li et al. (2021), who argued that for the operation capability of BCT to lead to managerial performance, the mediating role of SCI is necessary. This emphasis on the influence of BCT on SCI was also highlighted by Wang et al. (2020b). Furthermore, Kamble et al. (2023) validated the relationship between BCT, SCI, and performance. These studies collectively underscore the critical role of SCI in the effective implementation and performance outcomes of BCT. Nevertheless, considering BCT itself as an independent variable with a direct correlation can be risky as it may overlook the complex business processes related to an organisation's resources in the RBV approach (Menville and Kraemer 2004). Consequently, this study aims to verify the moderating effect of blockchain utilisation on the enhancement of SCI as a supply chain capability by IT competency, which is the ability to utilise IT resources. Hypothesis 5 (H5) posits that BCU has a moderating effect on the relationship between IT competency and the enhancement of maritime SCI, and consequently, it also affects the improvement of operational and financial performance, as shown in Figure 4-5.

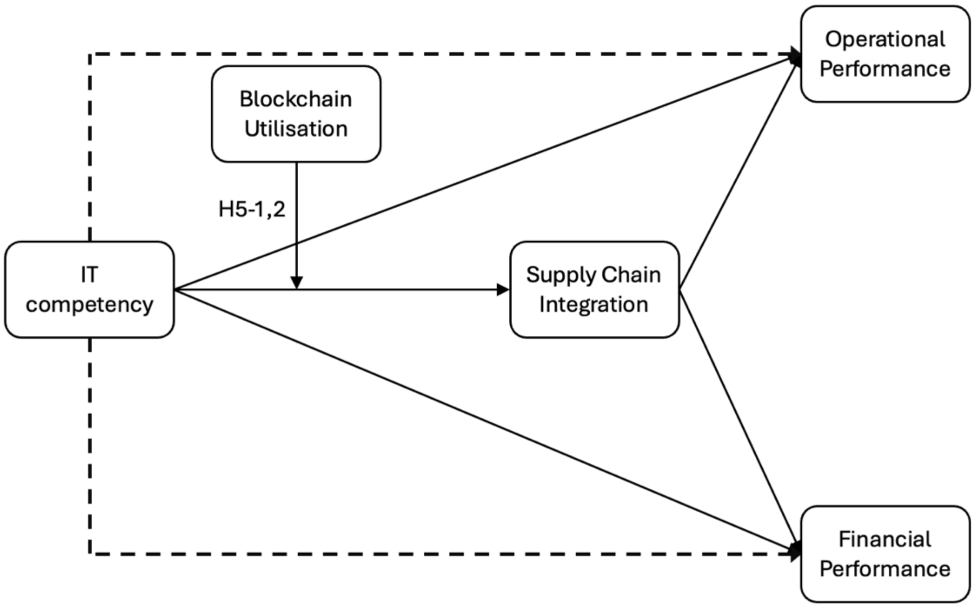


Figure 4-5 Conceptual model for H5
Source: Author

H5-1: blockchain technology utilisation enhances the relationship between IT competency and supply chain integration, leading to improved operational performance.

H5-2: blockchain technology utilisation enhances the relationship between IT competency and supply chain integration, leading to improved financial performance.

4.3 Measurement Construct of latent variables

Based on the redefined concepts and structured model, the development of measurement constructs is required to measure each concept. IT competency, maritime SCI, performance, and BCT utilisation are composed of detailed constructs.

4.3.1 IT competency

In Section 3.1, IT competency was explored as a concept encompassing the characteristics of IT assets and IT capabilities as an IT resource. The constructs adopted from previous studies share common elements to measure IT competency as a latent variable, centred around the concepts of tangible IT resources, human IT resources, and intangible IT-enabled resources as proposed by Bharadwaj (2000). Notably, the study by Tippins and Sohi (2003) presented IT competency as constructs composed of the firm-level ability to leverage IT resources: IT knowledge, IT operations, and IT objectives, which have been cited in recent research (Pérez-López and Alegre 2012; Turulja and Bajgoric 2018; Cai et al. 2019; Mao et al. 2021). Liu et al. (2016) conceptualised these constructs as Flexible IT infrastructure (FITI), IT assimilation (ITA), and managerial IT knowledge (MITK) to assess their relationship with SCI. This study adopts the constructs of FITI, ITA, and MITK as dimensions of IT competency, and extends them by incorporating IT personnel skills (ITPS) from the human resources dimension to operationalise IT competency as a latent variable.

4.3.1.1 Flexible IT infrastructure

IT infrastructure is a concept that encompasses the hardware, operating software, communications, other equipment, and support required to enable business applications (Turnbull 1991). IT infrastructure is formed by a firm's physical IT assets such as computers, communication technologies, and the shareable technical platform and databases (Bharadwaj 2000). Weill (1992b) defined IT infrastructure based on literature and empirical observations from IT managers as *“The base foundation of IT capability budgeted for and provided by the information system function and shared across multiple business units or functional areas. The IT capability includes both the technical and managerial expertise required to provide reliable services".* IT infrastructure is determined by the reach, which is the extent to which information can be accessed and linked, and the range, which is the breadth of information that can be seamlessly and automatically shared across systems and devices (Keen 1991). IT infrastructure can be distinguished between firm-wide infrastructure and business unit-level infrastructure. Firm-wide infrastructure is shared across all the business units by the corporate IT function, while business unit infrastructure refers to the infrastructure shared among the functional areas (Weill 1992b).

In particular, IT infrastructure is described as a major business resource and a key source that can secure a sustainable competitive advantage. An architecture that leverages the synergies from an integrated IT infrastructure to propel the corporate platform and enable the launch of business applications is not a mere commodity but a source of competitive advantage (Mata et al. 1995). From the viewpoint of the RBV, IT infrastructure contributes not only to feasible innovation but also to the continuous improvement of products and services. Consequently, the characteristics of IT infrastructure enable organisations to deploy the right applications at the right time, differentiating the value of technology for each company. More specifically, IT infrastructure allows organisations to 1) quickly identify and develop key applications, 2) share information across products and services, regions, and partners, 3) execute transaction processes and SCM across businesses, and 4) activate synergies between business units or entities (Reed and DeFillippi 1990). To take advantage of economies of scale, IT infrastructure requires large, long-term investments. When an organisation invests considerable time and expertise to develop an Integrated IT infrastructure that spans the entire organisation, it connects key suppliers and customers. This has led to the development of rules associated with the distribution and management of hardware, software, and other support services (Ross et al. 1996)

Flexible IT infrastructure refers to the capacity of an organisation's technical systems to accommodate wide variety of resources quickly and efficiently, leveraging the existing physical and technical foundations (Terry Anthony Byrd 2000; Hou 2020). This concept emphasises the importance of adaptability within the IT framework, allowing for the seamless integration of various components and services across systems and business units (Chung et al. 2003; Angeles 2009). The defining characteristic of a flexible IT infrastructure is its ability to adjust and evolve in response to emerging, divergent, or shifting business demands (Fink and Neumann 2009). By embracing such flexibility, organisations can ensure that their IT systems remain aligned with their strategic objectives, even as those objectives evolve and change over time. A flexible IT infrastructure enables organisations to adapt to new market conditions and prepare for future integration (Mao et al. 2021). The value of building and developing a flexible IT infrastructure has been identified as one of the most important overall IT management concerns by many companies' senior IT executives (Brancheau et al. 1996; Terry Anthony Byrd 2000). The flexibility of the IT infrastructure enables a firm to lead in strategic innovations in business processes, making it difficult for competitors to imitate and thus solidifying the firm's leading position (Duncan 1995). A fully-integrated IT infrastructure provides standardisation of data and rules, as well as applications, and must ensure compatibility with different operating systems (Hou 2020).

4.3.1.2 IT assimilation

IT assimilation serves as an intangible resource within IT competency. While IT infrastructure represents the physical and technical aspects, IT assimilation is the process by which information technology contributes to a firm's value-chain activities and business strategies, thereby creating business value (Armstrong and Sambamurthy 1999). This represents a different effort from the IT investment that is primarily focused on IT infrastructure, as it supports the effective application of IT in business activities. Technology assimilation refers to the ability to utilise technology within business processes (Ranganathan et al. 2004). When applying new technology within an organisation, IT assimilation is the capacity to overcome challenges in learning, understanding, and reconceptualising their work process activities that the organisation faces. The multidimensional definition presented by Kouki et al. (2010) consists of several key components: the users' sense of ownership over the system, the institutionalisation and diffusion of the system within the organisation's business processes, and the enhancement of operational and managerial control, in addition to the support of the business strategy. Organisations where IT assimilation is established as a competency can approach this process more simply and easily, ensure a clear relative advantage over the current working process, and make it compatible with the existing working domain and new IT system (Purvis et al. 2001; Zhu et al. 2006). This involves the successful application of IT in supporting, shaping, and enabling the organisation's business strategies and activities along the value-chain (Armstrong and Sambamurthy 1999). Generally, IT assimilation capability plays a crucial role in enhancing performance in areas such as communication, procurement, logistics, and inventory (Liu et al. 2013b). This importance often leads an organisation to place greater emphasis on IT applications when making strategic decisions, especially those related to inter-organisational cooperation like customer relationship management and SCI (Armstrong and Sambamurthy 1999).

The utilisation of IT applications that support interorganisational communication and information processes helps in knowledge management. Well-integrated IT assimilation strengthens collaboration among business functions, departments, and units within an organisation, reducing existing gaps (Pavlou and El Sawy 2006; Manuel Maqueira et al. 2019). The work between departments involves absorbing, transforming, and commercialising new knowledge from external sources (Tigga et al. 2021). Furthermore, the accumulated knowledge assets expand the organisation's narrow and proprietary network with channel partners into a broad and open network through IT applications, extending the scope of the company's knowledge within the supply chain. The IT application, once diffused and established within the organisation, enhances the acquisition and assimilation of information and knowledge. This, in turn, influences the integrated interorganisational process among partners in the supply chain, shaping routines, processes, and information systems (Malhotra et al. 2005).

4.3.1.3 Managerial IT knowledge

Bailey and Clarke (2000) defined knowledge management as *"How managers can generate, communicate and exploit knowledge for personal and organisational benefits".* The concept emphasises both importance of enhancing organisational effectiveness and personal motivation for managers to adopt a knowledge management perspective, which is crucial for strategy, operations, and change management, and highlights the need for managers to recognise knowledge as a viable action within their scope of authority.

IS knowledge is one of the general areas of knowledge and skills required by all employees (Nelson 1991). General IS knowledge includes hardware and software concepts, IS potentials, organisational IS policies and plans, and existing IS applications. A key component of an organisation's IT capability is the sharing of IT-related and business-related knowledge between IT managers and business unit or line managers (Lee et al. 1995). This intertwined and dynamic pool of knowledge embodies the concept of managerial IT knowledge (Ray et al. 2004). Specifically, the knowledge shared between IT managers, who understand business processes, and line managers, who recognise potential opportunities for applying IT to enhance process performance, contributes to a mutual understanding of how IT can be effectively utilised to improve processes (Mao et al. 2021). The IT knowledge capability of top managers, encompassing their business acumen and technical skills, enables the effective utilisation of IT to achieve alignment between business processes and organisational goals (Liu et al. 2016). Therefore, managerial IT knowledge is an important capability enabling organisations to conceive, develop, and exploit specific IT applications to support and improve the performance of business functions and processes (Boynton et al. 1994; Mata et al. 1995). Key competencies for IT management knowledge include: (1) the capacity of IT managers to understand and value the business requirement of managers in other departments, as well as the needs of suppliers and clients. (2) the ability to collaborate with other functional managers, suppliers and customers to develop appropriate IT solutions. (3) the capability to align IT initiatives in a manner that support the objectives of these stakeholders. (4) the foresight and preparedness to anticipate and address the future IT needs of these stakeholders (Mata et al. 1995). Managerial IT knowledge requires the development of experts who possess both managerial capability and technical capability, which can take many years, making it difficult to imitate, therefore it is rare to possess compared to other resources (Lioukas et al. 2016).

Several studies have described managerial IT knowledge as a sub-factor of IT assimilation, from the perspective that managerial IT knowledge enables firms to utilise IT more effectively than their competitors (Mata et al. 1995; Ranganathan et al. 2004; Mishra et al. 2007). Armstrong and Sambamurthy (1999) identified the evidence that senior's IT knowledge for management has a positive influence on the degree of IT assimilation. Additionally, Purvis et al. (2001) examined the impact of managers' knowledge embeddedness on the assimilation of IT use. Chatterjee et al. (2002) pointed out the importance of top management's meta-structuring actions for maximising the assimilation of IT. In their research, they identified activities in which managers need to engage to facilitate the use of IT applications. These activities include providing visions and guidelines, as well as addressing the risks associated with assimilating the IT application across managers in departments and business units. The research states when top management is proactively involved in forming the vision and strategies for the use of IT, they lead the way in encouraging the participation in structuring actions by individual managers, groups, and departments across the entire organisation. The study by Ranganathan et al. (2004) found that a high level of managerial IT knowledge has a positive effect on the assimilation process in SCM, suggesting that a manager's knowledge and understanding, based on insight into the potential of IT, can facilitate the easier and more widespread assimilation and utilisation of innovative technologies, thereby enhancing SCM.

4.3.1.4 IT personnel skills

In traditional research, technical skills were paramount for IT-related employees such as IT programmers (Strout 1971). As the value of IT has become increasingly important in modern organisations, the value of the requisite skills of IT personnel has also risen. Employees' IT skills, along with managers' IT knowledge, are mutually reinforcing elements of an organisation's IT competency (Nelson 1991). Not only simple technical skills but also the importance of managerial, business, and interpersonal skills is cited as essential for technical employees (Byrd and Turner 2001). As proposed by Ross et al. (1996), IT skills are an important part of human assets within IT assets. The technical skills of IT staff serve as a critical bridge connecting old and new systems, distributing data across locations and applications within the organisation. Furthermore, the business understanding and problem-solving abilities of IT staff have also been emphasised. Through business understanding and problem-solving capabilities, IT personnel can expand interactions between individual business units and with clients, and assist in establishing IT requirements and leading IT initiatives. Cross et al. (1997) also noted a transformation in the competencies of IT personnel from a focus on system providers, analysts, and craftsmen, towards infrastructure planners, business planners, and project managers which acquires better management, business, and interpersonal skills. The competencies required of IT professionals include knowledge of IT resources and an understanding of other technologies that currently exist and are anticipated in the future within the environment (Duncan 1995).

As previously mentioned, while investments in IT have been focused on infrastructure to secure and enhance IT capability and competency, the research by Broadbent et al. (1996) found that the foundational IT components are transformed into valuable IT infrastructure services through the skills of IT personnel. The IT personnel skills integrate the IT components to form a reliable set of IT infrastructure services that can be shared. The skills of IT personnel, while intangible and challenging to analyse or prescribe, are critically important as they can impact the management level and quality of the fundamental component resources (Duncan 1995). The research by Harkness et al. (1996) suggested that before the development of an Integrated IT infrastructure, it is necessary to improve the depth and scope of IT personnel. Fink and Neumann (2009) emphasised the importance of IT personal skills, including the technical skills of IT personnel, as factors that enable IT infrastructure flexibility to enhance an organisation's IT competency. Furthermore, several studies have validated the positive influence of IT personnel skills as a component of IT infrastructure or IT capability on SCM. The research by Chung et al. (2003) set modularity and integration, along with IT personnel skills, as subcomponents of IT capability in the development and evolution of SCM systems solutions. Hou (2020) adopted the framework of Chung et al. (2003) to investigate the mediating relationship between supply chain capability and performance, analysing the importance of IT application and its impact on organisational outcomes. Table 4-3 presents the observations for measuring the IT competency, based on the discussion of the constructs FITI, ITA, MITK, and ITPS that constitute IT competency.

Latent variables	Observed variables	References
Flexible IT infrastructure		Turnbull (1991); Weill (1992b); Davenport and Linder (1994); Broadbent et al. (1996); Terry Anthony Byrd (2000); Byrd and Turner (2001); Chung et al. (2003); Angeles (2009); Fink and Neumann (2009); Hou (2020); Mao et al. (2021)
FITI1	Our organisation has established corporate rules and standards for hardware and operating systems to ensure platform compatibility.	
FITI2	Our organisation has identified and standardized data to be shared across systems and business units.	
FITI3	The manner in which the components of our information systems are organised and integrated allows for rapid changes.	
FITI4	Our organisation's information systems are designed to support new business relationships easily.	
FITI5	Our organisation's information systems are designed to rapidly accommodate changes in business requirements.	
IT assimilation		Armstrong and Sambamurthy (1999); Purvis et al. (2001); Ranganathan et al. (2004); Zhu et al. (2006); Kouki et al. (2010); Manuel Maqueira et al. (2019); Tigga et al. (2021)
ITA1	Our organisation can implement IT in many business processes.	
ITA2	Our organisation can implement IT in a large number of functional areas.	
ITA3	The extent to which IT is used in our business processes (e.g., operation, management, and decision making) is great.	
ITA4	Our organisation can integrate existing and new IT systems for business application.	
Managerial IT Knowledge		

MITK1	In our organisation, top managers are interested in using IT applications.	Nelson (1991); Lee et al. (1995); Pérez-López and Alegre (2012); Liu et al. (2013b); Liu et al. (2016); Mao et al. (2021)
MITK2	In our firms, top managers consider IT applications as important.	
MITK3	In our firms, top managers commit to support IT applications.	
IT Personnel Skill		Nelson (1991); Lee et al. (1995); Broadbent et al. (1996); Byrd and Turner (2001); Chung et al. (2003); Fink and Neumann (2009); Liu et al. (2013b); Hou (2020)
ITPS1	Our IT personnel works well in cross-functional teams addressing business problems.	
ITPS2	Our IT personnel is encouraged to learn new technology.	
ITPS3	Our IT personnel is able to interpret business problems and develop appropriate technical solutions.	
ITPS4	Our IT personnel has the ability to work cooperatively in a project team environment.	
ITPS5	Our IT personnel is skilled in multiple technologies and tools.	

Table 4-3 IT competency indicators

Source: Author

4.3.2 Maritime supply chain integration

Efforts to develop methods for measuring the concept and phenomena of SCI have been identified in prior research, however, there is a lack of measurement tools in the container maritime supply chain context that reflect the multifaceted nature involving all maritime operators. The measurement of SCI in the maritime supply chain should reflect the mutual interests of collaboration among supply chain members and the nature of the maritime industry.

In the studies conducted by Seo et al. (2015) and Seo et al. (2016) that elucidate the relationship between port performance and SCI, they developed a tool for measuring SCI that is applicable not just to specific operators but across a broad range of all maritime supply chain parties and empirically validated it. Six dimensions of SCI in containerised maritime supply chain are elaborated to develop the concept of SCI which includes ‘information sharing (IS)’, ‘knowledge creation (KC)’, ‘collaborative communication (CC)’, ‘goal similarity (GS)’, ‘decision harmonisation (DH)’, ‘joint performance measurement (JPM)’.

4.3.2.1 Information sharing

The first dimension is the Information Sharing (IS) that assists in the visibility of the supply chain and the sharing of frequent, relevant, and accurate information (Seo et al. 2015). The scope of IS can include a variety of elements such as tracking containers for shipping companies, monitoring the movement of containerised cargo, managing data related to security and environmental concerns, coordinating hinterland connections, and compiling port data and supplementary services, all of which can streamline the flow of goods within the port supply chain (Seo et al. 2015). Yuen et al. (2019) proposed information management related to sharing information among members of the supply chain through seamless technology as a critical success factor for container shipping.

IS also facilitates rapid and adequate actions to avoid duplication of documents and reduce total costs (Marlow and Casaca 2003). Lotfi et al. (2013) mentioned that shared information enables quick determination of changes within the supply chain and forecasting of customers' needs, thereby enhancing the competitive advantages of the supply chain. Information and data sharing enable a high level of coordination and resource utilisation. In turn, the accumulated information from data sharing can be leveraged to develop and implement innovative shipping analytics, which are essential for enhancing operational performance and strategic planning to increase productivity (Lind et al. 2021). Jayaram et al. (2010) also argued that both formal and informal sharing activities foster communication among supply chain partners and promote the prompt and appropriate responses and corrective actions across the entire supply chain.

4.3.2.2 Knowledge creation

Knowledge Creation (KC) reflects the degree to which supply chain partners enhance their comprehension of market and competitive dynamics through collaborative efforts (Cao and Zhang 2011). This concept traditionally stems from the philosophy of ‘organisational learning’, where the shared or collective learning of knowledge in networking activities creates greater value than the sum of individual knowledge (Harland et al. 2004). Knowledge creation involves the ability to search for, explore, acquire, assimilate, and apply knowledge regarding resources, opportunities, and the strategic configuration of resources to exploit opportunities (Bhatt and Grover 2005). This process not only enhances an organisation's absorptive capacity but also serves to build and regenerate its capabilities, thereby establishing a source of competitive advantage (Hunter 2003). Hunter (2003) suggested two type of knowledge creation activities: knowledge exploration and knowledge exploitation. Knowledge exploration refers to the acquisition and experience of new and relevant ideas, technologies, strategies, and knowledges, while knowledge exploitation involves assimilating and applying knowledge to improve and refine capabilities (March 1991). Bhatt and Grover (2005) argued knowledge creation activities across the supply chain, become a source of competitive advantage, particularly in modern environments where heightened awareness and responsiveness, reinforced are crucial. KC differs from IS in that its goal is to generate knowledge intended for strategic collaboration, whereas IS focuses on disseminating information for use at the tactical or operational levels of collaboration (Seo et al. 2015).

4.3.2.3 Collaborative communication

Collaborative Communication (CC) entails frequent and two-way communication that help supply chain members make timely decisions regarding the most effective and practical ways to distribute goods and information (Frankel 1999). Mohr and Nevin (1990) suggested that a CC strategy is likely to emerge in relational structures, supportive environments, and symmetrical power relationships if the appropriate collaborative channel conditions are met. Prahinski and Benton (2004) assumed that by emphasising the formality of communication and communication feedback, CC acts as a factor that strengthens the relationship between supply chain partners by reducing unnecessary communication, thereby cutting costs and enabling the perception of market changes. In the study by Gimenez et al. (2012), it was found that structured communication is highly correlated with various SCI dimensions, particularly joint improvement and delivery integration, which as a result, indirectly contribute to the improvement of service. Furthermore, the research argued that informal communication is a prerequisite for SCI, as it constitutes cooperative behaviour. CC is distinct from mere information sharing as it focuses on the ways in which supply chain operators engage with each other through consistent meetings and diverse types of interactions (Seo et al. 2016). Dynamic and collaborative communication fundamentally underpins collaborative efforts and is a critical factor in facilitating strategic partnerships between ports and their users, serving as a key aspect of relational competency (Paulraj et al. 2008). Yu et al. (2021) emphasised that with the rapid development of IT, which has expanded the channel, method and scope of communication, the importance of adequate communication in effective cooperation has become increasingly highlighted.

4.3.2.4 Goal similarity

Goal similarity (GS) refers to the degree to which supply chain partners pursue similar objectives, aiming to achieve the overall supply chain's objectives in an efficient and effective manner (Angeles and Nath 2001). Goal congruence facilitates a clearer comprehension of the capabilities of the partnering firm and enables the attainment of mutual objectives across the supply chain (Huang et al. 2020). An integrated group with similar goals is motivated to engage in cooperative behaviours, such as constructive communication, mutual support, and high commitment. This allows resources that would have been spent on resolving conflicts or monitoring behaviour to be utilised in supporting value-added activities, such as exploring solutions, acquiring technical expertise and talent, and investing in key infrastructure (Yan and Dooley 2013). Maintaining consistent goals through establishing a common vision, selecting partners with shared visions and objectives, and establishing the clear responsibilities and duties support firms in their efforts to integrate and optimise the supply chain (Yuen et al. 2019). Angerhofer and Angelides (2006) argued that the closer the objectives of the business strategies of the participants in SCI are to the strategy of the collaborative supply chain, the more integrated actions and processes can be facilitated. This, in turn, reduces information delays and increases forecast accuracy of inventory management, thereby improving the quality of service. Seo et al. (2015) provided examples of shared objectives within the maritime supply chain, including the integration of shipping liners and terminals to improve hinterland connections, minimise ship waiting times, and identify the most efficient container routes.

4.3.2.5 Decision harmonisation

Decision Harmonisation (DH) refers to the collaborative process in which ports and their users coordinate their decisions to create integrated transportation plans and operations across the entire port supply chain (Hudnurkar et al. 2014). Agreement on decision-making authority and responsibilities is a major requirement for successful integration (Simatupang and Sridharan 2002). According to Simatupang and Sridharan (2002), decision-making domain encompasses customer service requirements, forecasting, inventory, ordering, and transportation in the short-term; logistics capability, service development, and market segmentation in the medium-term; and business objectives, market strategy, and capability planning in the long-term. Different decision-making processes among operators at various stages of the supply chain can result in suboptimal performance. Therefore, coordinated and joint decision-making among supply chain members provides continuity and connectivity in the previously mentioned decision domains, leading to better performance (Simatupang and Sridharan 2005b). Regarding information exchange, decision synchronisation helps identify the appropriate data to be collected and the format for its transfer to decision-makers. Simatupang and Sridharan (2008) pointed out that individual decision-making, which involves capturing, storing, and processing information such as scheduling, delivery, and cargo flow, as well as transferring it to other parties, can be costly. Seo et al. (2015) noted that maritime operators adjust schedules and modify container transport routes to accommodate changes in shippers' requirements. In addition, by harmonising operational decisions with ports and inland transport companies, shipping liners are able to guarantee end-to-end services.

4.3.2.6 Joint performance measurement

Joint Performance Measurement (JPM) is a tool used to assess the results of collaborating with partners in the maritime supply chain (Yuen et al. 2019). Consistent measuring the performance of a supply chain promotes continuous improvement, provides incentives for collaboration, and clarifies the roles of the members within the supply chain. The lack of adequate metrics can lead to a failure to satisfy consumer or end-user demands, poor company performance, missed opportunities for competitive advantage, and conflicts within the supply chain (Lambert and Pohlen 2001). Lambert and Pohlen (2001) emphasised the need for a unified measurement tool for competitiveness, customer value, and shareholder value, as they argued that traditional financial and logistics measures fail to provide insight into how effectively business processes are performed. Joint performance metrics and objectives should be determined to simultaneously achieve collaborative goals of supply chain members and the overall success of the supply chain (Simatupang and Sridharan 2008). A well-designed performance objective is characterised by clear outcomes, measurability and quantifiability, a defined time frame, and being challenging yet attainable. Lai et al. (2002) argued that in the context of SCM, performance measurement should take into account the expectations of other members that cover the supply chain from suppliers to customers, and that coordination between the various parties in the supply chain must be prioritised. Performance in the maritime supply chain encompasses enhancing associated maritime operations such as reducing the time for container processing, increasing the capacity for vessel accommodation, minimising port stay duration, and collaborative efforts in managing security and risks (Seo et al. 2015). Table 4-4 lists the observable variables for measuring the components of SCI, which include IS, KC, CC, GS, DH, and JPM, as elaborated.

Latent Variables	Observed variables	References
Information sharing	Our firm and supply chain partners	Heide and John (1992); Fynes et al. (2004); Simatupang and Sridharan (2005b); Li et al. (2009); Panayides and Song (2009); Seo et al. (2015,2016)
IS1	Provide any information that might help within our maritime supply chain.	
IS2	Frequently exchange information within maritime supply chain.	
IS3	Have informed each other of changing needs in advance within our maritime supply chain.	
IS4	Keep each other informed about events or changes that may affect our maritime supply chain.	
IS5	Exchange accurate information within our maritime supply chain.	
Knowledge Creation	Our firm and supply chain partners	Harland et al. (2004); Lee and Song (2010); Cao and Zhang (2011); Song and Lee (2012); Seo et al. (2015,2016); Huang et al. (2020)
KC1	Search and acquire new and relevant knowledge within our maritime supply chain.	
KC2	Assimilate and apply relevant knowledge within our maritime supply chain.	
KC3	Identify customer needs for our maritime supply chain.	
KC4	Discover new technology for our maritime supply chain.	
KC5	Learn the intentions and capabilities of other maritime supply chain in competition.	
Collaborative Communication	Our firm and supply chain partners	Carr and Pearson (1999); Paulraj et al. (2008); Woo (2010); Cao and Zhang (2011); Gimenez et al. (2012); Seo et al. (2015,2016)
CC1	Have frequent contacts on a regular basis in our maritime supply chain.	
CC2	Have open and two-way communication in our maritime supply chain.	
CC3	Have informal communication in our maritime supply chain.	
CC4	Have many different channels to communicate through in our maritime supply chain.	

CC5	Have influence over each other's decisions through discussion in our maritime supply chain.	
Goal Similarity	Our firm and supply chain partners	Angerhofer and Angelides (2006); Ryu et al. (2009); Lee et al. (2010); Yan and Dooley (2013); Seo et al. (2015,2016); Huang et al. (2020)
GS1	Pursue efficient multi-modal transport of container cargoes for our maritime supply chain.	
GS2	Stress the importance of collaboration within our maritime supply chain.	
GS3	Pursue the provision of value-added logistics services for our maritime supply chain.	
GS4	Pursue cost reduction throughout our maritime supply chain.	
GS5	Pursue reduced cycle times and enhanced inventory management for our maritime supply chain.	
Decision Harmonisation	Our firm and supply chain partners	Stank et al. (2001); Simatupang and Sridharan (2005b); Song and Panayides (2008); Seo et al. (2015,2016); Huang et al. (2020)
DH1	Plans on emergent situations within our maritime supply chain.	
DH2	Plan on altering schedules and amending orders when customers demand them within our maritime supply chain.	
DH3	Manage the flow of cargoes within our maritime supply chain.	
DH4	Plan on transport planning and scheduling transport our maritime supply chain.	
DH5	Advice each other of any potential problems in meeting the shipper's need within our maritime supply chain.	
Joint Performance Measurement	Our firm and supply chain partners	Lambert and Pohlen (2001); Lai et al. (2002); Simatupang and Sridharan (2005b); Fawcett et al. (2007); Seo et
JPM1	Develop systems to evaluate supply chain performance for our maritime supply chain.	
JPM2	Deal with security and risks that may occur for our maritime supply chain.	

JPM3	Develop systems to enable shippers to identify their cargoes' location for our maritime supply chain.	al. (2015,2016); Yuen et al. (2019)
JPM4	Keep seamless transport flows even in a peak time for our maritime supply chain.	
JPM5	Solve the problems together (i.e. delay and accidents in transport) for our maritime supply chain.	

Table 4-4 Supply chain integration indicators

Source: Author

4.3.3 Performance

As discussed in the previous section, this study has explored prior research to measure the performance of the supply chain operation. Performance has frequently been adopted as a dependent variable in numerous studies to assess organisational improvement. However, the use of objective versus subjective indicators in measuring performance has been the subject of academic debate (Andrews et al. 2006). Subjective indicators typically refer to measures derived from respondents' perceptions via surveys, whereas objective indicators are based on statistical records maintained by the respective agency (Parks 1984). In the field of social sciences, objective indicators are not commonly employed due to the inconsistency among performance measures, the lack of scholarly consensus regarding the reliability and validity of research models that utilise these indicators, and the practical difficulty of obtaining consistent and comparable objective data across the entire sample of organisations under investigation (Singh et al. 2016). In this context, this thesis adopts subjective indicators based on respondents' perceptions as the measurement of performance. In addition, to address the limitations of traditional financial performance metrics, it also examines operational performance, which evaluates the efficiency of overall supply chain operations.

4.3.3.1 Operational performance

This study employs speed, cost, service quality, value creating, responsiveness, and lead time as metrics to assess performance improvements in supply chain operations. *Speed* refers to the duration that takes for supply chain operation to deliver products and services (Prajogo and Olhager 2012). The rapid adjustment to alterations in operations between firms is significantly enhanced by decision-making processes and the exchange of information, which are facilitated by the features of information technology (Balfaqih et al. 2016). *Transaction processing cost* is often the largest contributor to total logistics costs

(Stewart 1995). A company that raises prices to compensate for an inefficient revenue structure loses competitiveness, which can lead to a failure to attract customers (Talley 2017). *Service quality* traditionally refers to the efforts made towards service performance, which determine the degree of user satisfaction. In the supply chain, service quality satisfies consumer demands through collective efforts with different parties as an integral part of the supply chain link (Gupta and Singh 2012). *Value creation* refers to the process of achieving operational efficiency and competitive advantage by engaging in activities that go beyond traditional logistics functions to meet the demands of a wide range of customers (De Martino and Morvillo 2008). Value-added services in the supply chain involve adding value on the context of different operations, services, and capabilities by a variety of activities, including the expansion of logistics scope, securing flexibility, meeting diverse consumer demands, and simplifying lead times (Song and Panayides 2008). Measure the supply chain's *responsiveness* to any unexpected changes in market demand (Ramanathan et al. 2011). Responsiveness is typically associated with short lead times, which are influenced by the degree of collaboration (Lee 2002). This is also related to the role of modern IT in facilitating communication. *Reducing lead times* facilitates timely delivery, thereby improving overall delivery performance. Timely delivery, in turn, influences the reliability of delivery and the completeness of orders. Additionally, high inventory turnover positively affects the liquidity of a company's capital, enhancing financial flexibility (Gunasekaran et al. 2004).

4.3.3.2 Financial performance

The financial measures which are grounded in accounting practices directly reflect the financial status of a company as a consequence of its operational performance (Shi and Yu 2013). Identified potential indicators of accounting-based financial performance encompass return on investment (ROI), return on sales (ROS), and net income. ROI and ROS are financial ratios that signify assessing the business operating profit earned from net investment and sales

(Friedlob and Plewa Jr 1996). ROI and ROS represent a firm's ability to utilise asset and capital, while net income serves as an indicator that allows for the evaluation of a company's capability to generate profits (Shi and Yu 2013). To address the limitation of these accrual measures which fail to account for the intangible benefits of SCM practices, cash flow has been proposed as a means to evaluate a company's profitability and liquidity. On the other hand, market share, as the market-based financial metric, refers to the aggregated market share in the industry at the company level (Edeling and Himme 2018). Market share is a financial metric that is meaningful for measuring performance as it reflects customer satisfaction and purchasing or usage patterns for a service (Stank et al. 2003). Table 4-5 details the observations used to measure operational and financial performance.

4.3.4 Blockchain utilisation

The items for blockchain utilisation were constructed based on the results identified in the previous systematic literature review. A systematic literature review was conducted to organise the domains where Blockchain Technology (BCT) has been applied in the maritime supply chain, as well as the application factors and benefits that operate within each domain. BCU Indicators were formed based on the extent of resource investment in blockchain and the degree of application in each domain, identified as BCU. First, questions were designed to inquire about the level of organisational investment in BCT. For the document management category, questions were centred around document digitalisation, real-time information exchange, and document unification. Question regarding transaction management focused on the use of BCT's decentralised and automated network with partners. Lastly, item was composed concerning access to physical hardware through BCT, addressing cargo, vessel, and terminal operations. The observations for measuring BCU are presented in Table 4-6.

Latent Variables	Observed variables	References
Operational performance		
OPP1	Our organisation has improved the speed of supply chain operations	Chen et al. (2004); Rai et al. (2006); Flynn et al. (2010); Wong et al. (2011); Sheel and Nath (2019); Jiang et al. (2021)
OPP2	Our organisation has reduced transaction costs of supply chain operations	
OPP3	Our organisation and maritime supply chain can improve the quality of services provided to customers	
OPP4	Our organisation and maritime supply chain can create value in supply chain integration	
OPP5	Our organisation and maritime supply chain can quickly respond to changes in market demand	
OPP6	The lead time for fulfilling customers' orders in our maritime supply chain (the time which elapses between the receipt of customer's order and the delivery of the goods) is short	
Financial performance		
FNP1	Our organisation has improved its return on investment by efficient operation of maritime supply chain	Flynn et al. (2010); Cao and Zhang (2011); Qi et al. (2017); Kim and Shin (2019)
FNP2	Our organisation has improved its return on sales by efficient operation of maritime supply chain	
FNP3	Our organisation has improved its market share by efficient operation of maritime supply chain	
FNP4	Our organisation has improved its net income before tax by efficient operation of maritime supply chain	

FNP5	Our organisation has improved its cash flow from operations by efficient operation of maritime supply chain	

Table 4-5 Performance indicators

Source: Author

Latent Variables	Observed variables	References
Blockchain utilisation		
BCU1	Our organisation invests resources to adopt BCT	Kim and Garrison (2010); Oliveira et al. (2014); Wamba et al. (2020); Malik et al. (2021); Khalil et al. (2022)
BCU2	Our organisation is using BCT to support document management by supporting digitalisation, real-time exchange, and standardisation	
BCU3	Our organisation is utilising BCT to support transactions with supply chain partners in the decentralised and automated system	
BCU4	Our organisation is utilising BCT in the physical movement of cargo through vessel and port terminal	

Table 4-6 Blockchain Utilisation indicators

Source: Author

4.4 Summary

This chapter has established the relationships between variables prior to empirical analysis, develops hypotheses and a conceptual model, and identifies components to measure each variable, thereby developing measurement instruments. In summary, the degree of IT competency is posited to have a positive impact on SCI, which in turn positively affects operational and financial performance. Furthermore, BCT is assumed to act as a moderating variable in the relationship between IT competency and SCI, influencing the overall improvement of the performance. The next chapter will describe the methodology and data analysis process for examining these hypotheses.

Chapter 5 Research Methodology

The preceding chapters have focused on identifying the research model and hypotheses, as well as the research model. This chapter will discuss the philosophical and methodological background necessary for determining the appropriate research methods and analysis techniques.

5.1 Research design

Research design refers to the overall plan for implementing empirical research to address a research problem (Bell et al. 2022). This process involves addressing research questions by testing research hypotheses with research objectives and analysis methods under the given constraints (Saunders et al. 2019). Research design encompasses the discussion of research philosophy, strategy, approach, and methodological choices, which is distinct from research methods that focus on data collection and analysis techniques (Bell et al. 2022). Saunders et al. (2019)'s framework explains different perspectives of research to be investigated for establishing a systematic research design. Figure 5-1 illustrate the framework, with the elements adapted in this thesis highlighted in bold.

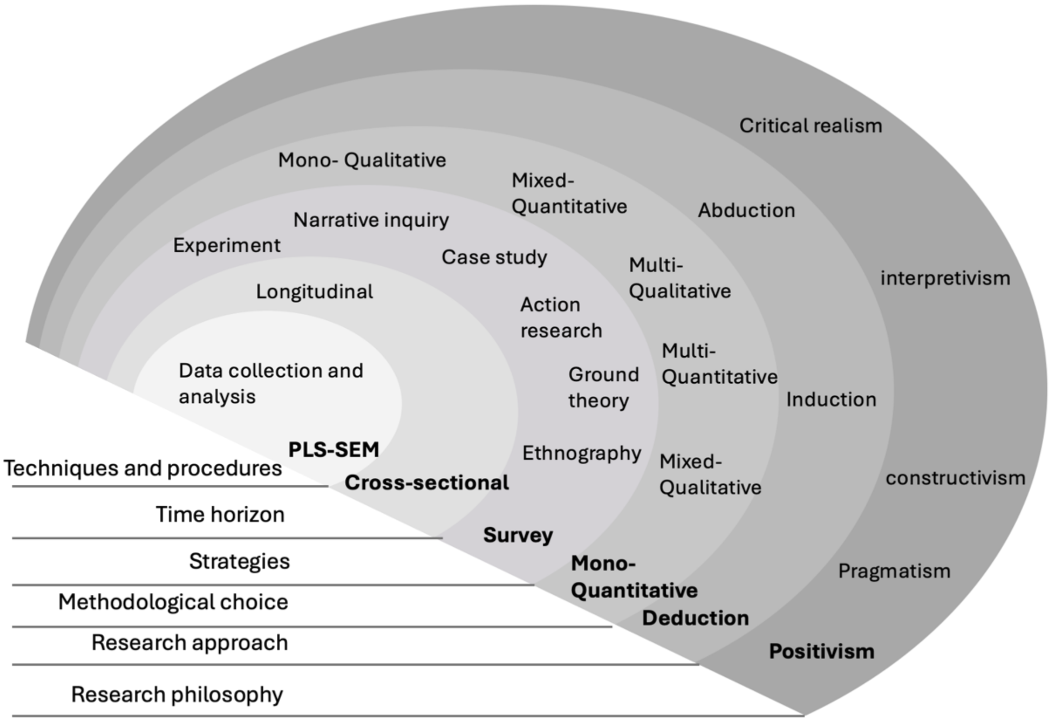


Figure 5-1 Research design overview
Source: adapted from Saunders et al. (2019)

5.1.1 Research philosophy: positivism

Research philosophy encompasses two major approaches: ontology and epistemology. Ontology theory is defined as the science of the constitution and structure of reality while Epistemology theory examines the nature of knowledge and the methods by which knowledge is acquired (Hartel 2003). Researchers recognise the reality objectively or subjectively from the ontological perspective and make effort to explain the phenomenon of the reality from the epistemological perspective (Bryman 2016; Saunders et al. 2019). In an ontological approach, if social entities are perceived as independent from external reality in understanding how the world works, this is labelled as objectivism. Alternatively, subjectivism refers to the view that reality is constructed through individual perception, experience, and social interaction (Bryman 2016). From a scientific paradigm perspective, the ontological dimension is divided into realism and nominalism, while the epistemological dimension is divided into positivism and interpretivism (Klein and Hirschheim 1987). Ontological dimensions distinguish between realism, which assumes that reality and the observer are independent entities, and nominalism, which assumes that reality is a subjective construct. Epistemological dimensions consist of positivism, which seeks to explain observable phenomena through causal relationships, and interpretivism, which emphasises the importance of the observer's pre-understanding. Figure 5-2 illustrates that the perspective on social phenomena is associated with its own epistemology that allows for interpretation, and encompasses a set of methodologies that enables to produce a specific type of data (Solem 2003). Positivism asserts that knowledge is hard, real, and can be transmitted in tangible forms. In contrast, constructivism or interpretivism views knowledge as soft, more subjective, and potentially spiritual or even transcendental, rooted in experience, insight, and fundamentally personal in nature (Morgan and Smircich 1980).

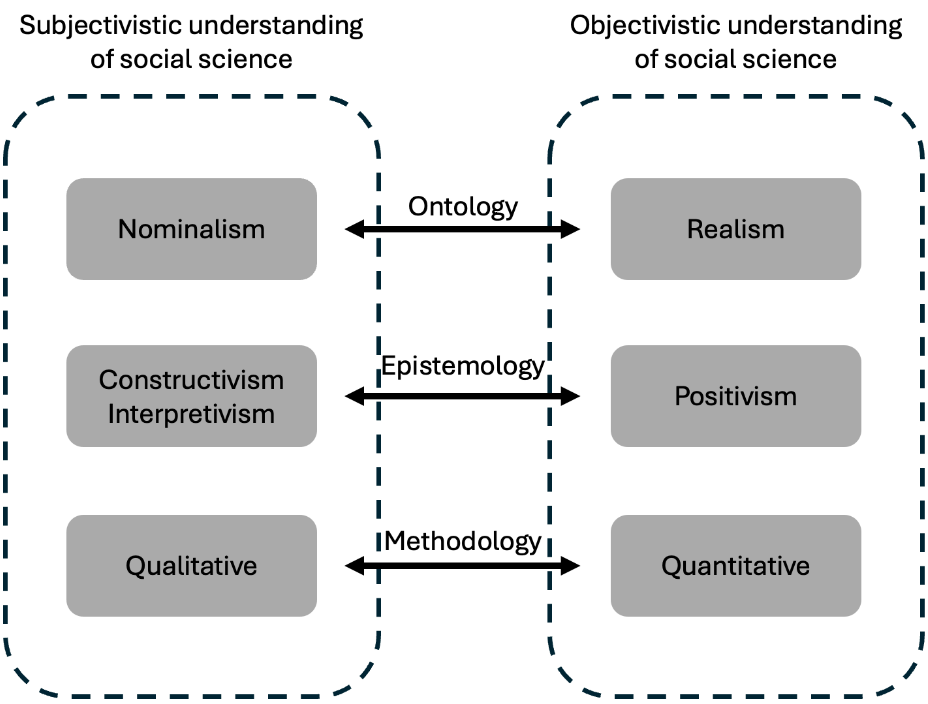


Figure 5-2 Main Roads of paradigm in science theory
Source: Solem (2003)

In supply chain modelling, the two significant paradigms are: the objectivist paradigm, which is defined by a realist-positivist position, and the subjectivist paradigm, which is defined by a nominalist-interpretivist position (Grubic and Fan 2010). The review study by Grubic and Fan (2010) indicates that supply chain ontology models predominantly adopt an objectivist position. Healy and Perry (2000) synthesised the four major paradigms used in scientific research, namely: positivism, which is associated with quantitative methodology; critical theory, constructivism and realism which are related to qualitative methodology, as shown in Table 5-1.

Element	Paradigm			
	positivism	Critical theory	Constructivism	Realism
Ontology	Reality is real and apprehensible	“virtual” reality shaped by social, economic, ethnic, political, cultural, and gender values, crystallised over time	Multiple local and specific “constructed” realities	Reality is “real” but only imperfectly and probabilistically apprehensible
Epistemology	Objectivist: findings true	Subjectivist: value mediated findings	Subjectivist: created findings	Modified subjectivist: findings probably true
Common methodologies	Experiments/surveys: verification of hypotheses, mainly quantitative methods	Dialogic/dialectical: researcher is a “transformative intellectual” who changes the social world within which participants live	Hermeneutical/ dialectical: researcher is a “passionate participant” within the world being investigated	Case studies / convergent interviewing: triangulation, interpretation of research issues by qualitative and by some quantitative methods such as SEM

Table 5-1 Categories of scientific paradigm and their elements

Source: Healy and Perry (2000)

In logistics and supply chain operation research, positivism has been a strong foundation and has been continually emphasised (Mentzer and Kahn 1995). Knowledge from research findings have been systematically accumulated from the beginning of exploratory studies through the process of identifying key issues and further research directions. The study by Näslund (2002) indicates that the positivist paradigm has been dominantly preferred in logistics research. Similarly, the research by Woo et al. (2011) presented that positivism has been overwhelmingly adopted in port-related research through a review analysis. The review study by Lau et al. (2013) synthesised research topics from past studies in the maritime and shipping industry. As indicated in Table 5-2, the primary focus of these studies was on improving performance through various aspects, and it was evident that the majority of the research aimed to verify the causal relationships between influencing factors adopting the positivist perspective.

Research topics	Aspects	Specific focuses
Shipping operation	Tangible, engineering and physical aspects.	Maximising operational efficiency and minimising operational costs
Shipping management	Nonphysical and engineering aspects.	Enhancing performance, competitiveness, reputation, and impact on surrounding environment
Shipping economics	Utilisation of economic resources	Cost and production, demand analysis, competition and market structure, regulation and conference, efficiency, economic development, labours and employment, pollution control, and sustainability

Table 5-2 Research topics in maritime industry
Source: Lau et al. (2013)

As illustrated in Figure 5-2 and Table 5-1, positivism is characterised by the pursuit of general laws through measurement and the analysis of causal relationships between variables. Knowledge accumulates through the process of selecting and rejecting hypotheses, with the aim of explaining and predicting phenomena in the world (Näslund 2002). Positivism assumes that value-neutral data and analysis from objective observation of independent facts can be measured quantitatively (Healy and Perry 2000). The present research aims to identify the phenomenon of organisational IT competency and the utilisation of BCT for SCI activities and their effects on performance. It also aims to examine the causal relationships between these activities. In other words, this research stands objectively observing the phenomenon of SCI and exploring the causal relationships among various phenomena by developing hypotheses and testing with a mathematical technique. Consequently, this study can be regarded as embracing a positivist paradigm from an objectivist perspective.

5.1.2 Research approach: deductive

A research approach is referred as the process of conscious and scientific thinking (Peirce 1974). A research approach discusses the relationship between theory and data analysis (Bell et al. 2022). Research approach is categorised into three main types based on the nature of the relationship between data collection and analysis and between theory and data: deduction, induction, and abduction (Kennedy and Thornberg 2018).

The deductive approach is an approach that examine the validity of hypotheses based on a specific theory or generalisation and applies conclusions to specific instances (Kennedy and Thornberg 2018). This approach explains the causal relationships between concepts and enables the prediction of relationships. In quantitative research, a hypothesis can be deduced from theory and then empirically tested in order to confirm or falsify the hypothesis, and thus the theory. On the other hand, the inductive approach is a process of theory development that generates a general statement by finding specific patterns and regularities through the observation of a series of empirical cases. In other words, inductive logic focuses on inferring categories or conclusions based on data (Charmaz 2011). Research that employs inductive reasoning emphasises the importance of data in discovering new interpretations and conclusions of existing knowledge. Lastly, the abduction approach, which combines the deductive and the inductive approaches, begins with the discovery of surprising phenomena, data, or events that cannot be explained by existing knowledge (Reichertz 2019). Abduction involves interactions between theories and data to understand and explain these new phenomena with the process of suggesting hypotheses, testing theories, and generalising conclusions (Saunders et al. 2019). Figure 5-3 illustrates the research process representing the paths of reasoning used in the deductive, inductive and abductive approach.

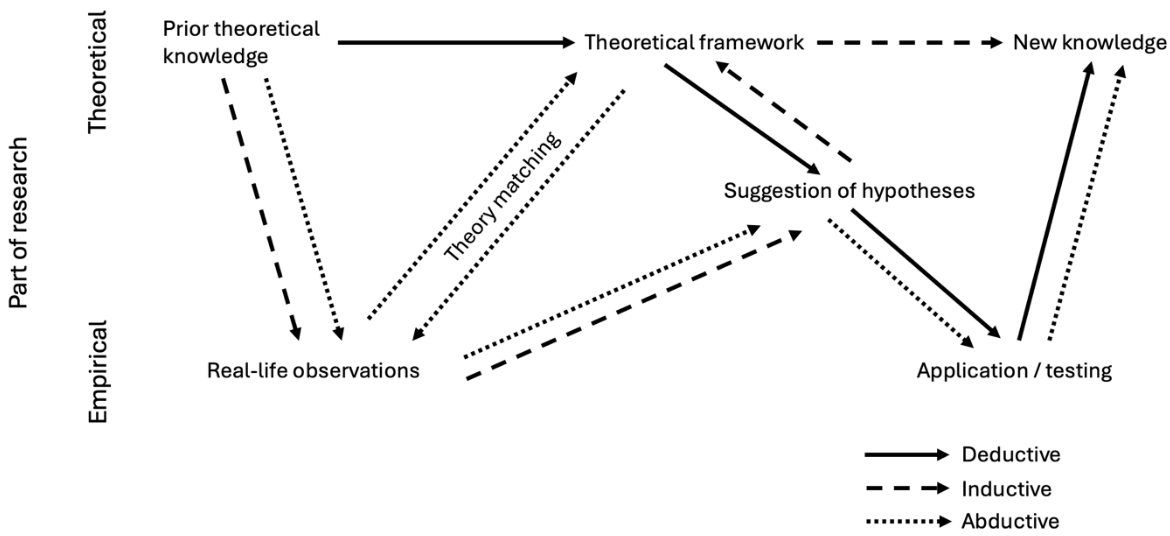
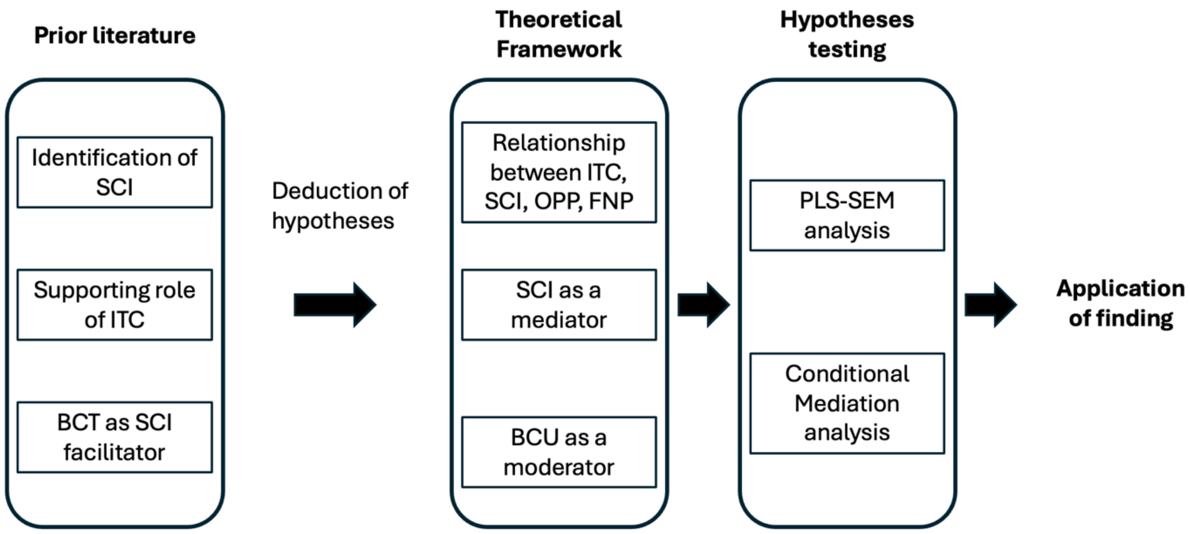


Figure 5-3. The research approaches path
Source: Kovács and Spens (2005); Spens and Kovács (2006)

Positivism is aligned with the hypothetico-deductive method in that it seeks to verify a priori hypotheses where functional relationships between causal factors and outcomes can be derived (Park et al. 2020). Spens and Kovács (2006) argued that deductive positivism is the dominant research approach in the field of logistics research. This is because logistics business research, a relatively new area of study, has focused on borrowing existing theories from other academic disciplines to test these established theories (Kovács and Spens 2005). In this sense, this study adopts the hypothetico-deductive model to establish testable hypotheses regarding the causal relationships between factors derived from existing literature and theories, thereby enabling the explanation of phenomena through the results of verification. The deductive approach of the present study is illustrated in Figure 5-4.



Note: SCI: Supply chain integration; ITC: IT competency; BCT: Blockchain technology; BCU: Blockchain utilisation; OPP: Operational performance; FNP: Financial performance; PLS-SEM: Partial least square structural equation modelling

Figure 5-4. Research approach of this study

Source: author

5.1.3 Choice of Methodology: A quantitative research

Decisions regarding the choice of methodology are divided into quantitative, qualitative, or mixed methodology approaches, depending on the methods of data collection and analysis techniques employed (Saunders et al. 2019). Qualitative research aims to understand human and organisational behaviour, the motivations behind these behaviours, and their differences underpinning interpretivist or constructivist philosophies (Ang 2014). This type of research is conducted through the contextualisation of the research setting, taking into consideration the context and environment of the research. The logic of qualitative research primarily operates through an inductive approach. This involves adjusting the research framework as new phenomena or patterns are discovered, either during the initial data collection process or as a broader understanding emerges from the data collected. This contrasts with typical deductive quantitative research, which follows a predefined script. Quantitative research aims to clearly and accurately establish the relationship between two or more constructs through multiple observations shaped by objectivist positivism (Ang 2014). To test the relationships between constructs that may vary across different contexts and conditions, multiple observations are used to contextualise these relationships. In this process, the level of significance of a relationship is quantified. Given that multiple observations in quantitative research is involved, the constructs selected for study must be observable. These observations are interpreted consistently across different entities, ensuring the validity and viability of the research.

Qualitative research methods employ open-ended questions that enable researchers to probe participants, thereby allowing for a deeper understanding of the collected data (Ang 2014). Especially, by asking 'how' and 'why', the researcher seeks to provide insight into the research problem. On the other hand, Quantitative research enables the comparison of behavioural patterns through the data coding process, which quantifies the observed constructs. The measured constructs are numerically coded, including nominal, ordinal, and interval scales. In this sense, quantitative research often utilises standardised measurement tools such as questionnaires and employs statistical and mathematical analysis methods and techniques to verify, describe and predict relationships between constructs or variables (Saunders et al. 2019). The difference between two methodologies is indicated in the Table 5-3. Lastly, the mixed research method refers to an approach that integrates qualitative and quantitative methods as needed according to the research problem, question, and purpose.

	Qualitative	Quantitative
Conceptual	Concerned with understanding human behaviour from the informant's perspective	Concerned with discovering facts about social phenomena
	Assumes a dynamic and negotiated reality	Assumes a fixed and measurable reality
Methodological	Data are collected through participant observation and interviews	Data are collected through measuring variables
	Data are analysed by themes from descriptions by informants	Data are analysed through numerical comparisons and statistical inferences
	Data are reported in the language of the informant	Data are reported through statistical analysis

Table 5-3. Research methodology

Source: Minichiello et al. (2008)

This study is founded on positivism and employs a quantitative methodology via a deductive approach. As outlined in previous sections, the research design has been developed with the aim of testing hypotheses concerning the relationships between constructs derived from an earlier literature review. By gathering observable data capable of measuring these constructs through a questionnaire survey and subsequently quantifying this data, comparative analysis can be conducted.

5.1.4 Research strategy

A research strategy refers to a suitable guidance for an action plan which is designed to find answers to the research questions under consideration and to achieve the research objectives (Johannesson and Perjons 2014). It represents the methodological links between the research philosophy, research method and the methods for data collection and analysis (Saunders et al. 2019). The foundation of the research strategy is based on the choice of research method, considering quantitative, qualitative, or mixed research approaches. Quantitative research is primarily conducted through the use of questionnaires, surveys, structured interviews, or structured observation, while strategies such as ethnography, action research, grounded theory, and narrative inquiry are involved in qualitative research. Documentary research or case studies may be linked to both methodologies and to a mixed research design.

This study uses survey as a main means of collecting quantitative primary data, which enables standardisation of collected data from a large number of respondents, bringing consistency and coherence for analysis (Roopa and Rani 2012). The survey strategy is commonly adopted in business management research to obtain answers to questions such as 'what', 'who', 'where', 'how much', and 'how many'. Therefore, it is primarily used in exploratory and descriptive research (Saunders et al. 2019). The collected data enables the explanation of possible reasons for relationships between variables through the use of descriptive and inferential statistical analysis. This data has the advantage of yielding general findings that are representative of the entire population. In this study, the survey was adopted as an appropriate research strategy to measure variables for comparing and evaluating the relationships between IT competency, SCI, BCU, and performance.

5.2 Data collection method

As shown in Figure 5-1, the data collection method is involved in the research strategy regarding decisions about collecting the appropriate type of data about the phenomenon under investigation according to the methodological choice (Johannesson and Perjons 2014). The current study conducted a questionnaire survey as a tool to gather and measure necessary information about the constructs associated with the hypotheses. The questionnaire survey is the most widely used data collection method among survey strategies characterised by its suitability for exploratory and descriptive research (Saunders et al. 2019). It involves distributing an instrument composed of the same set of questions in a predetermined order to each person and collecting their responses as data. The questions in a questionnaire are typically brief and composed of straightforward information including simple facts from respondents, such as age, gender, and income, or pertaining to opinions, behaviours, perspectives, experiences, and attitudes about the topic (Johannesson and Perjons 2014). Questions can be of two types: closed questions, where the researcher has predetermined a set of permissible answers, or open questions, where respondents answer in their own words without predefined answers. This section discusses the design and development of a closed questionnaire as part of quantitative research.

5.2.1 Sample design for questionnaire survey

In survey research, a key starting point is defining the population that will be the subject of the study. The term "population" refers to the set of elements that are the focus of the research, where the "elements" represent the units of analysis, such as individuals or organisations (Kalton 2021). Defining the population precisely is an important process that influences the results of the survey, and therefore, it must be considered in relation to research questions and objectives (Saunders et al. 2019). This process begins with establishing the target population, determining who should be included or excluded from the sample. The target population is the assemblage of elements or objects that can provide the information the researcher explores (Kalton 2021).

5.2.1.1 Sample target population

The current study has defined its target population as organisations within the maritime supply chain, with a particular focus on those involved in container shipping. Containerisation has transformed the scope and scale of global freight distribution, emphasising the concept of the maritime supply chain, and has become the centre of maritime transport activity (Paridaens and Notteboom 2022). In Chapter 2, an in-depth literature review identified the major operators in the maritime supply chain as shipping liners, terminal operators, and freight forwarders. This identification aligns with the results of a systematic literature review and case studies that have confirmed the participation of these operators in the adoption and utilisation of BCT solution. Additionally, the case studies revealed that port authorities are also entities developing their own blockchain solutions. A port authority is an institution with a hybrid nature, encompassing the management of both public and private elements (Tijan et al. 2021b). As an administrative body involved in port management or administration, the port authority operates a Port Community System (PCS), which concentrates, centralises, serves, and optimises communication related to business processes within the port (Tijan et al. 2021b). The PCS contributes to the enhancement of the port's competitiveness by facilitating fast and safe data exchange among private and public organisations within the port. From that perspective, the port authority was selected as one of the target organisations in this study, being an entity engaged in SCI activities and the utilisation of BCT (Yoon et al. 2020).

Additionally, this study determined the questionnaire survey sample to primarily consist of companies operating in South Korea (Republic of Korea). As a major container hub in Asia, South Korea's prominent Busan port handles the second-largest volume of container cargo among international ports, excluding those in China, following Singapore (Park 2021). The majority of this volume consists of transhipment, which positions Busan as a significant hub within the global maritime supply chain (WSC 2024). According to a report by UNCTAD (2023), Korea's container port efficiency ranked fourth in the world with the use of ICT for automation, which has minimised container movement and handling times. In practice, ports in Korea, starting with Busan port, have been striving to improve port management environments and efficiency with the development and implementation of blockchain-based platforms (Park 2019; Park et al. 2021). This demonstrates that maritime supply chain operators in Korea are at the forefront of applying innovative technology at the centre of maritime SCI. Consequently, it signifies that they are an appropriate target for observing the phenomena of the constructs of ITC, SCI, and BCU in the current study.

In terms of a sample frame, it involves identifying the target population taken from sources or databases accessible to the researcher, such as an industry association directory or a customer database (Saunders et al. 2019). For this study, the sampling frame was developed using the directories of the Korea Shipowners Association (KSA) for shipping liners and the Korea International Freight Forwarder Association (KIFFA) for freight forwarders and terminal operators in the ports of Busan, Incheon, and Gwangyang. Furthermore, the port authorities of Busan, Incheon, Ulsan, Yeosu, and Gwangyang were included as potential sources for the sample frame. The target companies in the sample frame include international maritime organisations which are positioned in the leading roles of the BCT solution cases presented in Section 2.2.2.1. Furthermore, a large number of target companies are actively involved as members in large-scale BCT initiatives, thereby ensuring that the target selection is sustainable and aligned with the research objectives.

5.2.1.2 Sample method

Researchers must choose an appropriate sampling method within limited time and budget constraints to achieve the objectives of a survey efficiently and practically (Thomas 2004). Two main types of sampling methods: probability and non-probability (Saunders et al. 2019). Probability methods refer to those where every element of the population, known as the sample frame, has an equal probability of being selected. Random selection methods include simple random sampling, systematic random sampling, stratified random sampling, and cluster sampling (Thomas 2004). A random population is desirable for empirical generalisation because it allows for statistical inference based on data derived from samples. However, in practice, non-probability methods using non-random samples are often employed as alternatives in management research. In practical terms, non-probability methods allow the collector to choose which samples to include, thereby saving costs and time within limited resources, as opposed to probability methods that may be difficult to implement through an entirely random mechanism (Forster 2001). While non-random samples may be criticised for their lack of adequacy as a basis for generalisation, this does not reduce their importance for achieving research objectives (Kalton 2021). In approaching a non-random population, methods such as quota sampling, convenience sampling, purposive sampling, and theoretical sampling can be included. Considering the limited resources permitted for this research and the need to ensure the reliability of the data, a non-probability sampling method, specifically convenience sampling, is employed to establish and access a practical survey target. Convenience sampling involves constructing a sample frame targeting population options that are easily accessible to the researcher, which is commonly accepted as a standard sampling method in the field of business and management (Bell et al. 2022). By adopting a sample that is relevant to the objectives of the survey, the selection criteria of a purposive sample can be met, thereby offsetting the potential drawback of lacking credibility (Saunders and Townsend 2018).

In this research, to appropriately measure the IT competency and the extent of SCI within maritime organisations, participants who perform tasks familiar with these elements should be targeted. Employing a convenience sampling approach, the researcher approached the professional network to access potential participants within the sample frame who align with the research aims. This network includes part-time postgraduate colleagues and alumni from the university, joint project collaborators, and members of academic advisory boards, all of whom are engaged in the maritime industry. Additionally, each respondent was encouraged to circulate the questionnaire to their business partners or colleagues within their organisations.

In addition, this study partially adopted a purposive sampling perspective to determine the scope of the sample. Respondents to the survey are employees working in IT and SCI-related tasks with a sufficient level of knowledge and experience which is required to evaluate the variables in the questionnaire. The fundamental tasks in maritime organisations are based on utilising networks that operate on common or individual platforms, facilitating information exchange, transactions, and communication between supply chain partners (Yang and Lin 2023). Given the need for familiarity with IT competency and SCI within their organisations, this research distributed the questionnaire to staff at all levels in maritime organisations.

The data for this study were collected relying on the researcher and the researcher's network, which may raise questions about the possibility of generalisation. However, considering the limitations of time, cost, and resources, as well as the relationship between the research objectives and the characteristics of the sample (Thomas 2004), non-probability sampling seems to be an efficient and practical method for collecting reliable data.

5.2.1.3 Size sample

The decision on sample size is critical because it influences the margin of error in survey results and, consequently, the potential for generalisation. Therefore, having a sample size that aligns with the chosen sampling method and analysis technique is a significant issue (Saunders et al. 2019). In a survey research, a relatively large number of units is required to decrease the magnitude of sampling errors (Thomas 2004). While it is ideal to mobilise as large a sample size as possible in studies using probability sampling techniques, the rules for determining sample size in non-probability sampling methods are ambiguous (Saunders et al. 2019). In such studies, the appropriate sample size often depends more on the specific purpose and methods of the researcher. In this study, which employs Partial Least Square-Structural Equation Modelling (PLS-SEM), the sample size is guided by the research objectives and the resources available (Bell et al. 2022). SEM fundamentally requires large samples to avoid issues associated with small samples, which include estimation convergence failure, improper solutions, inaccurate parameter estimates, and model fit statistics (Kyriazos 2018). Hair et al. (2019a) recommended that, for conducting PLS-SEM, a larger sample size of generally over 100 is preferable. However, they noted that in exceptional cases, depending on the research objectives, a small sample of less than 100 can also be acceptable. They also pointed out that, assuming other situational characteristics are equal, a more heterogeneous population requires a larger sample size to achieve an acceptable sampling error.

5.2.2 Questionnaire Development

5.2.2.1 Specifying information

The hypotheses and conceptual model underlying this study's questionnaire survey are closely related to the verification of the relationships among IT competency, SCI, performance, and BCU. Therefore, the questionnaire is composed of characteristics pertaining to five measurement constructs: 1) IT competency, 2) SCI, 3) BCU, 4) OPP, and 5) FNP. Information on the measurement constructs and indicators is elaborated in Chapters 2, 3, and 4. In addition, demographic information was included to understand the background of respondents and organisations, and to reveal patterns or differences in the data according to characteristics across categories.

5.2.2.2 Type of questionnaire and method of administration

Self-administered questionnaires are one of the most frequently used data collection types in research studies, allowing people to complete the instrument by themselves without supervision, thus ensuring anonymity. However, this method has the disadvantage of lacking control over the respondents and providing no direct information on the answerability of questions (Bourque and Fielder 2003). This study utilised email and hardcopy distribution to deliver the questionnaire to respondents, achieving cost efficiency and ensuring the convenience of the respondents. In addition, the researcher made an effort to facilitate respondents' understanding by providing detailed information on the research topic and constructs within the questionnaire. For instance, to aid respondents' understanding, supply chain entities were specified in the supply chain integration section, and to enhance comprehension of BCT, a brief explanation of BCT and the forms in which it is implemented were provided.

5.2.2.3 Contents of individual items

The questionnaire is structured into five parts, following the sequence of hypotheses and the conceptual model. The first part consists of a total of 30 questions that measure the degree of SCI within the maritime organisations to which the respondents belong, focusing on six key attributes of maritime SCI (i.e., IS, KC, CC, DH, GS, JMP). SCI is categorised into six dimensions, however, to reduce the possibility of common response bias, the attributes were listed without any distinctions. The second part of the questionnaire is composed of questions designed to measure the degree of IT competency, which encompasses 17 question items measuring four components (i.e., FITI, ITA, MITK, ITPS). The third part investigates the moderating role of the degree of utilisation of BCT by including 4 items that assess how extensively blockchain is used in the maritime industry. In the fourth part, OPP and FNP are examined by 6 and 5 items respectively to evaluate the extent of performance improvement. Finally, for the descriptive analysis, questions pertaining to the background of the respondents were formulated, such as business types, firm size, job position, etc.

5.2.2.4 Form of the response to questions

This study aims to measure the perceptions of respondents regarding the degree of five constructs, and the data obtained from these measurements are intended to be quantified for the analysis using the PLS-SEM method. Reflecting this, the questionnaire questions are composed of closed-ended questions, and the collected results are coded into numerical form for statistical analysis (Rattray and Jones 2007). The closed-ended questions adopted the form of a Likert scale to allow respondents to express their opinions on the items in the questionnaire. The Likert scale records how strongly respondents agree or disagree with a given question. It is a type of attitude scale, which is a method of rating scales used to measure an individual's predisposition toward any person, object, or other phenomenon, alongside the semantic differential (Taherdoost 2019). The questions in the instruments used a 7-point scale ranging from 'strongly disagree' to 'strongly agree'.

5.2.2.5 Wording of each question

The words and terms used in questionnaires should be carefully considered to ensure that respondents can easily understand it, avoiding the use of abstract terms or jargon (Bourque and Fielder 2003). This is especially important in self-administered questionnaires, where there is no surveyor present to provide explanations or definitions for terms that might cause confusion or hesitation among respondents. The failure for the respondents to understand the questions and complete the questionnaire undermines the validity and reliability of the data and results in a high rate of missing data (Synodinos 2003). In adherence to the guidelines by Bell et al. (2022), efforts were made to design the questions to avoid ambiguous terms, lengthy questions, double-barrelled questions, leading questions, and overly general questions. Firstly, all question items were categorised within section headings and additional explanations were provided for any specialised terms. Secondly, superfluous and repetitive expressions were minimised, and double-barrelled questions were avoided. Thirdly, questions were designed to be neutral, steering clear of leading respondents toward specific answers (Baruch and Holtom 2008). Consequently, the questionnaire was designed to help respondents easily understand and complete it in a relatively short time.

5.2.2.6 Sequence of questions

The introductory section of the questionnaire provides a clear idea about the research to invite respondents to participate, which influence the response rate (Saunders et al. 2019). By outlining the survey's structure, ensuring anonymity, and highlighting the importance of the research, respondents are made to feel comfortable proceeding with the questionnaire. The sequence of questions is important since respondents evaluate the questionnaire not only as a compilation of individual questions but also in terms of the larger context (Dillman et al. 2014).

A well-structured order of questions motivates respondents to complete the questionnaire as well as minimise the influence between different questions. As Churchill et al. (2009) suggested, the questionnaire was designed to start with questions about SCI, which is related to respondents' ordinary task. It then sequentially transitioned to questions about IT competency, followed by a series of questions on BCU. Questions that could be relatively sensitive for respondents, concerning performance and background, were placed at the end. Each section was grouped to help respondents consistently engage with one topic at a time, enabling them to complete the answers using retrieved information before moving on to a new topic (Dillman et al. 2014).

5.2.2.7 Layout and physical characteristics of the questionnaire

The visual presentation of survey questions can influence how respondents understand the questions and provide their answers. In this study, the questionnaire was distributed through the online survey platform Qualtrics as well as delivery and collection. Firstly, Qualtrics is a professional and popular online survey platform that is optimised for non-interactive survey. Such software platforms do not require special programming skills and offer an intuitive and streamlined interface, making it easy to create, edit, and manage surveys (Molnar 2019). Moreover, they comply with the newest standards and trends in survey research, with a strong emphasis on user experience and visual design. Therefore, the questionnaire's construct, as previously described, was automatically generated within a framework optimised for both mobile and PC browsers screen. Secondly, in the case of questionnaire delivery and collection, considering the respondents' pretensive processing, each section was clearly divided into segments, and each item was numbered to display a clear flow of the questions.

5.2.2.8 Re-examination and revision – Pilot test

Prior to gathering data through a questionnaire survey, it is crucial to conduct a pilot test with a group that resembles the target respondents or with experts to secure evidence of the questionnaire's validity and reliability (Saunders et al. 2019). The panel for peer review consisted of five practitioners from different maritime operators and two academics in the field of maritime management. These seven experts were asked to evaluate whether the instrument's measurements were clear and comprehensive, as indicated, and acceptable in the form of questions. Each provided feedback aimed at improving the questionnaire, which led to subsequent revisions. Table 5-4 presents the result of pilot test of the questionnaire.

The survey's translation process was also included as a part of the pilot-testing phase. The questionnaire was originally written in English. However, since the survey targeted employees of companies operating in Korea, a Korean-translated version was also supplemented. The translation process adhered to the recommendations for translation in cross-cultural research outlined by Su and Parham (2002), which include: 1) cultural translation; 2) back-translation iterative process; 3) pre-test. Firstly, a researcher fluent in both English and Korean undertook the cultural translation. This was followed by a bilingual practitioner with an English background in the maritime industry who assisted with the Korean translation. Subsequently, a professor with an academic background in maritime logistics from the UK, who was also part of the pilot test participants, involved as a back-translator, rendering the Korean version back into English. Finally, all participants collectively compared the two translated questionnaires to ensure conceptual equivalence.

<table>
<tr><th>Business types</th><th>Position</th><th>Meeting</th><th>Feedback</th></tr>
<tr><td>Shipping liner</td><td>Manager</td><td>Face to face</td><td rowspan="7">• Word selection (in Korean)
• Suggestions for further explanation
• Mentions of how questions are read
• Feedback for the construction of the questionnaire
• Translation checking</td></tr>
<tr><td>Shipping liner</td><td>Director</td><td>Face to face</td></tr>
<tr><td>Shipping liner</td><td>Director</td><td>Face to face</td></tr>
<tr><td>Terminal operator</td><td>Managing director</td><td>Face to face</td></tr>
<tr><td>Freight forwarder</td><td>Manager</td><td>Messenger and phone call</td></tr>
<tr><td>University</td><td>Professor</td><td>Face to face</td></tr>
<tr><td>University</td><td>Professor</td><td>Messenger</td></tr>
</table>

Table 5-4 Pilot test for the questionnaire

Source: Author

As a result of the pilot test, significant modifications were made. Feedback indicated that the term "Supply chain" could be academic and unfamiliar to practitioners in Korea. To address this, the scope and main stakeholders of the maritime supply chain were specified to aid respondents' understanding of supply chain activities within their work and to enable them to reflect their experience in their survey responses. Additionally, considering that blockchain is still an emerging technology, explanations about its role and actual use cases in the current industry were added to prepare for the possibility that respondents might not be aware of the use of BCT. In questions about SCI, feedback about the lack of emphasis on the collaborative aspect was reflected in the translation process. Moreover, for terms that are more commonly used in English than in Korean in the workplace, the original English terms were also provided.

5.3 Data analysis methods

The objective of this research is to examine the statistical interrelations between IT competency, SCI, and organisational performance, and to explore the extent to which BCT influences these dynamics. To validate the hypotheses related to the mentioned relationships using data obtained from a questionnaire survey, this study employed the Structural Equation Modelling (SEM) method. SEM is a multivariate statistical analysis technique used to verify structural theories about observed phenomena, allowing for a clear conceptualisation of the theoretical relationships between constructs (Hair et al. 2019a). Testing extensive causality between constructs is challenging with other multivariate techniques such as factor analysis and multiple regression analysis. SEM is an extension of other multivariate techniques as it examines a series of dependence relationships by simultaneously solving multiple equations (Thakkar 2020). SEM is especially appropriate for inferential data analysis and the testing of hypotheses when the interrelationship patterns among the constructs of the study are explicitly defined and grounded on established theoretical frameworks (Hoe 2008).

SEM shares several similarities with traditional techniques such as correlation, variance analysis, and regression. To begin with, both SEM and traditional methodologies are grounded in the principles of linear statistical models. Additionally, when performing statistical analyses, both approaches adhere to certain fundamental assumptions; traditional methods presume a normal distribution, while SEM assumes multivariate normality. Finally, neither method provides a means to test for causation (Thakkar 2020). Table 5-5 explains the differences between traditional method and SEM method. Reflecting these characteristics, the application of SEM as a data analysis approach is increasing in empirical research within SCM literatures. SCM researchers choose SEM as an analytical model that includes path analysis (causal modelling), confirmatory factor analysis, analysis of second-order variables, latent variable analysis, regression models, and structural models (Hazen et al. 2015). Therefore, SEM can be defined as an analytical method that combines factor analysis and linear regression modelling techniques such as multiple regression analysis and Analysis of Variance (ANOVA) simultaneously (Dash and Paul 2021). Based on the hypotheses illustrated in Chapter 4, this study aims to validate a model that includes latent variables and simultaneously examines the complex relationships among them. Hence, SEM has been chosen as the main analysis methodology for this research.

Basis	**Traditional statistical techniques**	**SEM**
Flexibility	Not much flexible	Highly flexible and comprehensive methodology
Nature of model	Default model is specified	No default model is offered Model is specified based on research hypothesis
Variable analysis	Analyse only measured variables	Multivariate technique incorporating observed (measured) and unobserved variables (latent)
Errors	Assumes measurement occurs without error	Explicitly specifies error providing flexibility to imperfect nature of measures
Significance test	Determines group differences, relationships between variables, or the amount of variance	No straightforward test to determine model fit. Various model fit test is used (CFI, Bentler-Bonett, NNFI, RMSEA)
Approach	No graphical approach	Presenting graphical language of set of variables providing intuitive appeal and convenience in understanding the model to test model fit and estimate parameters

Table 5-5 Differences between traditional statistical techniques and SEM

Source: Thakkar (2020)

5.3.1 Choice of Partial Least Squares – Structural Equation Modelling (PLS-SEM)

Hair et al. (2017) (p.109) explained that "CB (Covariance-Based)-SEM aims to estimate model parameters that minimise the differences between the observed sample covariance matrix, calculated before the analysis, and the covariance matrix estimated after the revised theoretical model is confirmed." CB-SEM is based on the common factor model, which utilises only the calculation of data covariance, employing solely the common variance in its analysis. Consequently, specific variance and error variance are excluded from the model evaluation process, which has been pointed out as a limitation in predicting dependent variables in theoretical models (Hair et al. 2017). On the other hand, PLS (Partial Least Squares)-SEM aims to maximise the explained variance of the endogenous latent variables within the model. This involves an iterative process of estimating the relationships of partial models through iterative sequence of ordinary least squares (OLS) regressions (Hair et al. 2012). PLS-SEM is based on a composite model that includes common, specific, and error variance, thereby utilising all variance from independent variables to predict the variance in dependent variables (Hair et al. 2017). PLS-SEM is attractive in many research contexts because it allows for the prediction of complex models with many constructs, indicator variables, and structural paths.

The philosophical approaches of CB-SEM and PLS-SEM are distinctly different. CB-SEM is suitable when the primary purpose of the research is to examine 'measurement model invariance' or 'overall goodness-of-fit' (Hazen et al. 2015). Measurement model invariance refers to the process of confirming that a measurement tool consistently measures the same concept across different groups or over time, despite any changes. Overall goodness-of-fit is an indicator that evaluates how well the theoretical model in the research aligns with the collected data, playing a crucial role in the validation of the model's validity (Cheung and Rensvold 2002; Hair et al. 2011). Reflecting on the methodological characteristic, CB-SEM is more appropriate when the research objective is to test and confirm existing theories (explanation). In contrast, PLS-SEM is valuable for exploratory research purposes such as prediction and theory development, as it provides causal explanations (Dash and Paul 2021). This is because PLS-SEM operates similarly to multiple regression analysis. In research contexts where data is rich, but theory is underdeveloped, PLS-SEM helps to extract new knowledge from the data, which enriches theoretical framework (Hair et al. 2014).

Hair et al. (2017) provided guidelines for researchers to choose between the two methodologies, as presented in Table 5-6. CB-SEM is known to be suitable for confirmatory research, while PLS-SEM is considered appropriate for exploratory research. However, Sarstedt et al. (2014) pointed out the risks involved in the process of pursuing model fit in CB-SEM. In most studies utilising CB-SEM, it is very common for the initially hypothesised models to not show adequate model fit. In such cases, the common approach is to either reject the model or re-specify the original model in order to improve fit indices. The final models supporting the theory in the result from these modifications often do not correspond to the correct population models and represent scenarios that are not applicable in reality. Consequently, CB-SEM analysis is practically more exploratory than confirmatory in nature (Diamantopoulos 1994). Sarstedt et al. (2014) argued that the concepts of explanation and prediction are not distinct, as an existing strong theory that explains phenomena can also lead to forecast or discoveries. However, as a 'causal-predictive' technique, PLS-SEM enables the combination of explanation and prediction perspectives in model estimation (Hair et al. 2017). PLS-SEM is recommended for its ability to provide meaningful solutions in situations involving complex theoretical models with a large number of indicators, higher-order constructs, unobserved heterogeneity, multi-group analysis, and various algorithms.

Traditionally, CB-SEM has been the preferred method of analysis compared to PLS-SEM. However, the use of PLS-SEM has been continuously increasing, and it is expected to be employed more often and gain greater acceptance in supply chain research in the future (Hazen et al. 2015). This study aligns with the objectives of PLS-SEM as it seeks to confirm and explain hypotheses established based on existing theories and to make predictions regarding the utilisation of BCT. Furthermore, the research model employs BCU measured on a Likert scale as a moderating variable, and IT competency and SCI are designed as second-order constructs. Reflecting these characteristics, the current research utilises PLS-SEM to analyse the data.

Types of analysis		Recommended method		
		PLS-SEM	CB-SEM	Both
Objective	Prediction	✓		
	Exploratory or theory development	✓		
	Explanation only		✓	
	Explanation and prediction	✓		
Measurement philosophy	Total variance (composite based)	✓		
	Common variance (factor-based)		✓	
Reflective measurement model specification				✓
Formative measurement model specification		✓		
Metric data				✓
Non-metric data = ordinal and nominal		✓		
Smaller sample size <100		✓		
Larger sample size >100				✓
Binary moderators				✓
Continuous moderators		✓		
Normally distributed data				✓
Non-normally distributed data		✓		
Secondary (archival data)		✓		
Higher order constructs	Two 1st order constructs	✓		
	Three of more 1st order constructs			✓
Latent variable scores needed for subsequent analysis		✓		

Table 5-6 Guidelines for selecting PLS-SEM and CB-SEM

Source: Hair et al. (2017)

Nevertheless, even when researchers follow the established guidelines for selecting PLS-SEM, the methodological limitations of this approach remain evident. First, although PLS-SEM is a robust statistical technique, it often lacks sufficient depth in interpreting the conceptual foundations and theoretical coherence of the research design (Zeng et al. 2021). Given that PLS-SEM is inherently prediction-oriented, applying it with an explanatory objective may result in insufficient interpretive insight of model evaluation (Hair Jr et al. 2020). Therefore, when attempting to establish causal relationships, it is essential to ground interpretations within a solid theoretical framework and consider the broader research context. Furthermore, compared to traditional covariance-based structural equation modelling, the absence of well-established Goodness-of-Fit (GOF) indices in PLS-SEM presents a challenge for statistical validation (Hair et al. 2019b). To address this issue, researchers should employ complementary evaluation criteria such as AVE to assess convergent validity, VIF to detect multicollinearity, and cross-loading analysis to examine discriminant validity, thereby reinforce the rigor and transparency of the statistical analysis. In light of these limitations, a carefully constructed research design is required to mitigate the impact. Accordingly, the PLS-SEM analysis should be conducted in accordance with the methodological procedures presented in the next section.

5.3.2 PLS-SEM analysis procedures

(1) Preliminary considerations

Hair et al. (2019b) outlined considerations and items that need to be assessed when using PLS-SEM, as shown in Figure 5-5. They suggest that before choosing PLS-SEM, sample size, distribution assumptions, data types, statistical power, and goodness-of-fit should be considered. PLS-SEM has the advantage of being able to operate with relatively small sample sizes, yet it can also provide valuable results when analysing large data quantities (Akter et al. 2017). Secondly, while CB-SEM assumes large sample sizes with normally distributed data, PLS-SEM shows higher robustness in cases where normality cannot be assured, particularly with smaller sample sizes (Reinartz et al. 2009). Therefore, PLS-SEM is recommended over CB-SEM in situations of non-normality, but this does not mean that PLS-SEM is unsuitable for normally distributed data (Hair et al. 2017). Regarding data types, PLS-SEM is emphasised as an alternative to CB-SEM, which may have limitations in achieving model fit with secondary data. However, this research does not consider it as it utilises primary data collected through questionnaires. The statistical power of PLS-SEM is noted to be higher than that of CB-SEM, enabling a broader range of research, including both exploratory and confirmatory studies. Lastly, PLS-SEM is less affected by the concept of model fit compared to CB-SEM, which heavily relies on it. Applying the concept of model fit from CB-SEM to PLS-SEM models requires extreme caution (Henseler and Sarstedt 2013).

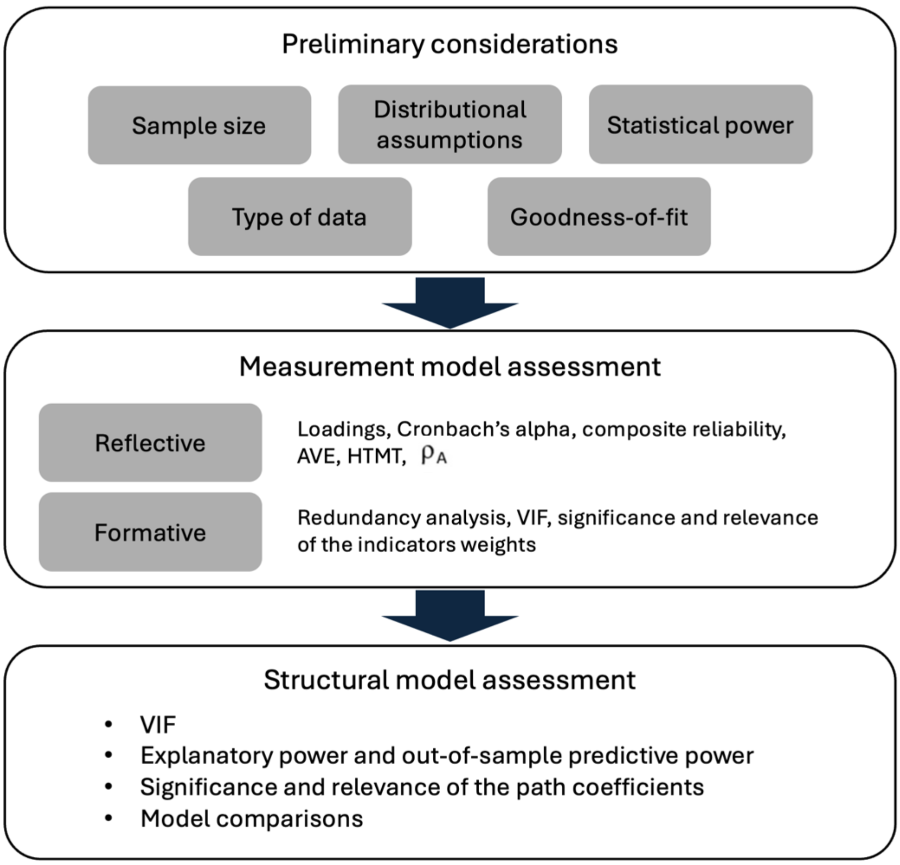
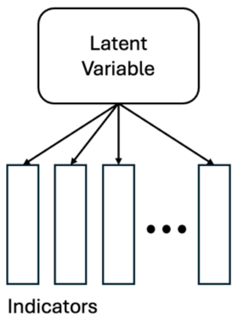
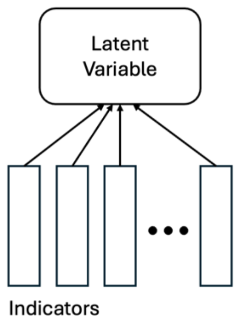


Figure 5-5 Aspects and statistics to consider in a PLS-SEM analysis

Source: Hair et al. (2019b)

(2) Measurement model assessment – reflective measurement model

As depicted in Figure 5-5, the measurement model is divided into two types based on the direction of causality between the latent variables and their observed indicators: reflective and formative and each approach has different assessment elements. If changes in an indicator are assumed to reflect changes in a latent construct, this is considered a reflective relationship. However, if a construct is formed by multiple indicators that are not intercorrelated items, the causality flows in the opposite direction, and this is known as a formative relationship (Coltman et al. 2008). The detailed comparison between reflective and formative constructs are illustrated in Table 5-7. In this study, the indicators were developed to measure each latent construct and are composed of associated concepts, leading to the assumption of a reflective relationship.

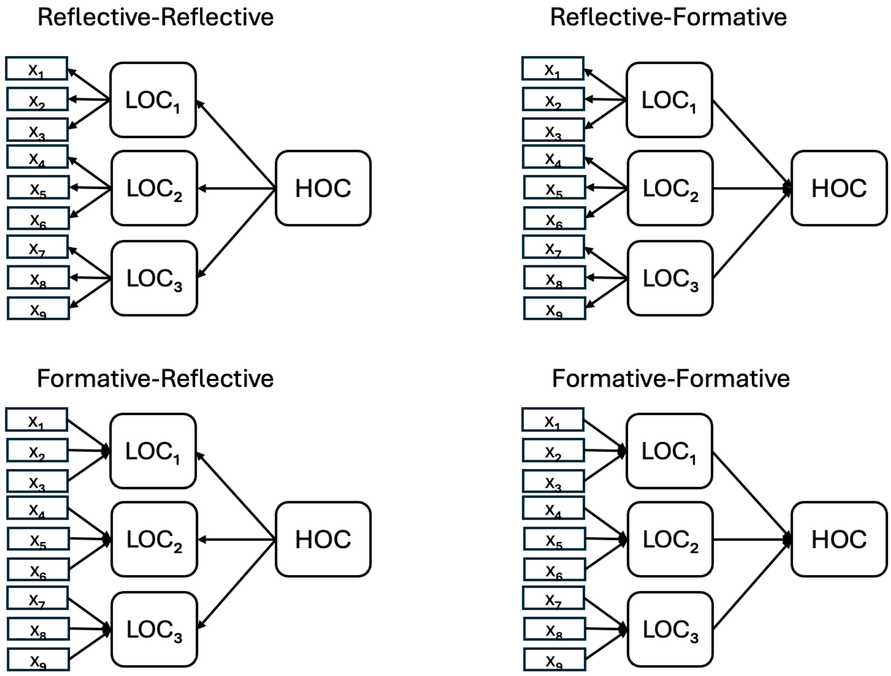
Determinants	Reflective	Formative
Model		
Nature of construct	Latent construct exists independent of the measured used	Latent construct is a combination of its indicators
Directions of causality	Causality from construct to items	Causality from items to construct

	: Variation in the construct causes variation in the item measure	: variation in the item measures causes variation in the construct
Characteristic of items	• Items share a common theme • Items are interchangeable • Adding or dropping an item does not change the conceptual construct	• Items need not share a common theme • Items are not interchangeable • Adding or dropping item may change the conceptual construct
Item intercorrelation	Items should have high positive intercorrelations	Items can have any pattern of intercorrelation but should possess the same directional relationship

Table 5-7 Reflective versus Formative constructs

Source: Adapted from Coltman et al. (2008)

Additionally, IT competency and SCI are modelled as second-order constructs in this study. Higher-order constructs (also known as hierarchical latent variable model) provide a framework for understanding dimensions at a more abstract level (higher-order components) and more concrete subdimensions (lower-order components) (Hair Joseph et al. 2018). By specifying the lower-order components, higher-order constructs allow for the expression of more general conceptual variables of interest into concrete traits (Sarstedt et al. 2019). Higher-order constructs are differentiated into four types based on the relationships between constructs across different dimensions: reflective-reflective, reflective-formative, formative-reflective, and formative-formative (Figure 5-6). In this study, the constructs of IS, KC, CC, GS, DH, and JPM were composed as lower-order constructs to explain SCI, while FITI, ITA, MITK, and ITPS were constituted as subcomponents to measure IT competency. Given that the characteristics of a reflective model, these low-order constructs serve as latent variables to describe a single conceptual idea, and changes in them influence the higher-order construct. Therefore, a reflective-reflective model, where a reflective approach is applied to both higher and lower-order constructs, was employed.



Note: LOC = Lower-order component; HOC = Higher-order component

Figure 5-6 Types of higher-order constructs

Source: Sarstedt et al. (2019)

Higher-order constructs can be specified and estimated using two approaches, namely the (extended) repeated indicators approach and the two-stage approach (Sarstedt et al. 2019). The (extended) repeated indicator approach measures the higher-order component by assigning the indicators of the lower-order components to it. As shown in Figures 5-7, this approach assigns indicators x_1 to x_9, which are used for the lower-order constructs, to measure the higher-order component (Y_4). In contrast, the two-stage approach first measures the constructs using all the indicators of the lower-order constructs, including the antecedent construct in the structural model, same as the standard repeated indicators approach. Secondly, it saves the scores of the lower-order constructs as new variables in the dataset, and then uses these construct scores as indicators in the measurement model of the high-order construct (Y_4), represented by (Y_1, Y_2, Y_3). The embedded two-stage approach differs in that all other constructs in the model are measured with single items that capture each construct's latent variable score from the previous stage. The distinction of the disjoint two-stage approach is that it only considers the path model that includes the higher-order construct. As can be seen in Figures 5-7, the variable Y_5 is measured by the indicators in the original model. This study established the model using the two-stage approach's disjoint method, which demonstrates better parameter recovery for paths leading from exogenous constructs to the higher-order construct, and from the higher-order construct to an endogenous construct (Becker et al. 2012).

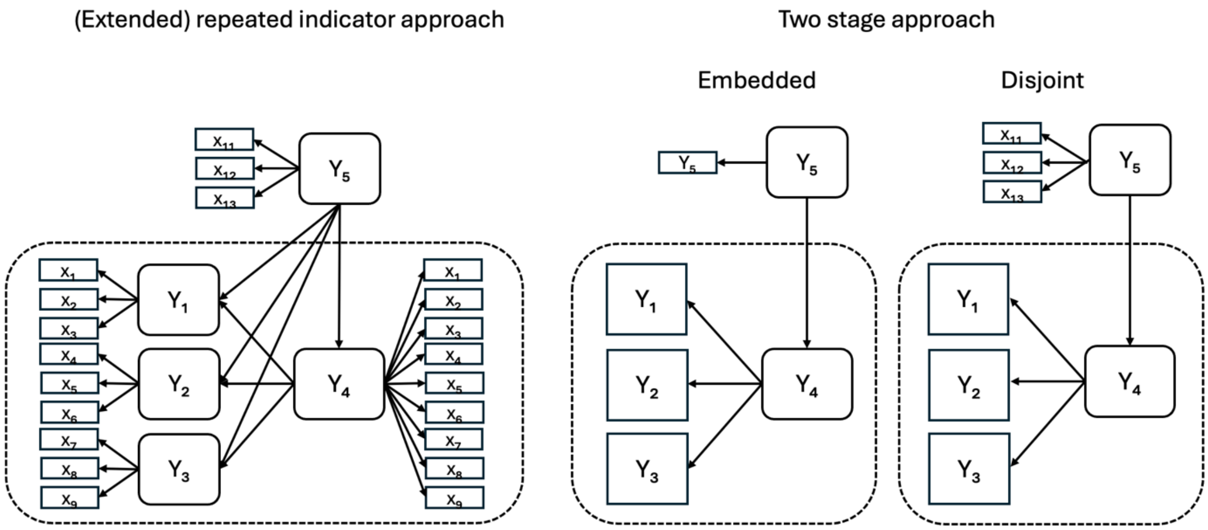


Figure 5-7 Approach for specifying and estimating higher-order constructs
Source: Sarstedt et al. (2019)

The measurement model is evaluated in terms of reliability and validity. Reliability refers to the degree to which an experiment, test, or any measuring procedure yields consistent results across repeated trials (Carmines and Zeller 1979). The reliability of a measurement assesses whether multiple indicators of a latent construct are interrelated, thereby consistently measuring the same concept, which is used to indicate the internal consistency of the indicators (Thakkar 2020). On the other hand, validity concerns how well the measurement model captures the intended concept and phenomenon (Carmines and Zeller 1979). When the reliability and validity of a measurement model satisfy the requirements of SEM, the empirical indicators sufficiently represent the given theoretical concept.

Indicator reliability

The first step in assessing a reflective measurement is to examine the outer indicator loadings. Indicator reliability indicates the degree to which indicators are correlated within a common theme that is conceptualised by the construct. It is recommended that loadings exceed 0.708, indicating that the construct accounts for more than 50% of the variance in the variables, which signifies an acceptable level of item reliability (Hair et al. 2019b).

Internal consistency reliability

Secondly, internal consistency reliability should be assessed. While traditionally measured using Cronbach’s alpha, which assigns equal weights to the indicators (tau equivalence) (Jöreskog 1971), composite reliability is recommended as more appropriate because it takes into account the differential weights of the indicators. Cronbach's alpha is criticised for the lack of accuracy in terms of reliability since the items are unweighted, whereas composite reliability assigns weights to the items based on the individual loadings of the construct indicators, resulting in higher reliability compared to Cronbach's alpha (Hair et al. 2019b). Higher values of composite reliability are preferable. Generally, values between 0.60 and 0.70 are considered acceptable for exploratory research, while values between 0.70 and 0.90 are regarded as satisfactory (Hair et al. 2011).

Convergent validity

Convergent validity is the third aspect to be tested. Convergent validity underscores the internal consistency among indicators which measure the same underlying construct. This form of validity is concerned with the extent to which a construct explains the variance in its associated items (Hair et al. 2019b). To evaluate convergent validity, AVE is calculated to assesses how well a construct captures the variance of its indicators. The AVE is determined by taking the average of the sum of the squared completely standardised factor loadings for the construct's indicators, divided by the number of indicators (Cheung et al. 2023). An AVE value greater than 0.5 indicates that the construct accounts for more than 50 percent of the variance in its items, which is generally considered sufficient evidence of convergent validity (Fornell and Larcker 1981a).

Discriminant validity

The fourth aspect to assess is discriminant validity. Discriminant validity refers to the extent to which a construct is different from other constructs within a model (Cheung et al. 2023). This involves comparing each construct's AVE to the squared inter-construct correlations, ensuring that the shared variance for all model constructs is not greater than their respective AVEs (Fornell and Larcker 1981a). This is known as the Fornell-Larcker criterion. However, Henseler et al. (2015) have argued that this criterion can be challenging to apply when the indicator loadings on a construct shows only slight differences (Hair et al. 2019b).

As an alternative, Henseler et al. (2015) proposed the Heterotrait-Monotrait (HTMT) ratio of correlations. The HTMT compares the mean value of the item correlations across different constructs to the geometric mean of the average correlations among items measuring the same construct (Hair et al. 2019b). This ratio assesses how distinctly two concepts are measured, and a high HTMT value indicates that the two concepts are not sufficiently distinguished and are being measured similarly. If the HTMT value exceeds a threshold of 0.85 or 0.90, it implies a problem of discriminant validity (Ab Hamid et al. 2017).

(3) Structural models assessment

If the measurement model satisfies the evaluation, the next step is to assess the structural models. Criteria for evaluating structural models include examining collinearity, the coefficient of determination (R^2), and path coefficients.

Collinearity assessment

The structural model derives model coefficients by estimating a series of regression equations that represent the relationships between constructs. Before evaluating structural relationships, it is essential to examine for collinearity to ensure that the regression results are not biased. Collinearity occurs when two latent variables are highly correlated, and it is assessed using the VIF (Hair et al. 2019b). A VIF value greater than 5 for a latent variable indicates a potential problem with collinearity among the constructs, and ideally, a VIF value should be close to or lower than 3 to be considered acceptable (Hair 2014).

Coefficient of determination (R^2 value)

If collinearity is not an issue, then the R^2 value should be examined. R^2 measures the variance explained in each endogenous construct and represents the explanatory power of the model (Hair et al. 2011). A high R^2 indicates that the model well explains the variance of the endogenous latent variables. R^2, which ranges between 0 and 1, is considered to have greater explanatory power the higher it is, however, the threshold for what is considered high can vary depending on the specific research field (Hair et al. 2019b). A rough criterion is that R^2 values of 0.75 can be considered substantial, 0.50 as moderate, and 0.25 as weak. Specifically, in the field of social sciences, R^2 results of 0.20 are considered high, while in research on inherently predictable phenomena such as physical processes, an R^2 of 0.90 is plausible (Hair et al. 2011).

Path coefficient

After demonstrating the explanatory power of the model, the statistical significance and relevance of the path coefficients must be evaluated. Path coefficients describe the hypothesised relationships between linking constructs. To assess the significance of the path coefficients and to evaluate their values, bootstrapping is performed, and path coefficients take on values between -1 and +1 (Hair et al. 2019b). Bootstrapping is a non-parametric resampling procedure that, for instance, creates J samples composed of randomly selected data points from the original data in order to obtain J estimates for each parameter, thereby estimating the parameters (Streukens and Leroi-Werelds 2016). Values closer to +1 indicate a strong positive relationship, while values closer to -1 represent a negative relationship, and values near 0 suggest a weaker relationship. Significant paths indicate that the proposed causal relationship is supported by hypothesised empirical direction (Hair et al. 2011).

5.3.3 Conditional Mediation Analysis in PLS-SEM: moderated mediation

A mediated relationship, also known as an indirect relationship, refers to the intervention of one or more variables, known as mediator variables M, which transmit the influence of an independent variable X on a dependent variable Y (Sarstedt et al. 2020). In mediation analysis research, three relationships are considered: the direct path between the independent and dependent variables, the path between the independent variable and the mediator, and the path between the mediator and the dependent variable (Cheah et al. 2021). On the other hand, a moderated relationship refers to the presence of moderator variables W that affect the strength or direction of the relationship between independent variable X and dependent variable Y, depending on the value of the moderators (Dawson 2014). In other words, the moderation model examines whether changes in a moderating variable strengthen or weaken the relationship between two constructs. Figure 5-8 shows the simple model of a mediation and moderation.

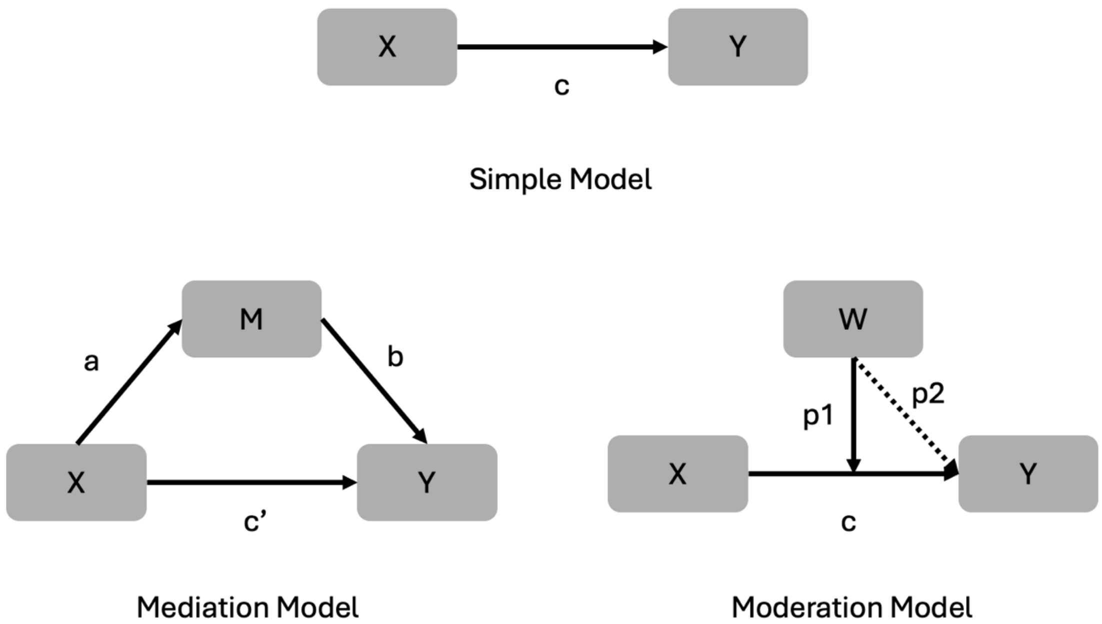


Figure 5-8 Mediation and Moderation
Source: Sarstedt et al. (2020)

In statistical mediation model analysis, the indirect effect of the independent variable X on the dependent variable Y through the mediator M is represented by (ab), while the direct effect is denoted by (c'). The direct and indirect effects combine to yield the total effect of X on Y, which is represented by (c). Mediation can be characterised by three distinct attributes based on outcomes.

Complementary mediation occurs when both the indirect and direct effects are significant. Competitive mediation refers to when the effects are observed in opposite directions (negative). Indirect-only (full mediation) is when the indirect effect is significant, but no direct effect is resulted (Hair Jr et al. 2021). Figure 5-9 illustrates the procedure for deciding the mediation model. When validating a moderating model, the direct relationship p2 in Figure 5-8 of the moderator variable to the endogenous construct is included to control for the potential overestimation of the effect p1. Consequently, in a moderating path model, the independent variable is mathematically represented as Y = c*X + p2*W + p1*X*W.

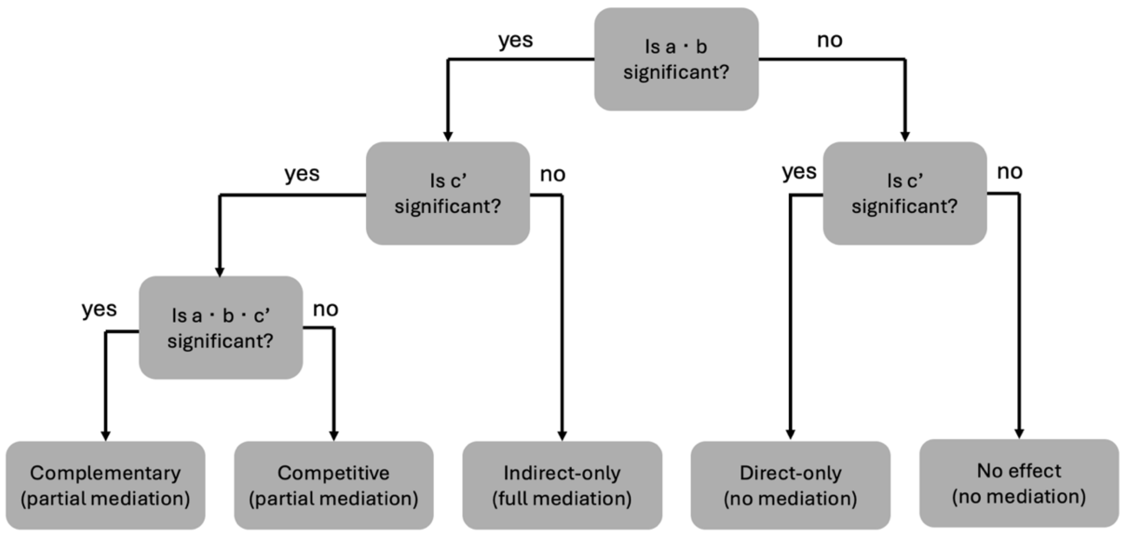


Figure 5-9 mediation analysis procedure

Source: Hair Jr et al. (2021)

Conditional Mediation (CoMe) analysis is a PLS-SEM technique designed to examine models that include both mediation and moderation relationships (Cheah et al. 2021). This method, compared to traditional sequential mediated moderation analysis, allows for (1) the simultaneous analysis of complex interrelationships among latent variables, and (2) accounts for measurement errors that can occur in multi-item measurements, thereby enabling more accurate estimation of the relationships between variables (Hayes and Scharkow 2013). In CoMe, the significance of the CoMe index, which quantifies the effect of moderators on the mediated relationship, is calculated and assessed to measure the size of the conditional mediated effect at different levels of the moderators.

In CoMe model (figure 5-10), it is assumed that variable W affects the initial stage of the mediation mechanism. While W moderates the effect between X and M, it does not influence the relationship between M and Y. To verify the overall effect of the moderated mediation, it is crucial to avoid isolating the path p2 (between M and Y) and to consider the influence of the moderator on the entire mediation effect (Cheah et al. 2021). To formally test the effect within the entire model, the following formula has been proposed (Hayes 2018):

$$\omega = p1 \cdot p2 + p2 \cdot p5 \cdot W = (p1 + p5 \cdot W) \cdot p2 \quad (1)$$

Based on the formula that describe the CoMe effect, "p2 · p5" denotes the slope of W's mediated impact, which is conditional on ω, illustrating the CoMe index (ω) (Hayes 2018). If the index "p2 · p5" significantly distinct from zero, it indicates that the influence of X on Y through the mediator M is reliant on the moderating variable W.

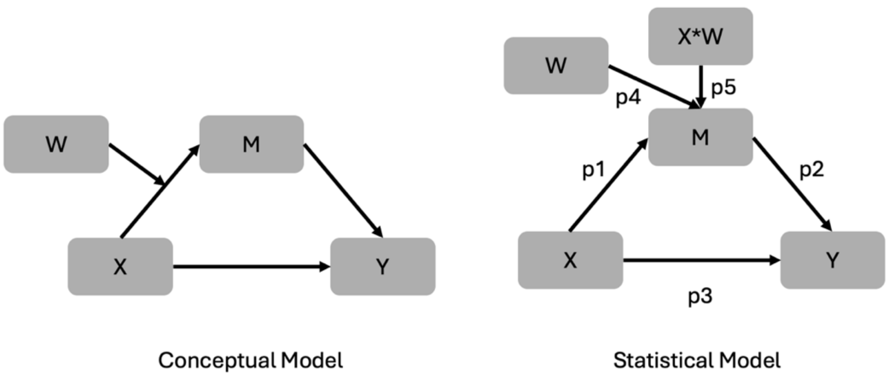


Figure 5-10 Mediated moderation model
Source: Cheah et al. (2021)

Subsequently, to further delve into the conditions under which mediation exists, the mediated influence need to be investigated at representative levels of the moderator by comparing the mean of the moderator and the value of standard deviations below, average, and above. In accordance with Cheah et al. (2021)'s guidelines, the result is obtained by conducting a bootstrapping analysis with 10,000 samples to the following equations:

- CoMe effect (low) = [(p1 + (p5 · -SD of W)) · p2] (2)
- CoMe effect (medium) = [(p1 + (p5 · SD of 0 for W)) · p2] (3)
- CoMe effect (high) = [(p1 + (p5 · +SD of W)) · p2] (4)

Through examining the aforementioned formula, it is possible to validate how the mediation model varies according to different levels of the CoMe effect.

5.4 Summary

This chapter described the process by which this study employs research methods according to the Research Design Framework. The research addresses issues of the phenomenon based on the positivism paradigm from the objectivist perspective. Furthermore, the study adopted a deductive approach, establishing and testing hypotheses based on existing theory, in relation to the conceptual constructs explored in previous chapters. The research collected primary data through a questionnaire survey to conduct analysis using quantitative data, and the process of developing questionnaire instructions and measurements is elaborated in the chapter. Finally, as a method for analysing the collected data, PLS-SEM is employed. The chapter presented the rationale behind how PLS-SEM is suitable for this research and provided an explanation of the process for using PLS-SEM. Next chapter focusses on the analysis of empirical data.

Chapter 6 Empirical data analysis

The main aim of this study is to examine the relationship between IT competency, SCI, operational performance, and financial performance, as well as to validate the moderating role of BCU. Therefore, this research utilised a questionnaire survey to obtain data suitable for empirical analysis using PLS-SEM, which is apt for analysing relationships between a large number of endogenous and exogenous variables, as well as latent variables. This chapter is divided into three thematic analyses: descriptive analysis and descriptive statistics, and empirical analysis for hypothesis testing. Descriptive analysis and descriptive statistics are not only important for exploring and summarising data to understand the general characteristics of the data but are also crucial for model formulation before the empirical analysis. The first section presents the results non-response bias and of common method tests to ensure the validity and reliability of our research findings, and information on the general background of the respondents and their organisations. The second section provides descriptive statistics for the responses to questionnaire items. The final section provides an assessment of the structural model for hypothesis testing. The assessment of the structural model involved verifying the significance of all hypotheses through a sequence of analyses for direct impact, indirect impact, and CoMe analysis to determine whether each hypothesis was supported.

6.1 Descriptive analysis

This section address issues related to nonresponse bias and common method bias and present the demographic profiles of survey respondents by characteristics.

6.1.1 Nonresponse and common method bias

In order to efficiently collect a large number of questionnaires, a web-based survey approach was chosen, supplemented with hard copy distribution to address the issue of a low response rate. The questionnaires were distributed to stakeholders related to the maritime supply chain, including shipping liners (containers), terminal operators, freight forwarders, and port authorities. Survey participants consisted of employees engaged in IT and SCI related roles, possessing the sufficient knowledge and experience to evaluate the questionnaire's items. Given the importance of understanding IT competency and SCI within their entities, this study distributed the questionnaire to employees across various levels within maritime organisations. Contact was made to distribute questionnaires to companies in the Korea Shipowners Association (KSA) for shipping liners and the Korea International Freight Forwarder Association (KIFFA) for freight forwarders. Further, terminal operators in Busan, Incheon, and Gwangyang port were selected as the survey targets. Lastly, the port authorities of Busan, Incheon, Ulsan, Yeosu, and Gwangyang were also contacted to seek their participation in the survey. A total of 87 web-based surveys and 43 surveys through email responses were collected. To collect additional samples, printed hardcopies were hand delivered and total of 172 hard copies were collected by visiting companies. As a result, a total of 302 samples were retrieved for data analysis.

Due to the limitations of the data collection method and the process of inviting qualified respondents, applying the traditional response rate calculation was considered inappropriate. To address this issue, this study assessed non-response bias as suggested by Armstrong and Overton (1977). Based on the low response rate of participants in the web-based survey, the non-respondents were defined as the participants of the web-based survey, and their responses were compared with those of the hardcopy survey respondents. To analyse the differences between the two data samples, nonparametric tests of difference, namely the Mann-Whitney test and the Wilcoxon matched-pairs signed-ranks test, were used(Clay 2009). The test results determined that there was no significant difference between the two groups (P > 0.05). Only one item (SCI_11) showed a significant p-value (0.01), therefore, it was assumed that non-response bias was not a significant issue in this study. The results of the non-response bias test are presented in Appendix C.

Common method bias describes the phenomenon where variance arising from the data collection methods or measurement tools used in research can distort the relationships among actual constructs. These discrepancies can lead to observed relationships appearing stronger or weaker than actual ones, potentially affecting the reliability of the research findings (Doty and Glick 1998). Common method bias is more likely to occur in research that uses the same informant to share measurements taken with the same scale, as was the case in this study (Podsakoff et al. 2003). As discussed in section 5.2.3, the questionnaire was designed to minimise the potential of common method bias by following Podsakoff et al. (2003)'s suggestions. To achieve this, the questionnaire was structured with divisions between constructs, creating separate sections. Additionally, the items were composed using clear and concise expressions, and an emphasis was placed on ensuring anonymity and confidentiality to alleviate respondents' apprehension about their evaluation. Along with the rigor in the survey design phase, additional statistical remedies are available to reduce biases arising from common method variance in the collected data. As discussed in the section 5.3.2, Kock and Lynn (2012) and Kock (2015) suggest that incorporating a data validation step equivalent to the common method bias test in the collinearity assessment can enhance the rigor of variance-based PLS-SEM analysis. To identify lateral collinearity, a random dummy variable is created to allow for the identification of collinearity among all variables within the model. An ideal VIF threshold is above 3, while a general threshold is above 5, indicating potential collinearity among variables (Hair et al. 2010). Thus, as seen in Table 6-1, since all figures are below 5, common method bias is not considered as a significant problem in this study.

Constructs	Random Variable (VIF)
IS	1.04
KC	1.11
CC	1.40
GS	2.44
DH	2.41
JPM	1.92
FITI	2.58
ITA	1.30
MITK	2.48
ITPS	2.65
BCU	1.72
OPP	3.91
FNP	3.12

Table 6-1 Full Collinearity Estimate
Source: Author

6.1.2 Demographic profiles of the respondents

6.1.3.1 Characteristics of respondent's organisations

As outlined in Section 5.2.2, this study conducted a questionnaire survey targeting maritime organisations located in South Korea. The questionnaire was distributed primarily among the main supply chain actors in the maritime industry, including shipping liners, freight forwarders, and terminal operators, and also included port authorities which manage the supply chain at ports. As indicated in Table 6-2, the sample representation was in the order of freight forwarders (45.7%), shipping liners (25.8%), terminal operators (18.9%), and port authorities (9.6%). The high proportion of freight forwarders can be interpreted as a reflection of the diverse range of companies operating complex maritime transactions and documentation, from small to large firms. Conversely, the port authority sample is relatively smaller because it was obtained from Korean port authorities. The port authorities based in the four major ports in South Korea, Busan, Incheon, Yeosu-Gwangyang, and Ulsan, were selected as the target (Song and Lee 2017). Consequently, the sample is considered to confidently reflect the composition of the maritime supply chain and is therefore suitable for analysis.

Demographic variable	Category	Frequency	Percentage (%)
Type of Business	Shipping liner	78	25.8
	Freight forwarder	138	45.7
	Terminal operator	57	18.9
	Port authority	29	9.6
	Total	302	100

Table 6-2 Types of business by respondents' organisations
Source: Author

Secondly, the survey results regarding the nationalities of the organisations are presented in Table 6-3. This was investigated to consider whether the research findings, while currently focused on Korea, could be extended globally. The results show that the majority of companies were of Korean nationality (n = 271, 89.7%), but the inclusion of companies with head offices in other parts of Asia (n = 19, 6.3%) and Europe (n = 21, 4%) suggests the possibility of interpreting the research findings within the context of global maritime supply chain processes.

Demographic variable	Category	Frequency	Percentage (%)
Nationality of organisation	Korean	271	89.7
	Other Asian	19	6.3
	European	12	4
	Total	302	100

Table 6-3 Nationality of organisations by respondents' organisations
Source: Author

Lastly, the number of employees was considered in assessing the general background of the respondents' organisations. Table 6-4 displays information on the size of the respondents' organisations. Companies with fewer than 100 employees accounted for 31.8% (n = 96), those with 101 to 300 employees comprised 23.8% (n = 72), organisations with 301 to 500 employees represented 27.8% (n = 84), and companies with over 500 employees made up 16.6% (n = 50). These results indicate that the sample was obtained from companies of various sizes, thereby implying that a large firm bias could be avoided in the study.

Demographic variable	Category	Frequency	Percentage (%)
Number of employees	1 ~ 100	96	31.8
	101 ~ 300	72	23.8
	301 ~ 500	84	27.8
	501 ~	50	16.6
	Total	302	100

Table 6-4 Number of employees by respondents' organisations
Source: Author

6.1.3.2 Characteristics of respondents

In this study, the questionnaire was distributed to staff members across all levels and departments within the organisation, without limiting the scope of their tasks. Considering that the core activities of maritime firms revolve around exchanging information with supply chain partners and engaging in supply chain processes through IT-based networks, it was determined that employees across all business functions and levels possessed the knowledge and experience necessary to answer to questions regarding SCI, IT competency, and BCU. Therefore, the empirical data gathered from employees working across all areas grant substantive validity to the research.

The descriptive analysis of the respondents' backgrounds indicates that the survey reached employees at all areas within the organisations, as shown in Table 6-5. Employees responsible for management accounted for 15.2% (n = 46), while those working in human resources were 6.6% (n = 20). Sales and customer management, who typically communicate most frequently with supply chain partners, represented the largest proportion at 31.5% (n = 95), whereas purchasing was at 5% (n = 15). Respondents who answered 'Others' constituted a relatively large percentage at 33.8% (n = 102), which can be interpreted as employees with responsibilities in specialised tasks specific to their organisations, rather than the general tasks presented as options in the questionnaire instructions, reflecting the diverse types of businesses involved.

Demographic variable	Category	Frequency	Percentage (%)
Task	Management	46	15.2
	Human resource	20	6.6

	Sale customer management	95	31.5
	IT support	24	7.9
	Purchasing	15	5
	Others	102	33.8
	Total	302	100

Table 6-5 Task of respondents

Source: Author

Finally, Table 6-6 presents the job positions of the respondents. The sample covers staff and senior staff at 13.2% (n = 40) and 16.9% (n = 51) respectively. This group, as the first tier of the management levels divided into top-level, middle-level, and frontline-level, contributes to day-to-day operations through interacting with workers, partners, and customers (Op de Beeck et al. 2018). In the composition of management levels, mid-level managers constitute 17.9% (n = 54), whereas general managers form a larger proportion at 38.1% (n = 115). Mid-level management plays a crucial role in organisational decision-making by serving as a bridge between top-level management's strategic decisions and frontline operations (Arıcıoğlu et al. 2020). At higher levels of responsibility, executive directors accounted for 11.9% (n = 36), and CEOs for 2% (n = 6) indicating that responses were collected centrally around managers, who are at the core of operations across all employee levels.

Demographic variable	Category	Frequency	Percentage (%)
Position	Staff	40	13.2
	Senior staff	51	16.9
	Manager	54	17.9
	General manager	115	38.1

Executive director	36	11.9
CEO	6	2
Total	302	100

Table 6-6 Position of respondents
Source: Author

6.2 Descriptive statistics for the main items

This section focuses on the results of the questionnaire items that were designed to incorporate measurement constructs following the investigation of demographic characteristics. As determined in section 4.3, the constructs consist of SCI, IT competency, BCU, and performance. Respondents were asked to indicate their perceptions pertaining to the constructs using a 7-point Likert scale, with options ranging from 1 = 'Strongly disagree' to 7 = 'Strongly agree'.

6.2.1 Descriptive statistics for SCI

Table 6-7 details the questionnaire items used to measure SCI, along with overall statistics that include the response scale, as well as the measured mean and Standard Deviation (SD) values for each item. Items GS4 (mean=5.39) and GS2 (mean=5.34) presented as the most strongly agreed, each exceeding a mean value of 5.3, whereas CC3, with a mean of 4.74, and JPM1, with a mean of 4.77, received the lowest ratings. The majority of responses had average values that fell between 4.74 and 5.39, which, while higher than the midpoint, indicate a slightly strong agreement.

Items	1 Strongly disagree	2 Disagree	3 Slightly disagree	4 Neutral	5 Slightly agree	6 Agree	7 Strongly Agree	Mean	SD
IS1	0	5 (1.7%)	10 (3.3%)	77 (25.5%)	96 (31.8%)	77 (25.5%)	36 (11.9%)	5.12	1.12
IS2	0	7 (2.3%)	15 (5%)	71 (23.5%)	93 (30.8%)	77 (25.5%)	38 (12.6%)	5.10	1.18
IS3	0	5 (1.7%)	22 (7.3%)	77 (25.5%)	93 (30.8%)	69 (22.8%)	35 (11.6%)	5.01	1.18
IS4	0	2 (0.7%)	23 (7.6%)	68 (22.5%)	104 (34.4%)	70 (23.2%)	34 (11.3%)	5.06	1.13
IS5	1 (0.3%)	4 (1.3%0	19 (6.3%)	74 (24.5%)	99 (32.8%)	69 (22.8%0	35 (11.6%)	5.04	1.17
KC1	0	0 7 (2.3%)	29 (9.6%0	72 (23.8%)	90 (29.8%)	66 (21.9%)	38 (12.6%)	4.97	1.25
KC2	0	9 (3.0%)	13 (4.3%)	93 (30.8%)	95 (31.5%)	59 (19.5%)	33 (10.9%)	4.93	1.18
KC3	1 (0.3%)	0	17 (5.6%)	65 (21.5%)	93 (30.8%)	82 (27.2%)	43 (14.2%)	5.22	1.14
KC4	0	4 (1.3%)	18 (6.0%)	75 (24.8%)	87 (28.8%)	77 (25.5%)	41 (13.6%)	5.12	1.18
KC5	0	3 (1.0%)	30 (9.9%)	83 (27.5%)	86 (28.5%)	73 (24.2%)	27 (8.9%)	4.92	1.17
CC1	1 (0.3%)	6 (2.0%)	16 (5.3%)	76 (25.2%)	81 (26.8%)	83 (27.8%)	37 (12.3%)	5.09	1.21
CC2	1 (0.3%)	4 (1.3%)	18 (6.0%)	85 (28.1%)	88 (29.1%)	66 (21.9%)	40 (13.2%)	5.03	1.20
CC3	1 (0.3%)	11 (3.6%)	34 (11.3%)	83 (27.5%)	93 (30.8%)	52 (17.2%)	28 (9.3%)	4.74	1.26
CC4	1 (0.3%)	11 (3.6%)	24 (7.9%)	82 (27.2%)	82 (27.2%)	68 (22.5%)	34 (11.3%)	4.90	1.28
CC5	0	9 (3.0%)	24 (7.9%)	76 (25.2%)	92 (30.5%)	73 (24.2%)	28 (9.3%)	4.93	1.20
GS1	1 (0.3%)	4 (1.3%)	23 (7.6%)	70 (23.2%)	98 (32.5%)	67 (22.2%)	39 (12.9%)	5.04	1.20
GS2	2 (0.7%)	3 (1.0%)	7 (2.3%)	56 (18.5%)	99 (32.8%)	81 (26.8%)	54 (17.9%)	5.34	1.16
GS3	1 (0.3%)	2 (0.7%)	11 (3.6%)	60 (19.9%)	104 (34.4%)	79 (26.2%)	45 (14.9%)	5.25	1.12
GS4	0	1 (0.3%)	13 (4.3%)	54 (17.9%)	87 (28.8%)	92 (30.5%)	55 (18.2%)	5.39	1.12
GS5	0	4 (1.3%)	19 (6.3%)	74 (24.8%)	86 (28.5%)	79 (26.2%)	39 (12.9%)	5.11	1.18
DH1	2 (0.7%)	1 (0.3%)	19 (6.3%)	60 (19.9%)	109 (26.1%)	72 (23.8%)	39 (12.9%)	5.14	1.15
DH2	1 (0.3%)	2 (0.7%)	14 (4.6%)	84 (27.8%)	108 (35.8%)	63 (20.9%)	30 (9.9%)	5.00	1.09
DH3	2 (0.7%)	7 (2.3%)	11 (3.6%)	68 (22.5%)	94 (31.1%)	73 (24.2%)	47 (15.6%)	5.16	1.24
DH4	1 (0.3%)	5 (1.7%)	8 (2.6%)	68 (22.5%)	91 (30.1%)	85 (28.1%)	44 (14.6%)	5.23	1.16

DH5	1 (0.3%)	5 (1.7%)	19 (6.3%)	79 (26.2%)	91 (30.1%)	71 (23.5%)	36 (11.9%)	5.02	1.20
JPM1	1 (0.3%)	7 (2.3%)	32 (10.6%)	92 (30.5%)	86 (28.5%)	56 (18.5%)	28 (9.3%)	4.77	1.22
JPM2	1 (0.3%)	3 (1.0%)	10 (3.3%)	74 (24.5%)	92 (30.5%)	80 (26.5%)	42 (13.9%)	5.19	1.14
JPM3	0	9 (3.0%)	21 (7.0%)	78 (25.6%)	84 (27.8%)	68 (22.5%)	42 (13.9%)	5.02	1.26
JPM4	1 (0.3%)	4 (1.3%)	18 (6.0%)	65 (21.5%)	86 (28.5%)	78 (25.8%)	50 (16.6%)	5.20	1.23
JPM5	1 (0.3%)	4 (1.3%)	15 (5.0%)	75 (24.8%)	79 (26.2%)	81 (26.8%)	47 (15.6%)	5.18	1.22

Table 6-7 Descriptive statistics for SCI

Source: Author

6.2.2 Descriptive statistics for IT competency

Table 6-8 illustrates the descriptive statistics for IT competency. For the items measuring IT competency, all except for FITI4 (mean=4.99) surpassed a mean score of 5, with particularly high values for MITK1 and MITK2, which scored 5.42 and 5.46, respectively. The response rates across all items suggest that there is a general tendency towards agreement regarding IT competency.

Items	1	2	3	4	5	6	7	Mean	SD
	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly Agree		
FITI1	0	4 (1.4%)	11 (3.6%)	59 (19.5%)	65 (21.5%)	116 (38.4%)	47 (15.6%)	5.39	1.15
FITI2	0	4 (1.3%)	10 (3.3%)	65 (21.5%)	73 (24.2%)	100 (33.1%)	50 (16.6%)	5.34	1.16
FITI3	0	3 (1.0%)	12 (4.0%)	70 (23.2%)	80 (26.5%)	90 (29.8%)	47 (15.6%)	5.27	1.16
FITI4	1 (0.3%)	5 (1.7%)	32 (10.6%)	69 (22.8%)	88 (29.1%)	66 (21.9%)	41 (13.6%)	4.99	1.27
FITI5	0	5 (1.7%)	30 (9.9%)	67 (22.2%)	84 (27.8%)	69 (22.8%)	47 (15.6%)	5.07	1.27
ITA1	0	7 (2.3%)	12 (4.0%)	61 (20.2%)	89 (29.5%)	83 (27.5%)	50 (16.6%)	5.25	1.20

ITA2	0	5 (1.7%)	21 (7.0%)	54 (17.9%0	85 (29.1%)	90 (29.8%)	47 (15.6%)	5.24	1.21
ITA3	0	4 (1.3%)	21 (7.0%)	57 (18.9%)	84 (27.8%)	90 (29.8%)	46 (15.2%)	5.24	1.20
ITA4	0	7 (2.3%)	16 (5.3%)	62 (20.5%)	91 (30.1%)	79 (26.2%)	46 (15.6%)	5.19	1.22
MITK1	4 (1.3%)	2 (0.7%)	21 (7.0%)	48 (15.9%)	62 (20.5%)	90 (29.8%)	75 (24.8%)	5.42	1.35
MITK2	5 (1.7%)	1 (0.3%)	23 (7.6%)	44 (14.6%)	55 (18.2%)	96 (31.8%)	78 (25.8%)	5.46	1.38
MITK3	5 (1.7%)	3 (1.0%)	19 (6.3%)	53 (17.5%)	75 (24.8%)	81 (26.8%)	66 (21.9%)	5.31	1.36
ITPS1	6 (2.0%)	3 (1.0%)	14 (4.6%)	46 (15.2%)	75 (24.8%)	100 (33.1%)	58 (19.2%)	5.36	1.31
ITPS2	5 (1.7%)	3 (1.0%)	7 (2.3%)	57 (18.9%)	78 (25.8%)	102 (33.8%)	50 (16.6%)	5.34	1.24
ITPS3	6 (2.0%)	5 (1.7%)	14 (4.6%)	60 (19.9%)	74 (24.5%)	94 (31.1%)	49 (16.2%)	5.22	1.33
ITPS4	5 (1.7%)	2 (0.7%)	15 (5.0%)	49 (16.2%)	80 (26.5%)	96 (31.8%)	55 (18.2%)	5.33	1.28
ITPS5	5 (1.7%)	7 (2.3%)	14 (4.6%)	68 (22.5%)	77 (25.5%)	81 (26.8%)	50 (16.6%)	5.15	1.34

Table 6-8 Descriptive statistics for IT competency

Source: Author

6.2.3 Descriptive Statistics for BCU

The next aspect to consider is the response results for BCU (Table 6-9). Excluding BCU1 (mean=4.01), the average responses for all other items indicated mean values below 4, generally remaining around 3.7. This suggests that the perceptions of respondents towards BCU are characterised by a lack of strong agreement or disagreement.

Items	1	2	3	4	5	6	7	Mean	SD
	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly Agree		
BCU1	39 (12.9%)	25 (8.3%)	33 (10.9%)	74 (24.5%)	53 (17.5%)	41 (13.6%)	23 (7.6%)	4.01	1.78

BCU2	46 (15.2%)	30 (9.9%0	45 (14.9%)	66 (21.9%)	43 (14.2%)	44 (14.6%)	14 (4.6%)	3.76	1.78
BCU3	47 (15.6%)	33 (10.9%)	45 (14.9%)	68 (22.5%)	45 (14.9%)	32 (10.6%)	18 (6.0%)	3.69	1.78
BCU4	48 (15.9%)	32 (10.6%)	39 (12.9%)	70 (23.2%)	42 (13.9%)	33 (10.9%)	24 (7.9%)	3.77	1.84

Table 6-9 Descriptive statistics for BCU

Source: Author

6.2.4 Descriptive statistics for Performance

Finally, Table 6-10 presents the descriptive statistics related to performance. OPP3 emerged as the item with the greatest mean value of 5.10 among the items. Other performance items displayed values ranging between 4.6 and 4.9. The OPP values, being above 4.7, showed a tendency towards slight agreement, in comparison to FNP values, which, falling between 4.6 and 4.7, indicated a more neutral position with a weaker degree of agreement.

Items	1	2	3	4	5	6	7	Mean	SD
	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly Agree		
OPP1	1 (0.3%)	10 (3.3%)	18 (6.0%)	82 (27.2%)	85 (28.1%)	78 (25.8%)	28 (9.3%)	4.94	1.22
OPP2	0	11 (3.6%)	31 (10.3%)	95 (31.5%)	90 (29.8%)	50 (16.6%)	25 (8.3%)	4.70	1.21
OPP3	1 (0.3%)	6 (2.0%)	17 (5.6%)	70 (23.2%)	85 (28.1%)	90 (29.8%)	33 (10.9%)	5.10	1.20
OPP4	1 (0.3%)	8 (2.6%)	25 (8.3%)	70 (23.2%)	91 (30.1%)	74 (24.5%)	33 (10.9%)	4.97	1.24
OPP5	1 (0.3%)	9 (3.0%)	20 (6.6%)	77 (25.5%)	91 (30.1%)	68 (22.5%)	36 (11.9%)	4.97	1.24
OPP6	1 (0.3%)	9 (3.0%)	20 (6.6%)	91 (30.1%)	87 (28.8%)	61 (20.2%)	33 (109%)	4.88	1.23
FNP1	3 (1.0%)	9 (3.0%)	27 (8.9%)	100 (33.1%)	84 (27.8%)	49 (16.2%)	30 (9.9%)	4.72	1.27
FNP2	3 (1.0%)	13 (4.3%)	30 (9.9%)	97 (32.1%)	72 (23.8%)	58 (19.2%)	28 (9.3%)	4.69	1.32

FNP3	3 (1.0%)	14 (4.6%)	31 (10.3%)	106 (35.1%)	67 (22.2%)	51 (16.9%	30 (9.9%)	4.63	1.33
FNP4	3 (1.0%)	13 (4.3%)	28 (9.3%)	107 (35.4%)	77 (25.5%)	45 (14.9%)	29 (9.6%)	4.63	1.29
FNP5	3 (1.0%)	13 (4.3%)	29 (9.6%)	111 (36.8%)	75 (24.8%)	44 (14.6%)	27 (8.9%)	4.60	1.28

Table 6-10 Descriptive statistics for performance

Source: Author

6.3 Empirical data analysis

In this section, the assessment of the measurement and structural models is conducted following the procedures outlined in Section 5.3.2. Subsequently, the outcomes of the hypothesis testing are discussed. The influence of IT competency on SCI and performance, the moderating effects of SCI, as well as the moderating impacts of BCU are examined through the PLS-SEM analytical process.

6.3.1 Data preparation

6.3.1.1 Missing data

Missing data is an issue that should be addressed in empirical data analysis as it can affect the generalisability of the results. To treat missing data, it is important to identify the patterns and relationships underlying the missing instances in order to maintain the original distribution as much as possible. According to Hair Jr et al. (2021), PLS-SEM is highly robust, therefore missing values can be considered at a reasonable level if they are less than 5%. In this case, it is suggested to treat missing values not by deletion but by replacing them with the mean, thereby handling the data sample effectively. In Table 6-11, none of the items had missing data rates above 5%, demonstrating a generally low level of missing data per indicator. In this study, the counted missing data were replaced with the mean values of their respective items.

Construct	Items	Count	Percentage
SCI	IS1	1	0.3%
	IS2	1	0.3%
	IS3	1	0.3%
	IS4	1	0.3%
	IS5	1	0.3%
	KC3	1	0.3%
	CC1	1	0.3%
BCU	BCU1	14	4.6%
	BCU2	14	4.6%
	BCU3	14	4.6%
	BCU4	14	4.6%
Performance	FNP2	1	0.3%

Table 6-11 Missing items
Source: Authors

6.3.1.2 Outliers

An outlier is an observation that is recognised as significantly different from the 'normal' values, possessing a unique set of characteristics (Hair et al. 2019a). Through outlier detection, the amount and diversity of data types are increased, thereby defining the context of the data and establishing what is considered 'normal'. Outliers can affect the fit of a statistical model, and parameter estimations becoming biased due to outliers can lead to problematic outcomes (Filzmoser 2005). The issue of outliers can be avoided by using robust techniques, or can be resolved by improving model fitting through the removal of outliers when using classical statistical methods. Byrne (2010) recommend retaining outliers due to the robustness of the bootstrapping resampling techniques in PLS-SEM. Including outliers in empirical analysis can provide valuable insights and enhance the generalisability of research findings to the entire population (Hair et al. 2019a). Therefore, bootstrapping method used in this research is considered adequately to cover the outlier issue, and as a result, outliers were not taken into consideration.

6.3.1.3 Data distribution

As explained in section 5.3.2, issues of normality are a key consideration when choosing between CB-SEM and PLS-SEM. CB-SEM prefers data that is normally distributed as it provides unbiased estimates, whereas PLS-SEM is inherently a non-parametric technique that employs bootstrapping to calculate standard errors, allowing for the testing of path significance regardless of the data distribution (Jannoo et al. 2014). Consequently, PLS-SEM can deliver robust results without being affected by the distributional form of the data. In this study, normality issues are not considered significant concerns due to the use of bootstrapping, a resampling technique, within the PLS-SEM method to estimate the weights of relationships.

6.3.2 Measurement model assessment

As discussed in Section 5.3.2, this study conducted four validation processes for the verification of the measurement model: indicator reliability, internal consistency reliability, convergent validity, and discriminant validity. The analysis was conducted using the SmartPLS version 4 software, which is the most frequently used tool specialised for PLS-SEM analysis.

6.3.2.1 Indicator reliability

In a reflective model, the outer loading represents the strength of the relationship between an indicator and its associated construct, indicating how well the indicator explains the construct. As explained in Section 5.3.2, an indicator loading should be 0.708 or higher to be considered acceptable, which means that the square of 0.708, corresponding to 50%, indicates that the construct explains over 50% of the variance of the indicator (Hair Jr et al. 2021). As presented in Table 6-12, it can be observed that all loading values exceed 0.708, indicating sufficiently high values.

Construct	Items	Loading	Construct	Items	Loading	Construct	Items	Loading	Construct	Items	Loading
Supply Chain Integration	IS1	0.846	Supply Chain Integration	GS1	0.815	IT competency	FITI1	0.792	Blockchain Utilisation	BCA1	0.916
	IS2	0.892		GS2	0.849		FITI2	0.864		BCA2	0.970
	IS3	0.855		GS3	0.831		FITI3	0.900		BCA3	0.974
	IS4	0.838		GS4	0.797		FITI4	0.848		BCA4	0.962
	IS5	0.837		GS5	0.794		FITI5	0.857	Operational Performance	OPP1	0.879
	KC1	0.866		DH1	0.806		ITA1	0.921		OPP2	0.858
	KC2	0.818		DH2	0.827		ITA2	0.921		OPP3	0.901
	KC3	0.805		DH3	0.820		ITA3	0.886		OPP4	0.893
	KC4	0.849		DH4	0.827		ITA4	0.878		OPP5	0.884
	KC5	0.828		DH5	0.779		MITK1	0.955		OPP6	0.852
	CC1	0.852		JPM1	0.783		MITK2	0.968	Financial Performance	FNP1	0.939
	CC2	0.869		JPM2	0.814		MITK3	0.949		FNP2	0.947
	CC3	0.822		JPM3	0.794		ITPS1	0.908		FNP3	0.919
	CC4	0.845		JPM4	0.804		ITPS2	0.930		FNP4	0.952
	CC5	0.817		JPM5	0.812		ITPS3	0.926		FNP5	0.940
							ITPS4	0.938			
							ITPS5	0.885			

Table 6-12 Factor loads of indicators

Source: Author

6.3.2.2 Internal consistency reliability and convergent validity

The Table 6-13 presents a summary of the results of consistency reliability and convergent validity. As discussed in section 5.3.2, reliability ensures consistent observation of variables, and validity examines whether the indicators adequately represent the construct. The reliability assessment, conducted through Cronbach's alpha and C.R (Composite Reliability), resulted in values exceeding the threshold of 0.70, indicating robust internal consistency. Convergent validity was supported as the AVE over the minimum requirement of 0.50. For the constructs of SCI and IT competency, higher-order structures were developed, consisting of 6 and 4 lower-order constructs, respectively. The validation for the higher-order structures will be discussed in later section. The indicators demonstrated factor loadings above the desired threshold of 0.70, confirming strong associations. Reliability assessments using Cronbach's alpha and C.R revealed values greater than 0.70, signifying good internal consistency for the higher-order constructs. The AVE for these advanced constructs was above 0.50, supporting convergent validity.

Variables	Latent variables	No. items	Consistency reliability		Convergent validity
			Cronbach's α	C.R	AVE
SCI	IS	5	0.907	0.931	0.729
	KC	5	0.89	0.919	0.694
	CC	5	0.897	0.924	0.708
	GS	4	0.876	0.909	0.668
	DH	3	0.871	0.906	0.659
	JPM	5	0.861	0.9	0.643
ITC	FITI	5	0.906	0.93	0.727
	ITA	4	0.923	0.946	0.813
	MITK	3	0.954	0.971	0.916

	ITPS	5	0.953	0.964	0.842
BCU	BCU	4	0.968	0.977	0.914
PERF	OPP	6	0.94	0.953	0.771
	FNP	5	0.967	0.974	0.883

Table 6-13 Internal consistency reliability and convergent validity

Source: Author

6.3.2.3 Discriminant validity

Discriminant validity verifies whether constructs are distinctly different from others. as explored in the previous section, discriminant validity has been assessed using the Fornell-Larcker criterion and the HTMT. Firstly, the Fornell-Larcker criterion was determined by comparing the correlations between latent variables with the square root of the AVE (Fornell and Larcker 1981b). Table 6-14 illustrates that the correlations are less than the corresponding AVE values (bold), ensuring discriminant validity as recommended.

Method	Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Fornell-Lacker Criterion	**(1) IS**	**0.854**												
	(2) KC	0.761	**0.833**											
	(3) CC	0.779	0.757	**0.841**										
	(4) GS	0.713	0.763	0.689	**0.817**									
	(5) DH	0.712	0.726	0.759	0.814	**0.812**								
	(6) JPM	0.698	0.723	0.707	0.753	0.782	**0.802**							
	(7) FITI	0.500	0.523	0.471	0.599	0.576	0.690	**0.853**						
	(8) ITA	0.459	0.483	0.399	0.509	0.495	0.614	0.808	**0.902**					
	(9) MITK	0.341	0.382	0.280	0.481	0.434	0.521	0.703	0.754	**0.957**				
	(10) ITPS	0.440	0.456	0.430	0.500	0.487	0.556	0.723	0.753	0.736	**0.917**			
	(11) BCU	0.394	0.393	0.433	0.406	0.446	0.509	0.505	0.491	0.452	0.475	**0.956**		
	(12) OPP	0.625	0.646	0.631	0.608	0.674	0.695	0.570	0.543	0.422	0.491	0.543	**0.878**	
	(13) FNP	0.538	0.589	0.583	0.545	0.578	0.654	0.471	0.437	0.367	0.427	0.522	0.838	**0.940**

Table 6-14 Fornell-Lacker criterion for discriminant validity

Source: Author

Furthermore, the HTMT was employed as a criterion for assessing discriminant validity and Table 6-15 presents the result. In the analysis, two values, DH - GS and JPM – DH, exceeded the threshold of 0.9 (Italic), thereby failing to meet the established criteria. The HTMT represents the mean of all correlations of indicators across constructs that measure different constructs. To address issues of discriminant validity, it is necessary to conduct a cross-loading assessment to ensure that the indicators do not show loadings of 0.70 or higher on other constructs after which any indicators that do should be removed (Farrell 2010). After revisiting cross-loadings, it was observed that the value for GS5 exhibited a loading of 0.705 on the construct DH, while DH3 showed a loading of 0.706 on JPM, and DH4 displayed a loading of 0.719 on GS. The cross loading result is presented in Appendix D. Following the removal of these items, the HTMT assessment was conducted with revised data set. The results indicated that all 13 constructs met the HTMT criterion, with values below 0.90, thereby demonstrating robust discriminant validity.

Method	Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Heterotrait-monotrait ratio of correlations (HTMT)	**(1) IS**													
	(2) KC	0.849												
	(3) CC	0.859	0.844											
	(4) GS	0.798	0.864	0.772										
	(5) DH	0.802	0.827	0.86	*0.932*									
	(6) JPM	0.789	0.825	0.801	0.865	*0.901*								
	(7) FITI	0.548	0.577	0.516	0.668	0.641	0.778							
	(8) ITA	0.501	0.532	0.437	0.566	0.55	0.689	0.88						
	(9) MITK	0.365	0.411	0.298	0.525	0.471	0.574	0.754	0.802					
	(10) ITPS	0.473	0.496	0.462	0.546	0.535	0.614	0.781	0.803	0.77				
	(11) BCU	0.419	0.422	0.463	0.442	0.486	0.557	0.535	0.52	0.472	0.497			
	(12) OPP	0.676	0.706	0.685	0.668	0.743	0.771	0.611	0.583	0.444	0.518	0.569		
	(13) FNP	0.573	0.634	0.624	0.588	0.628	0.716	0.497	0.462	0.379	0.444	0.538	0.878	
Revised Heterotrait-monotrait ratio of correlations (HTMT)	**(1) IS**													
	(2) KC	0.849												
	(3) CC	0.859	0.844											
	(4) GS	0.807	0.863	0.775										
	(5) DH	0.787	0.827	0.886	*0.865*									
	(6) JPM	0.789	0.825	0.801	0.866	*0.854*								
	(7) FITI	0.548	0.577	0.516	0.686	0.592	0.778							
	(8) ITA	0.501	0.532	0.437	0.576	0.496	0.689	0.88						
	(9) MITK	0.365	0.411	0.298	0.527	0.412	0.574	0.754	0.802					
	(10) ITPS	0.473	0.496	0.462	0.563	0.522	0.614	0.781	0.803	0.77				
	(11) BCU	0.419	0.422	0.463	0.445	0.476	0.557	0.535	0.52	0.472	0.497			
	(12) OPP	0.676	0.706	0.685	0.673	0.696	0.771	0.611	0.583	0.444	0.518	0.569		
	(13) FNP	0.573	0.634	0.624	0.594	0.599	0.716	0.497	0.462	0.379	0.444	0.538	0.878	

Table 6-15 HTMT for discriminant validity

Source: Author

6.3.2.4 Validating reflective-reflective higher-order construct

SCI and IT competency are the higher-order constructs in the study based on six (IS, KC, CC, GS, DH and JPM) and four (FITI, ITA, MITK and ITPS) lower constructs. SCI and IT competency are measured as reflective-reflective higher-order constructs in this study. Further verification is conducted to specify and estimate additional higher-order constructs. As described in Section 5.3.2, a disjoint two-stage approach was applied to construct the second-order components. The first stage involved calculating the latent variables of the lower order, and in the subsequent stage, the calculated latent variable scores were used as indicators to model the higher-order constructs (Sarstedt et al. 2019). To establish the validity of the higher-order construct, factor loadings, reliability, and validity were assessed. The summary of the results is presented in Table 6-16. All indicators for SCI and IT competency had factor loadings greater than the minimum acceptable value of 0.50. Reliability was verified using Cronbach's alpha and composite reliability, with the statistics for both being higher than the recommended value of 0.70 for the higher-order construct. The AVE values, which verify convergent validity, showed acceptable levels above 0.5.

Constructs	Outer Loadings	Cronbach's α	C.R	AVE
IS <- SCI	0.872			
KC <- SCI	0.892			
CC <- SCI	0.884	0.941	0.953	0.771
GS <- SCI	0.869			
DH <- SCI	0.870			
JPM <- SCI	0.880			
FITI <- ITC	0.909			
ITA <- ITC	0.924	0.921	0.944	0.809
MITK <- ITC	0.873			

ITPS <- ITC	0.891

Table 6-16 Factor loadings, reliability and AVE for HOC

Source: Author

Fornell & Larker Criterion			Heterotrait-monotrait ratio of correlations (HTMT)		
	SCI	ITC		SCI	ITC
SCI	**0.878**		SCI		
ITC	0.609	**0.899**	ITC	0.642	
BCU	0.489	0.535	BCU	0.509	0.566
OPP	0.723	0.567	OPP	0.767	0.603
FNP	0.656	0.476	FNP	0.683	0.498

Table 6-17 Discriminant validity for HOC

Source: Author

Discriminant validity was assessed using the Fornell & Larker criterion and the HTMT ratio. As evidenced in Table 6-17, the square roots of the AVE for both SCI and IT competency exceeded the correlations among other latent variables. Additionally, the HTMT values were below the required threshold of 0.90. Consequently, this confirms the establishment of discriminant validity for the higher-order constructs of SCI and IT competency. Thereby, the structural model is developed as depicted in Figure 6-1.

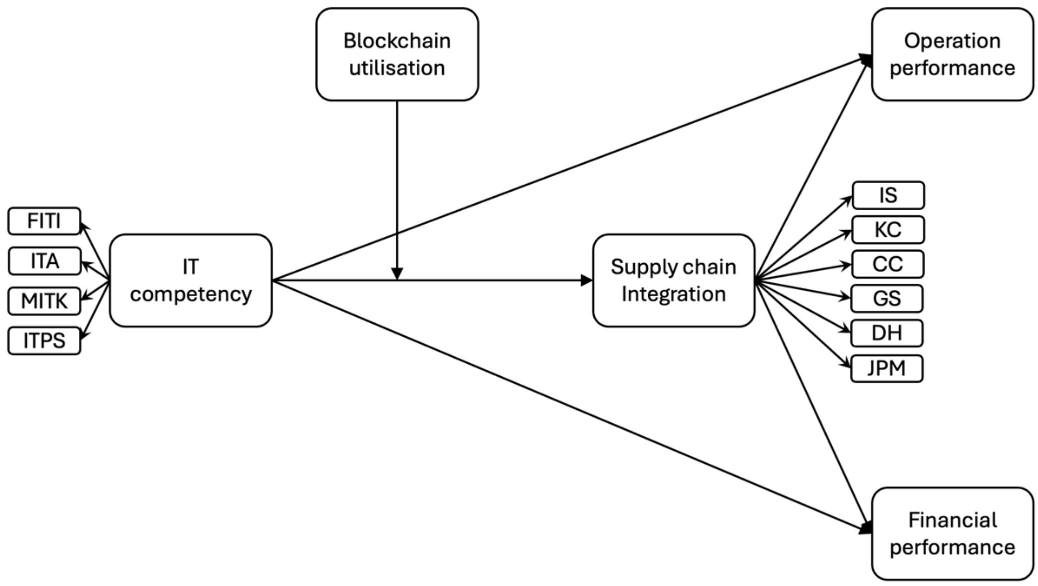


Figure 6-1 Structural model with HOC
Source: Author

6.3.3 Structural model assessment – hypothesis testing

Following the model assessment, a structural model assessment was conducted to investigate the relationships between constructs and to validate the hypotheses. Hypothesis testing involved examining the direct effects among IT competency, SCI, and performance (operational and financial) and the results are illustrated in Table 6-18. Additionally, the mediation relationship between IT competency and performance through SCI was examined, as well as the moderating effect of BCU on the relationship between IT competency and SCI, and its subsequent impact on performance. The next step is to evaluate the structural path for the path coefficients and their statistical significance.

Hypothesis	Path	β	SE	T	P	Outcomes
H1-1	ITC -> OPP	0.201	0.068	2.950	0.003**	Supported

H1-2	ITC -> FNP	0.121	0.055	2.207	0.027*	Supported
H2	ITC -> SCI	0.561	0.052	10.851	0.000***	Supported
H3-1	SCI -> OPP	0.601	0.063	9.520	0.000***	Supported
H3-2	SCI -> FNP	0.583	0.058	10.067	0.000***	Supported

*Note: ITC IT competency, SCI supply chain integration, OPP operational performance, FNP financial performance. β = beta coefficient, S.E = Standard Error, T = t-statistics, P = Probability value, *** p < 0.001, ** p < 0.05, * p < 0.1, NS: Non-significant.*

Table 6-18 Outcomes of direct impact analysis

Source: Author

6.3.3.1 Direct impact

As discussed in Chapter 4, Hypotheses 1 and 2 evaluate the direct effects of IT competency on operational performance, financial performance, and SCI. The results revealed that IT competency has a significant and positive impact on both operational performance ($\beta = .202$, $t = 2.950$, $p < 0.05$) and financial performance ($\beta = .121$, $t = 2.207$, $p < 0.1$). Therefore, Hypotheses 1-1 and 1-2 are supported, and the findings are presented in Figure 6-2. The notable impact of the link between IT proficiency and performance (both operational and financial) suggests that enhancing a organisations' IT capability can contribute to improved performance outcomes. With the digital transformation of maritime supply chain activities, the adoption of innovative technologies that facilitate effective information and communication exchanges within the supply chain is supported by the organisations' IT competency. This, in turn, positively influences the firm's ability to enhance its overall performance.

Nonetheless, the relatively low beta values suggest that the direct effect might not be strong. This means that while IT competency positively affects performance, it is likely not the solely determining factor (Prajogo and Olhager 2012). Some prior research has highlighted a sceptical perspective on the direct influence of IT on firm performance, proposing that the connection is more often indirect than direct (Li et al. 2009; Kim 2017). It is especially noted that the effect on financial performance is even more modest. This can be explained by the trade-off between the costs incurred in acquiring, developing, and sustaining IT resources, and the financial benefits they offer (Oduro et al. 2023). In addition, the overflow of IT resources and technologies may not be generated financial returns (Gebauer et al. 2020). However, the findings confirm a positive relationship between IT and performance, emphasising that utilisation of IT extends beyond merely facilitating business strategies and is vital to the operations of organisations within the maritime supply chain.

Hypothesis 2 was designed to explore the significant and positive influence of IT competency on SCI. The findings revealed a significant and positive effect of IT proficiency on SCI, with a beta coefficient of .561 and a t-value of 10.851, which was statistically significant ($p < 0.000$). These results empirically supported to Hypothesis 2. The results indicate that possessing a strong IT capability is linked to and positively influences the achievement of SCI in the maritime supply chain sector. This implies that organisations with robust IT competency are more effectively integrate their supply chain collaborators, leading to enhanced information exchange, better communication, more effective coordination, and superior performance across the supply chain.

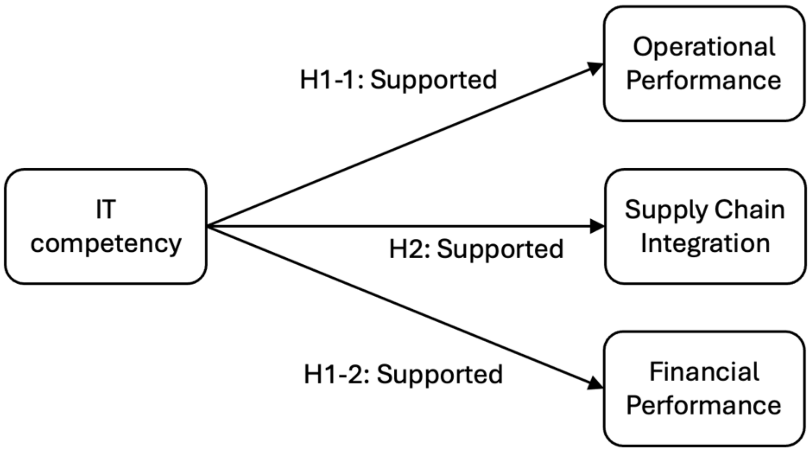


Figure 6-2 The impact of IT competency on operational performance, financial performance and supply chain integration (H1-1, H1-2 and H2)

Source: author

Next, the direct relationships between SCI and both operational performance and financial performance were examined. The results supported H3-1 ($\beta = 0.601$, $t = 9.520$, $p < 0.001$) and H3-2 ($\beta = 0.583$, $t = 10.067$, $p < 0.001$), indicating significant and positive influence of SCI on performance. Figure 6-3 presents these findings. This underscores the crucial importance of integration among partners in the supply chain in improving the efficiency of maritime supply chain activities. It expands the perspective of maritime transportation from just being a mode of transportation to being a central representation of integration among entities within the logistics context.

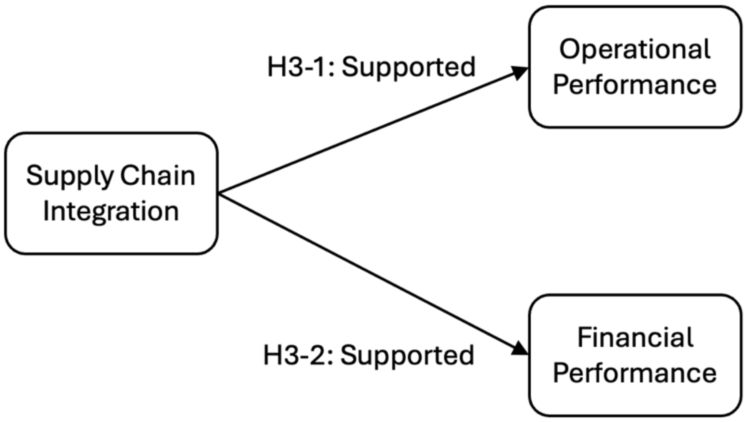


Figure 6-3 The impact of supply chain integration on operational performance and financial performance (H3-1 and H3-2)

Source: Author

6.3.3.2 Indirect impact

The next aspect to examine is the mediating influence of SCI on the relationship between IT competency and performance. A mediation analysis was performed to assess the mediating role of SCI in the relationship between IT competency and both operational and financial performance. The results summarised in Table 6-19 reveal that the indirect effect of IT competency on operational performance through SCI is significant (H4: $\beta = .337$, $t = 7.864$, $p < 0.001$). The total effect of IT competency on operational performance is also significant ($\beta = .538$, $t = 10.274$, $p < 0.001$), including the direct effect of IT competency on operational performance ($\beta = .201$, $t = 2.950$, $p < 0.05$). These findings demonstrate a complementary partial mediating role of SCI in the relationship between IT competency and operational performance, supporting Hypothesis 4-1. Similarly, the indirect effect of IT competency on financial performance through SCI was found to be significant and positive ($\beta = .327$, $t = 8.196$, $p < 0.001$). The total effect, including the direct impact of IT competency on financial performance, was significant, confirming the complementary partial mediating role of SCI in the effect of IT competency on financial performance, thereby supporting Hypothesis 4-2. The outcomes of mediation analysis are illustrated in Figure 6-4.

The examination highlights the key function of SCI as an intermediary between IT competency and the performance of maritime organisations. In the initial path analysis for Hypothesis 1 (H1), a low beta coefficient was noted between IT competency and performance, implying a weak direct relationship. However, upon assessing the indirect pathway via the mediator, SCI, a substantial beta coefficient emerged, signifying a strengthened effect of IT competency on performance through SCI. This reveals a mediating role where the impact of IT competency on performance is indirectly transmitted through SCI.

Hypothesis	Mediation	Path	β	T	P	CI 95%	
						Lower	Upper
H1-1	Direct	ITC -> OPP	0.201	2.950	0.003**		
H1-2		ITC -> FNP	0.121	2.207	0.027*		
H4-1	Indirect	ITC -> SCI -> OPP	0.337	7.864	0.000***	0.253	0.422
	Total	ITC -> SCI -> OPP	0.538	10.274	0.000***		
H4-2	indirect	ITC -> SCI -> FNP	0.327	8.196	0.000***	0.252	0.409
	Total	ITC -> SCI -> FNP	0.448	9.104	0.000***		

*Note: ITC IT competency, SCI supply chain integration, OPP operational performance, FNP financial performance. β = beta coefficient, T = t-statistics, CI = Confidential interval, P = Probability value, *** p < 0.001, ** p < 0.05, * p < 0.1, NS: Non-significant.*

Table 6-19 The outcomes of mediation analysis

Source: Author

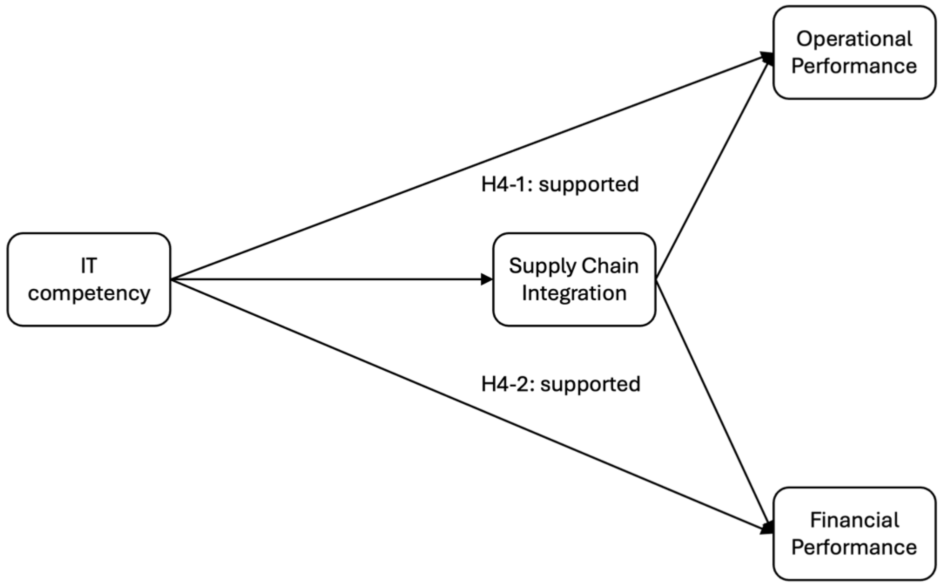


Figure 6-4 The impact of IT competency on operational performance and financial performance through supply chain integration (H4-1 and H4-2)

Source: Author

6.3.3.3 Conditional Mediation analysis

The final step in assessing the structural model involves verifying the significance of the moderating role of BCU. CoMe analysis was conducted followed by step by step procedure guided by Cheah et al. (2021). As discussed in Section 5.3.3, to test for the CoMe, it is first necessary to calculate the index (ω) corresponding to "p2･p5" in Figure 5-10. For Hypotheses 5-1 and 5-2, the CoMe analysis yields an index (ω) of 0.121 and 0.117 for the pathways BCU x ITC -> SCI -> OPP and BCU x ITC -> SCI -> FNP, respectively, based on the bootstrapped coefficient values obtained from bootstrapping (Table 6-20). Given that the index is significantly different from zero, it can be concluded that the mediated effect of IT competency on performance through SCI is contingent upon the level of blockchain utilisation.

Path	β	SE	T	P	CI 95%	
					Lower	Upper
BCU x ITC -> SCI -> OPP	0.121	0.034	3.519	0.000***	0.059	0.191
BCU x ITC -> SCI -> FNP	0.117	0.031	3.825	0.000***	0.061	0.180

*Note: ITC IT competency, SCI supply chain integration, BCU blockchain utilisation, OPP operational performance, FNP financial performance. β = beta coefficient, T = t-statistics, CI = Confidential interval, P = Probability value, *** p < 0.001, ** p < 0.05, * p < 0.1, NS: Non-significant.*

Table 6-20 Outcomes of moderating analysis

Source: Author

Next, in order to examine the mediated effect at different levels of the moderating variable, the standard deviation of the moderator BCU was calculated. Subsequently, 10,000 path coefficients from all direct effects of BCU, corresponding to "p5" in Figure 5-10, generated through bootstrap sampling, are inserted into equations 1-5 from section 5.3.3. moderating valuable (BCU)'s SD.

The outcomes of these calculations are summarised in Table 6-21. The coefficient for the CoMe effect was notably stronger for high BCU in hypothesis H5-1 ($\beta = .456$, $t = 6.697$, $p < 0.000$) compared to low BCU ($\beta = .215$, $t = 5.482$, $p < 0.000$). Similarly, hypothesis H5-2 demonstrated a greater effect for high BCU ($\beta = .443$, $t = 7.236$, $p < 0.000$) over low BCU ($\beta = .209$, $t = 5.256$, $p < 0.000$). Both effects were statistically significant, as indicated by the positive lower bounds of the confidence intervals, thus supporting hypotheses H5-1 and H5-2.

Hypothesis	Path		β	T	CI 95%		P	Outcome
					Lower	Upper		
H5-1		index	0.121	3.528	0.068	0.178	***	Supported

	BCU X ITC -> SCI -> OPP	SD -1	0.215	5.482	0.150	0.290	***	
		SD 0	0.335	7.692	0.265	0.409	***	
		SD +1	0.456	6.697	0.349	0.572	***	
H5-2	BCU X ITC -> SCI -> FNP	index	0.117	3.724	0.068	0.169	***	Supported
		SD -1	0.209	5.256	0.145	0.277	***	
		SD 0	0.326	7.983	0.261	0.395	***	
		SD +1	0.443	7.236	0.346	0.549	***	

*Note: ITC IT competency, SCI supply chain integration, BCU blockchain utilisation, OPP operational performance, FNP financial performance. β = beta coefficient, T = t-statistics, CI = Confidential interval, P = Probability value, *** p < 0.001, ** p < 0.05, * p < 0.1, NS: Non-significant.*

Table 6-21 Outcomes of Conditional Mediation analysis

Source: Author

The graphical representation of these results is illustrated using the Johnson-Neyman technique and simple slopes analysis (Preacher et al. 2007). The moderating role of blockchain utilisation has been verified, indicating that the positive relationship between IT competency and SCI becomes more distinct at higher levels of BCU (defined as +1 SD above the mean) compared to lower levels (defined as -1 SD below the mean). This variation is depicted in the plot in Figure 6-5. The results of the CoMe analysis demonstrate that BCU significantly moderates the mediating relationship between IT competency and firm performance via SCI. In contrast to a simple moderation analysis, which examines whether the strength or direction of a direct relationship varies by levels of a moderator, CoMe analysis provides a more nuanced view by assessing how the indirect effect of IT competency on performance through SCI changes across different levels of BCU. Statistically, the analysis reveals that the indirect effect of IT competency on performance mediated by SCI is significantly stronger when BCU is high, as evidenced by a steeper slope and greater effect size at higher levels of BCU. On the other hand, when BCU is low, the mediating effect of SCI weakens, indicating that the ability of IT competency to facilitate supply chain integration is contingent on the extent to which blockchain technologies are embedded in organisational operations and ultimately influence performance. The results implicitly suggest that an increased level of blockchain utilisation amplifies the influence of IT competency on SCI more than at reduced levels of utilisation. The outcomes of moderation analysis are presented in Figure 6-6.

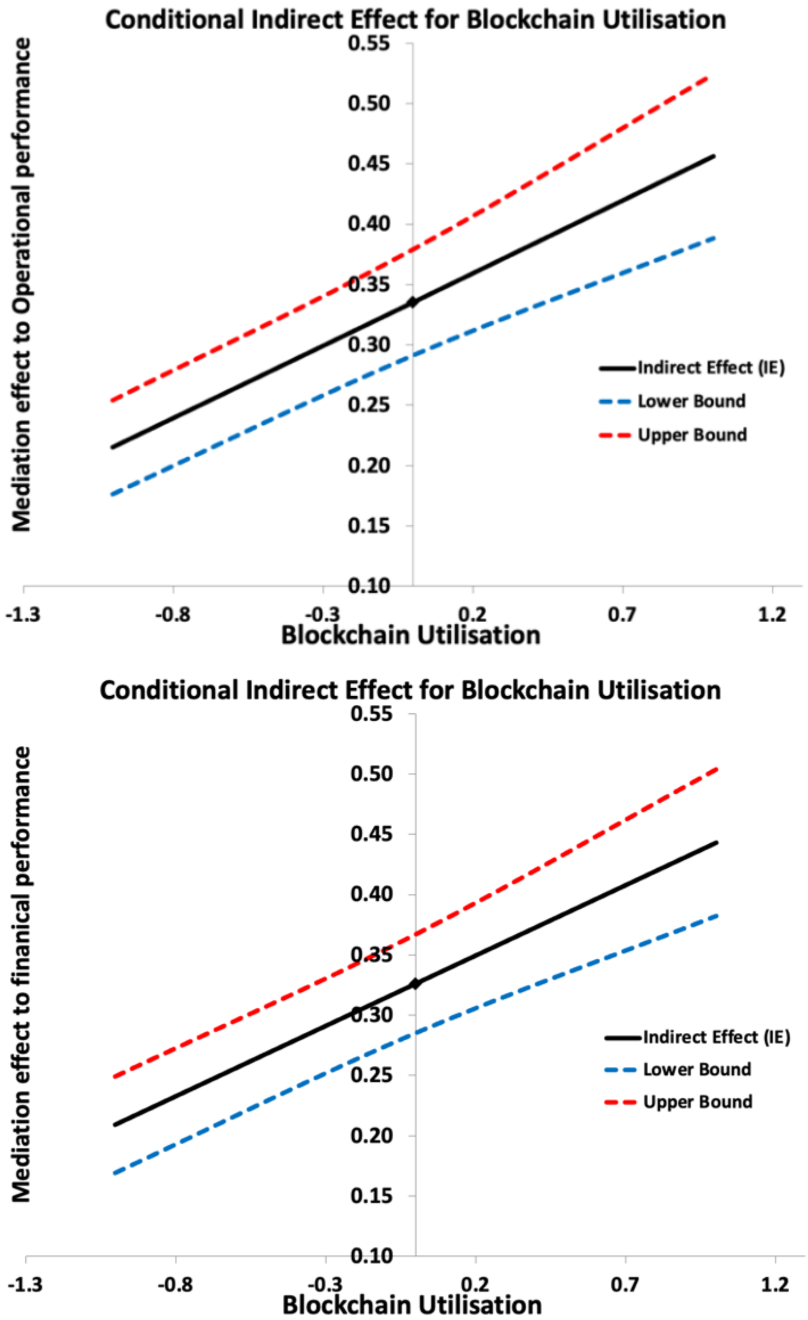


Figure 6-5 CoMe effect plots

Source: Author

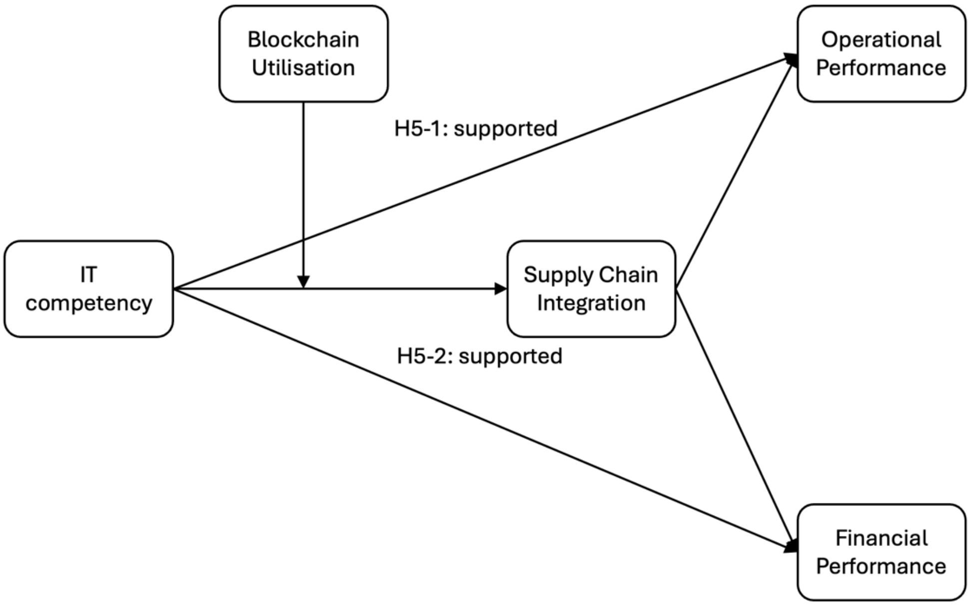
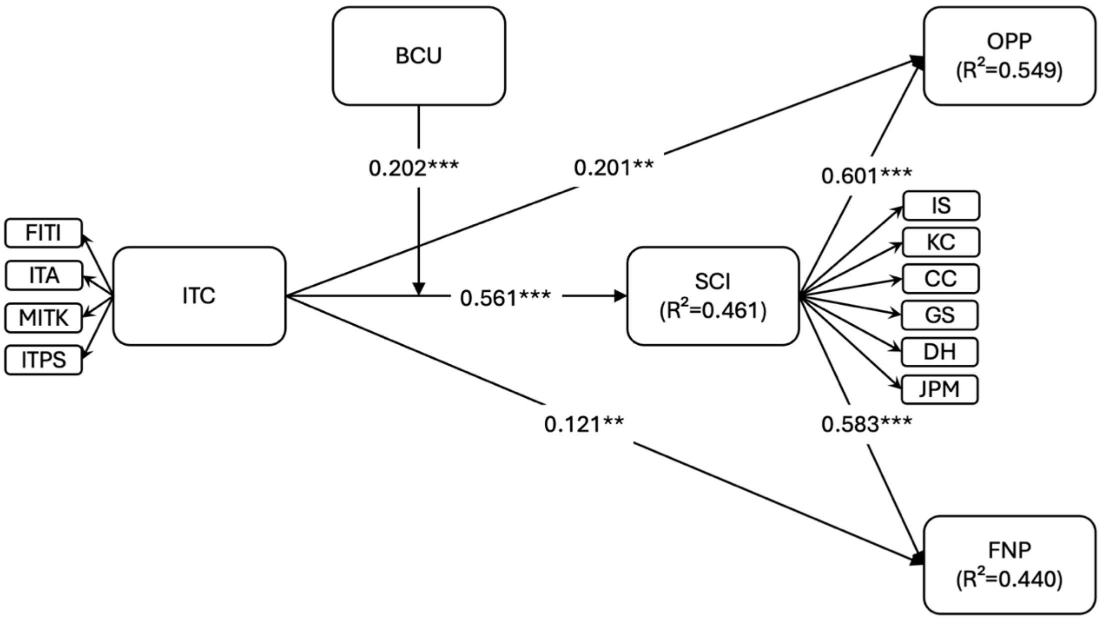


Figure 6-6 The moderating impact of blockchain utilisation (H5-1 and H5-2)

Source: Author

The hypothesis test results of structural model are illustrated in Figure 6-7



*Note: ***p<0.001, **p<0.05, *p<0.,1 NS: Non-significant*

Figure 6-7 results of path analysis

Source: Author

The empirical analysis of the structural model was conducted to derive results aligned with the research objective. Hypotheses 1 through 5 in the structural model examined the relationships between IT competency and its direct impacts on SCI, operational performance, and financial performance. Theses hypotheses also address the effects of SCI on both operational and financial performance, as well as the mediating roles among IT competency, SCI, and performance outcomes. Additionally, the model evaluated the moderating effect of BCU on the relationship between IT competency and SCI, and its subsequent influence on the overall model including performance variables. Through this analytical process, the research objective to verify the impact of the introduction and utilisation of BCT in the maritime industry on facilitating SCI strategies was successfully addressed. The overall findings suggest that maritime organisations with high levels of IT competency are more capable of facilitating SCI, which in turn leads to improved performance. Furthermore, the utilisation of BCT was shown to strengthen the relationship between IT competency and SCI, thereby enhancing SCI and ultimately contributing positively to both operational and financial performance.

6.4 Summary

This chapter presented a nonresponse bias and common method bias test, descriptive analysis of the background of the respondents and their organisations, as well as a descriptive statistical analysis of the data sample, followed by an empirical analysis conducted using the PLS-SEM method to test the hypotheses. Initially, through descriptive analysis, it was possible to ascertain that the data sample was appropriately targeted at a population that is relevant for studying SCI, IT competency, performance, and the utilisation of blockchain in maritime organisations. The results of the descriptive analysis revealed that data was obtained from staff at all levels who are involved in SCI and IT-related tasks within core operators of the maritime supply chain, including shipping liners, freight forwarders, terminal operators, and port authorities from various nationalities.

Subsequently, the descriptive statistical analysis provided insights into the mean and standard deviation of the responses for each item.

Finally, to validate the hypotheses, a screening process for missing values, outliers, and normality of the data sample was conducted, after which the measurement model was assessed, followed by the evaluation of the structural model. The measurement model was established through tests of reliability and validity, and the structural model for hypothesis testing was developed after the establishment process of the high-order construct. The structural model was evaluated in terms of direct impact for hypotheses H1 through H3, indirect impact for H4, and moderated mediation effect, referred to as the CoMe impact, for H5. The testing of direct relationships between ITC, SCI, OPP, and FNP supported H1-1, H1-2, H2, H3-1, and H3-2 as all were found to be significant and positive. The indirect influence of SCI on the relationship between IT competency and performance was confirmed as significant for both indirect and direct effects, thus supporting H4 by confirming the presence of a complimentary indirect impact. Lastly, a CoMe analysis was conducted to examine the moderating role of BCU. For the validation of the CoMe model, the moderating path coefficient was tested using bootstrapping technique, and the changes in the mediation model with different levels of the moderator, based on the standard deviation of the moderator, were found to be significant.

Chapter 7 Discussion and Conclusion

This final chapter consolidates the findings of the entire research and provides a discussion on them. Initially, the chapter presents a summary of how the research was conducted to answer the research questions, which are developed in order to achieve the study's objectives. Following this, the chapter discusses the findings of the study from the empirical analysis. The discussion explores the conclusions reached through the research findings, offering insights into the study's implications and contributions. Moreover, by acknowledging the limitations addressed by this research, the chapter suggests spaces for improvement and future directions for subsequent studies.

7.1 Summary of the study

SCI has become a core strategy for maritime organisations aiming to enhance the productivity, efficiency, and performance of supply chain operations, particularly in response to the traditional complexities and inefficiencies stemming from incompatibility between individual systems within the maritime industry. The adoption of BCT, a transparent and secure database technology, has been pursued to facilitate SCI by addressing those issues, leading to various stakeholders in the maritime industry developing and applying blockchain-based solutions in recent years. Despite the trend towards blockchain applications in maritime contexts and the numerous studies conducted on the topic, most research has remained at a conceptual level, focusing on the characteristics, potential applications, and future impact of BCT. Our initial intention was to move beyond the conceptual level of BCT adoption and examine the actual impact of BCT on the efficiency and performance of maritime supply chain integration. The overarching aim of this research is *to provide empirical evidence on the effectiveness of BCT in facilitating SCI strategies for maritime organisations, grounded in their IT competency.* This study was conducted to validate the empirical effects of BCT on SCI within the maritime industry. This study is a process to answer the following research questions.

RQ1. *How can the stakeholders, scopes and activities of maritime supply chain integration be clarified and what is the role of IT competency on maritime supply chain integration and performance?*

RQ2. *What are the key domains and application factors to consider when applicating blockchain technology for maritime supply chain integration?*

RQ3. *How does IT competency impact on supply chain performance through the mediating effect of SCI within maritime organisations?*

RQ4. *How does blockchain technology utilisation moderate the relationship between IT competency and supply chain integration within in maritime organisations, and what is the impact of this moderating effect on performance?*

Figure 7-1 depicts a research framework that illustrates how the research questions were addressed in this study. RQ1 aimed to conceptualise SCI, IT competency and supply chain performance in the context of maritime supply chain through a literature review, and to examine the direct relationships among these concepts. To answer RQ2, a systematic literature review method was employed to investigate the application of BCT for maritime SCI. RQ3 investigated the mediating effects of SCI across all constructs and RQ4 assessed the impact of BCT utilisations on the finalised model using PLS-SEM and the CoMe analysis technique.

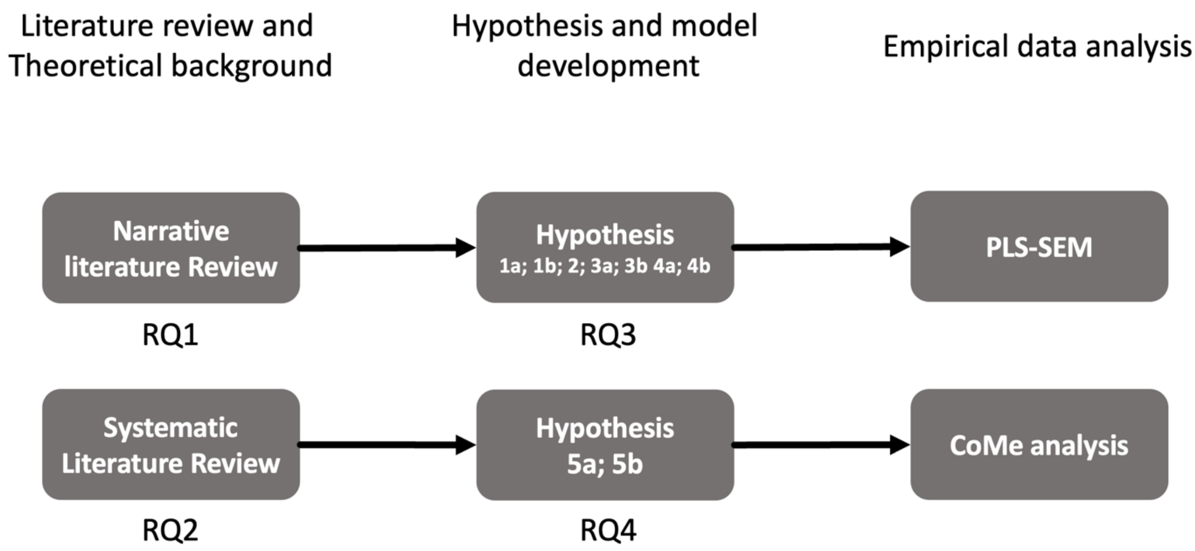


Figure 7-1 Research framework

Source: Author

In Chapter 2, a literature review was conducted to explore the theoretical background of the key concepts of this research: maritime supply chain integration and the application of BCT to the maritime supply chain for the integration. Additionally, this chapter aimed to clarify the research gap. This chapter provided a clear definition and scope for the relatively undefined concepts of maritime supply chain management and integration. Specifically, the application of BCT to maritime SCI was investigated using a systematic literature review method to identify the domains of application, roles, benefits, and impacts based on academic resources and practical cases. This stage of the study not only facilitated a deeper understanding of the concepts of Maritime SCI and BCT but also supported to clarify the research gap that this study addresses.

In Chapter 3, the focus was placed on establishing a theoretical framework to understand the impact of the relationship between SCI and the utilisation of BCT based on organisation's IT competency on performance. BCT, as an innovative information technology, its utilisation is influenced by the extent to which an organisation's IT competency, a core resource and capability, is established. Through the RBV lens, this study acknowledges IT competency and SCI as resources that can contribute to an organisation's sustainable competitive advantage, anticipating a positive relationship with performance. Furthermore, from the perspective of the value chain, it establishes the relationship that IT-related supportive activities can assist the primary activities of SCI, thereby contributing to the enhancement of performance.

In Chapter 4, based on the established theoretical background, hypotheses were formulated and a conceptual model was developed. Precise definitions were provided for the constructs of IT competency, SCI, performance (operational and financial), and BCT, as investigated in the previous chapters. Based on the relationships between these constructs, five main hypotheses were developed. Additionally, measurements constituting the variables were identified in accordance with the definitions of the constructs.

In Chapter 5, the research methodology for hypothesis testing was explored. This chapter described the approach taken by the study to achieve its research objectives through the research design process, specifying the adoption of data collection and analysis methods. The research adopted a quantitative method using surveys, guided by a deductive approach within the philosophical lens of objective positivism. Based on the methodological background, an appropriate sample and questionnaire were designed, and the PLS-SEM Technique was chosen to verify the relationships between constructs established by the hypotheses. Additionally, to consider the moderating impact of BCT, the CoMe was also incorporated.

Chapter 6 presented the process and results of the descriptive analysis of the collected sample and the empirical data analysis. Through nonresponse and common method bias tests, it has been confirmed that there are no issues with bias in the questionnaire data. An analysis of the characteristics of the respondents ensured that the data was well-distributed to achieve the research objectives, and it was determined that the respondents' answers were statistically appropriate for the analysis. PLS-SEM was conducted to test the five hypotheses (with a total of nine sub-hypotheses), and based on acceptable measurement assessment results, all nine hypotheses were confirmed to be significantly supported.

Lastly, a CoMe analysis was conducted to confirm the moderating impact of BCU. This examined how the introduction and utilisation of BCT influences the relationship between IT competency and SCI enhancement in maritime entities thus impacts on performance. The analysis indicated that the effect of IT competency on SCI was more determined with higher levels of BCU utilisation. Consequently, this was found to have a positive impact on both operational and financial performance. Table 7-1 summarises these findings.

Hypothesis	Impact path	result
H1a	ITC -> OPP	Supported
H1b	ITC -> FNP	Supported
H2	ITC -> SCI	Supported
H3a	SCI -> OPP	Supported
H3b	SCI -> FNP	Supported
H4a	ITC -> SCI -> OPP	Supported
H4b	ITC -> SCI -> FNP	Supported
H5a	BCU x ITC -> SCI -> OPP	Supported
H5b	BCU x ITC -> SCI -> FNP	Supported

Table 7-1 Summary of the hypothesis result
Source: Author

7.2 Research findings and discussion

The entire process of this research is aimed at answering the RQs, and the answers to questions RQ1 through RQ4 constitute the findings of the research. These findings serve as the basis for discussing the theoretical and practical implications.

7.2.1 RQ1. Maritime supply chain integration, IT competency, and performance

RQ1 serves as the first question leading into the remaining three questions, and the response to this question is designed to solidify the foundation of the entire study. Therefore, the process of answering RQ1 begins at a theoretical and conceptual stage. In the initial phase of this research, it is essential to clarify the concept of the maritime supply chain and the antecedent of integration. As the concept of logistics has expanded to encompass supply chains, it now refers to the comprehensive management from the supplier's production to the end customer. However, despite frequent mentions in related research, the maritime supply chain has often been left undefined or inadequately defined from a manufacturing perspective. In prior studies, the term “maritime supply chain” has often been used without a clear definition and has been interchangeably applied with concepts such as maritime logistics or transportation (Ascencio et al. 2014a; Seo et al. 2016; Wendler-Bosco and Nicholson 2020). Some researchers have simply adopted the traditional SCM concepts from the manufacturing discipline to maritime logistics (Tseng and Liao 2015; Osobajo et al. 2021; Liu et al. 2023), while others have described the maritime supply chain from the perspective of specific stakeholders, particularly ports (Lam 2011; Seo et al. 2015; Hussein and Song 2024). This study endeavours to clearly establish the scope and relationships between stakeholders within the maritime supply chain. By applying the concept of a service supply chain, the relationships among stakeholders in the maritime supply chain are identified in the structure of suppliers, focal companies, and customers. The maritime supply chain consists of key members such as shipping liners, port/terminal operators, and freight forwarders, by each organisation defining itself as a focal company and establishing its own supplier and customer relationships. When shipping liners are the focal companies, terminal operators act as suppliers by providing loading/unloading services, while freight forwarders are customers who receive cargo transportation information. Conversely, when terminal operators are the focal companies, both shipping liners and freight forwarders are considered customers who utilise the terminal's services. Lastly, when freight forwarders serve focal companies, shipping liners and terminal operators become suppliers that provide transportation and loading/unloading information.

Three antecedents for integrating the defined maritime supply chain were presented: information and communication, operational coordination, and strategic alliance. These three elements were detailed as constructs in the research model, comprising six dimensions: Information Sharing (IS), Collaborative Communication (CC), Knowledge Creation (KC), Decision Harmonisation (DH), Goal Similarity (GS), and Joint Performance Measurement (JPM), as theoretically established through a literature review. This indicates that to strengthen the integration of the maritime supply chain, information sharing and communication among stakeholders must be collaborative, and there must be a shared vision and joint movement towards common goals, with the ability to share performance outcomes. Through the lens of the RBV, SCI as an organisational capability is recognised as a crucial resource for achieving a sustainable competitive advantage. Therefore, it has been theoretically established that the higher the level of SCI, the more positive the impact on the enhancement of organisational performance.

The integration of the maritime supply chain can be further facilitated by maintaining frequent connectivity among supply chain members, for which the role of IT resources is critical. Competitive IT resources are considered as a key enabler for achieving sustainable competitive advantage from the RBV approach. IT competency consists of theoretical elements such as IT knowledge, IT operations, and IT objectives. IT knowledge refers to the appropriate actions and rules that dictate how IT systems are utilised and how to bring about the desired outcomes. IT operations represent the capability to manage and utilise IT resources in a way that generates greater value, functioning as the operational aspect of IT. Finally, IT objectives are comprised of the tools used for producing, processing, storing, and disseminating information. These components are embodied in four constructs: Flexible IT Infrastructure (FITI), IT Assimilation (ITA), Managerial IT Knowledge (MITK), and IT Personnel Skills (ITPS). This suggests that if an organisation can flexibly operate a well-equipped IT infrastructure, internalise IT resources based on managers' understanding of IT, and be supported by employees' IT-related skills, it can achieve a sustainable competitive advantage and contribute to the enhancement of organisational performance.

To define the relationship between IT competency and SCI, the value chain approach, a theory that explicates the activities necessary for an organisation to achieve a competitive advantage, was applied. IT-related activities serve as a support for management's primary activities aimed at integrating the supply chain. An organisation with strong IT competency can effectively leverage its IT capabilities to enhance SCI, thereby demonstrating a positive relationship between IT competency and SCI. As a result, RQ1 is addressed by firstly, defining the scope of the maritime supply chain and the relationships between stakeholders, and theoretically verifying the performance improvements through integration. Furthermore, by conceptualising the organisation's IT competency as a resource for the competitive advantage, the relationship between IT competency and performance is established theoretically. Lastly, the IT competency is suggested to play a supportive role in promoting SCI.

In addition, the measurement model for the performance of the maritime supply chain was established, with IT competency and SCI as the key resources aimed at achieving ultimate success. Performance was conceptualised with two constructs: operational aspects of the supply chain and traditional financial aspects. Financial performance was constructed with accounting-based and market-based metrics.

7.2.2 RQ2. Blockchain technology application for maritime supply chain integration

The second question is intended to deepen the understanding of BCT applications for integrating the maritime supply chain. Answering this question allows for an explanation of how BCT is applied across different areas of the maritime supply chain and the which influence it has. This establishes the theoretical foundation to achieve the empirical influence of BCT on maritime SCI, aligning with the research's objective. The three main domain is identified through the systematic literature review with academic sources and practical evidence of 22 cases: document management, transaction management, and cargo/terminal/vessel operations. In the document management domain, BCT facilitates the digitalisation of documents. Documents are securely and transparently managed within the BCT database and are updated in real-time. Additionally, the BCT platform enforces the use of standardised document formats, enhancing compatibility among various partners which have used individual systems. In the second domain, BCT has been utilised to manage transactions in the maritime supply chain by the nature of immutability of data. Within a BCT solution, transactions are automatically processed through a decentralised network based on the consensus of participants. Transactions are placed on the standardised and shared platform. Lastly, in the domain of cargo, terminal, and vessel operations, BCT has been adopted for the management of cargo and the optimisation of terminal operations, as well as the management of vessel data. Furthermore, BCT database integrates with other innovative technologies such as IoT to manage data from various sources.

The main benefits of BCT in the maritime supply chain include improving process efficiency and enhancing the security and transparency of related information. BCT also strengthens trust among stakeholders and enables the sharing of information that is trackable and traceable in real-time. All processes are represented in a unified format on the BCT-based platform. The outcomes of the systematic literature review provided insights into how BCT, as an innovative IT resource, facilitates SCI in the maritime industry. While previous literatures on BCT in the maritime supply chain has largely remained at a general conceptual level, with a primary focus on technological aspects, this study advances the field by addressing the research question in a more structured and applied manner. By systematically conceptualising BCT within the maritime supply chain drawing on both academic and practical resources, and elaborating its impact on SCI, this thesis extends existing literature and provides a more nuanced understanding of BCT's strategic role.

7.2.3 RQ3. Hypothesis testing: direct and indirect effect

RQ3 aims to statistically validate the relationships between IT competency, SCI, and Performance based on the theoretical background established in RQ1. Hypotheses 1 through 3 examine the direct relationships between IT competency, SCI, and performance. H1a and H1b tested the relationship between IT competency and operational and financial performance, respectively, while H2 examines the relationship between IT competency and SCI. H3a and H3b are concerned with the relationships between SCI and operational and financial performance, respectively, and these were tested using the PLS-SEM technique.

The analysis of the structural model supported that all proposed direct relationships are statistically positively significant. The outcomes of H1a and H1b revealed that strong IT competency is positively associated with improved operational performance as well as financial performance within the maritime supply chain. Theoretically, the positive impact of IT on enhancing organisational performance through achieving a competitive advantage has been validated by prior studies (Tippins and Sohi 2003). However, there are studies that have reported results contrary to the positive relationship between IT and performance (Ray et al. 2005; Li et al. 2009; Sabherwal and Jeyaraj 2015; Kim 2017). The results of this study are significant, whereas the relatively high p-values (.05 for H1a and .1 for H1b) and low beta coefficients (.202 for H1a and .121 for H1b) could be interpreted as reflecting this contrary perspective. According to Tippins and Sohi (2003), such issues may arise when research focuses on the influence of specific types of technology, or when the effects of IT are an indirect effect due to the leverage of mediators that precede performance enhancement (Bryan Jean et al. 2008). Reflecting this, the current study measured IT competency through multiple dimensions, and the indirect effects were tested through hypothesis 4. The findings from H2 testing indicated that organisations with higher IT competency tend to exhibit a higher degree of SCI. Organisations with high IT competency have been statistically proven to strengthen SCI by enhancing collaboration and communication within the supply chain (Sanders and Premus 2005; Sanders 2008; Vanpoucke et al. 2017; Yu et al. 2021). Furthermore, the result from test of H3a and H3b confirmed that maritime organisations with higher levels of SCI achieve better overall performance. The relationship between SCI and performance has been established in prior research (Prajogo and Olhager 2012). However, within the context of the maritime supply chain, majority of studies have predominantly examined the impact of SCI on performance with a focus on specific stakeholders such as port and shipping carrier (Panayides and Song 2008; Woo 2010; Seo et al. 2016; Yuen and Thai 2017c; Han 2018; Yuen et al. 2019). On the other hand, the importance of this study lies in its verification of the SCI-performance relationship across the entire scope of the maritime supply chain, building on the concept identified in RQ1.

As previously mentioned, studies in IT have shown that the relationship between IT competency and performance is more significant and stronger when relationship is indirect rather than direct. To verify the indirect impact of SCI as a mediator in the effect of IT competency on performance enhancement, a mediating model analysis was performed through H4a and H4b. The indirect effects were found to be mediated by SCI on both operational and financial performance. This confirmed that maritime organisations with established IT competency could strengthen SCI, which in turn significantly impacts the enhancement of both operational and financial performance. In other words, IT competency has a stronger impact on operational and financial performance when it is aligned with the SCI strategies and capabilities of maritime organisations, rather than having a direct effect on performance enhancement (Wu et al. 2006; Kim 2017; Vanpoucke et al. 2017; Yu et al. 2021).

7.2.4 RQ4. Hypothesis testing: moderating effect

The final research question, RQ4, aims to examine the changes in the indirect effect relationship of IT competency on performance through the mediating effect of SCI, as confirmed in the answer to RQ3, under the condition of the moderating variable, which is the utilisation of BCT. Based on the answers obtained from RQ2, H5a and H5b were tested to validate whether the benefits and impact of BCT in strengthening SCI within each domain of the maritime supply chain are statistically significant in practical aspect. The existing mediation model was extended to track changes in the model according to the detailed conditions of the moderator through a CoMe analysis, whereby hypotheses H5a and H5b were examined. The results indicated that when BCU intervenes in the enhancement of SCI by IT competency, the greater the degree of BCU, the stronger the relationship between an organisation's IT competency and SCI, ultimately enhancing performance. This confirmed that when maritime organisations strengthen SCI based on robust IT competency, the utilisation of BCT can further enhance SCI, leading to improvements not only in operational performance but also in financial performance showing the moderating effect of BCT. This inference can be supported by previous studies. The characteristics of BCT, such as the visibility of real-time information, the traceability of transactions and cargo, and the enhancement of trust among partners, have a positive impact on the SCI process (Wang et al. 2019; Dutta et al. 2020; Liu et al. 2021). The results of the data analysis are significant as an empirical analysis of the characteristics of BCT, which were emphasised at the conceptual stage in prior research.

7.3 Implications

This study encompasses significant implications from both theoretical and practical perspectives. The theoretical implications of this study contribute to the field by redefining concepts, establishing a conceptual framework, and elaborating on the research model to advance the theory in the context of examining the impact of BCT adoption in maritime SCI. On the other hand, from a practical standpoint, this research provides insights for practitioners considering the adoption of BCT in the maritime supply chain.

7.3.1 Theoretical implications

The study primarily reconceptualises the maritime supply chain by redefining its constituents, delineating its scope, and re-examining the relationships among the participating entities. Building on this, the study presents a conceptual framework for the adoption of BCT into maritime SCI and provides theoretical elaboration through a model for empirical analysis as the implications.

7.3.1.1 Reconceptualisation of maritime supply chain

The first major theoretical implication in this study is that it has delineated the concept of the maritime supply chain through a comprehensive review. It has been observed that previous conceptual research on the maritime supply chain lacked a precise articulation of its scope and components. For example, Panayides (2006) described the maritime supply chain as integrated liner shipping logistics which provides end-to-end delivery service. Lam (2011) described the maritime supply chain as having vertical relationships between shipping lines and ports in the chain, connected as customers-suppliers, while Lam (2013) focused on the integration of supply chain in maritime on the service activities of shipping liners. Studies by Lin et al. (2014) and Lin et al. (2021) determined the main stakeholders in the maritime logistics network as shipping carriers, freight forwarders, port operators, and cargo owners through interviews with professionals from maritime organisations, presenting the concept of maritime logistics focusing on the closeness of relationships based on contract types, service varieties, and forms of cargo transport. Wendler-Bosco and Nicholson (2020) suggested precise categorisation of the relevant stakeholders under the concept of the maritime transportation supply chain. In empirical research targeting maritime logistics or maritime supply chain, the scope of the study is often limited to specific stakeholders (Yuen and Thai 2017a).

The representative studies cited for the definition of maritime logistics and supply chain have applied the concepts of supply chain management and integration from manufacturing field to maritime and shipping logistics (Song and Panayides 2008; Tseng and Liao 2015; Wan et al. 2019). However, these concepts are used interchangeably with the terminology of maritime transportation, logistics management, and integration leading significant to a tendency not to distinguish them theoretically in the other publications (Lam 2011; Ascencio et al. 2014a; Yuen et al. 2019; Osobajo et al. 2021). Particularly when maritime research incorporates the concept of SCI, it has frequently been applied without considering the conventional supply chain management relationships among suppliers, focal firms, and customers. In other words, if the interrelationships among maritime stakeholders are properly conceptualised and structured, recognising the roles of suppliers, focal companies, and customers rather than merely listing them, this will enable the application of theoretical constructs from supply chain management and integration research—such as dimensions, layers, and structures—to the integration of maritime supply chains. This research attempts to re-establish the relationships among members of the maritime supply chain by employing the concept of the service supply chain. Rather than placing on a single focal company in a supply chain, the research presents a structure based on the relationships where each stakeholder acts as a service provider in a focal position, with other partners shifting roles between suppliers or customers. Therefore, this study makes a theoretical contribution by exploring and providing solutions on how to transplant the fundamental meanings of logistics, supply chain management, and supply chain integration into maritime logistics.

7.3.1.2 Conceptual framework of BCT adoption in maritime SCI

Secondly, this study contributes theoretically to the developing literature on BCT adoption and utilisation in the maritime supply chain management. Through a systematic literature review of academic and practical sources, the research presented a conceptual framework that facilitates the understanding of the phenomenon of BCT adoption in maritime SCI and provides an interpretive approach to examine its implications. The purpose of this framework is to classify the application domains of BCT within the maritime supply chain process. Furthermore, the framework illustrates the functions BCT facilities in each domain, as well as the benefits the technology provides to maritime SCI and the relationships between these elements.

In other words, previous studies on the BCT in the maritime supply chain have discussed general concepts (Shirani 2018; Li and Zhou 2020; Zhou et al. 2020; Liu et al. 2021; Marenković et al. 2021). For example, the study by Li and Zhou was limited to summarising the functions and benefits of various BCT solutions in maritime logistics through case studies, while Yang's research utilised the Technology Acceptance Model (TAM) to present BCT application areas across the entire maritime supply chain and logistics process, however, lacked reflection of maritime-specific characteristics. The conceptual framework for BCT application in maritime proposed by Pu and Lam (2020) divided the elements into five dimensions: technical features, commercial benefits, applicable areas, stakeholders, and potential challenges of BCT adoption. However, the relationships among the various elements within these numerous dimensions indicate complex interconnections and result in redundant elements. On the other hand, the conceptual framework presented in this research structurally establishes the roles and influences of the characteristics of BCT. The framework of the study categorises application factors and benefits into categories and sub-categories, under the criterion of the application domain in the maritime supply chain. For example, in document management, BCT is utilised for digitising documents, real-time updates, document management, and document unification. In transaction management, it is used for decentralised, consensus mechanism-based automated transactions and platform standardisation. On the other hand, in cargo/terminal/vessel operations, it is employed for the management and tracking of information on cargo, ships, and port equipment operations.

Particularly, most of conceptual studies of BCT in the maritime supply chain have neglected the perspective on SCI, which is a critical aim of BCT adoption within the industry. The framework developed in this research not only identified BCT application factors in the maritime supply chain but also made an effort to incorporate the perspective of SCI. This ensures that the elements of SCI are interwoven with BCT components within the identified benefits. As a result, the framework provides insights into how BCT influences connections and communication within maritime supply chain, which are essential for the effective implementation of SCI. This framework is articulated in a manner that is straightforward and specific, offering a clear depiction of these factors and their benefits.

In addition, the framework is the result of a systematic analysis that consolidates evidence from both academic research and practical applications. Therefore, future research on the phenomenon of BCT adoption and utilisation in maritime SCI will be able to focus on the nuanced impacts and effects, contributing to an organised analysis that enhances the coherence of empirical investigations but also enriches the theoretical understanding of the field (Hudon et al. 2015).

7.3.1.4 Theory elaboration with empirical evidence from the model testing

From the perspective of theory elaboration, this research contributes to theoretical advancement by refining existing research models as an extension of grounded theory and deductive approaches, thereby improving existing theories (Fisher and Aguinis 2017). By providing more precise definitions and distinctions of constructs than those found in the original theory, the study reduces confusion and ambiguity in the model's ability to explain and predict phenomena. This research developed a research model that applies the existing RBV theory's validation of the relationship between resources and performance to the phenomenon of the maritime supply chain facilitated by IT competency. This approach strengthens construct validity and, consequently, the overall utility of the theory in empirical research and practical applications by extending the scope of existing construct. Particularly from a structuring perspective that focuses on identifying previously unrecognised relationships, this study has achieved theoretical elaboration by adding mediation and moderation to the relationships between existing constructs (Fisher and Aguinis 2017). From this perspective, this study extends the research model by incorporating the value chain approach into the existing RBV framework of the relationship between IT competency and performance, including SCI as a mediating variable, and examining the moderating effect of the application of a new technology, BCT.

This study utilised existing RBV theory as a basis to examine how maritime supply chain organisations can enhance integration among partners and stakeholders within the chain by attaining IT competency. The empirical analysis model identified and described constructs to investigate the influence of BCT utilisation on performance, indicating the mediated moderating effect of BCT on the relationship between IT competency and SCI. The research model aims to verify the role of IT competency as a strategic resource that enables higher levels of SCI and improved performance outcomes through the effective use of BCT. The interrelationships of IT competency, SCI, and organisational performance has been a prominent theme in past research on supply chain management. The significance of this study lies in its application of the RBV approach and the value-chain model to the maritime and shipping sectors of the supply chain, thus reinforcing and affirming the current theoretical frameworks. This study validated whether the IT competency as a resource can support organisational capabilities which is SCI, leading to a sustainable competitive advantage in performance. This contributes to the expansion of the scope of RBV theory within the context of maritime supply chain management. Furthermore, the study verified the empirical influence of BCT impact factors, which were developed from a conceptual framework based on systematic literature, thus grounding the theoretical model in practical evidence.

While IT is acknowledged as a vital resource for achieving a competitive advantage, the direct effects of IT on performance have been debated. Studies by Li et al. (2009) on IT implementation and Devaraj et al. (2007) on eBusiness have not been able to prove a direct connection between IT and performance. This research confirms that in the context of the Fourth Industrial Revolution, IT competency is an essential resource that not only has a direct impact on an organisation's SCI and performance but also amplify its impact through indirect effects. This is consistent with previous studies that applied the theoretical lens of the RBV to highlight the mediating role of SCI in the IT-performance relationship, as demonstrated by Sanders and Premus (2005), Liu et al. (2016) and Sundram et al. (2020). In the digital-driven integration of the maritime supply chain, it is anticipated that improving performance through SCI, with the support of IT will be more advantageous than focusing solely on the investment of IT competency.

In addition, this research contributes to the growing body of knowledge on BCT within the field of maritime supply chain management by offering empirical evidence. The findings suggest that BCT's application plays a moderating role in the dynamics between IT competency and SCI, which in turn enhances the performance of maritime supply chain organisations. The CoMe model introduced in this research offers a more detailed insights than what is typically provided by mediation or moderation models when used separately. Validating a complex model allows to facilitate a richer interpretation of the data. The originality of this study apart from previous BCT research, which often considered SCI as a mediating influence, is its approach to BCT. Prior studies have treated BCT as an independent variable, employing metrics that encompasses the characteristic of BCT as a type of IT (Kim and Shin 2019; Khalil et al. 2022). In contrast, this study lays a stronger grounded theory by positioning a firm's IT competency as the independent variable and BCT as a moderating variable. This approach delineates the assessment of how supply chain operations adapt to technological advancements, focusing on maritime organisations in the supply chain with established IT competency and their use of BCT. This research contributes to a deeper comprehension of the functions of BCT in the maritime supply chain. Despite the active adoption of BCT in the maritime industry since 2017, the majority of studies to date have concentrated on conceptual and theoretical framework. There is a notable lack of empirical research examining the tangible outcomes of BCT implementation in the industry. This study fills this gap by providing fresh insight with empirical evidence. It underscores the profound influence of BCT utilisation on the interactions within the model presented, thereby establishing a solid foundation for subsequent inquiries in this domain.

7.3.2 Practical implications

This research is undoubtedly valuable for managers seeking to grasp the essential elements of adopting and leveraging BCT in the maritime and shipping sectors to enhance SCI. The maritime supply chain has seen a decline in profitability due to various factors, including the global economic depression, prompting stakeholders to focus on improving operational efficiency through strategical SCI. With the trend of the Fourth Industrial Revolution, the push for SCI is intensifying with the advent of innovative technologies and the convergence of industry boundaries. Maritime organisations are currently striving to optimise supply chain performance by developing their IT capabilities and competency and cultivating strong partnerships within the supply chain. As illustrated in the cases from the systematic literature review in the previous chapter, numerous maritime firms are investing in advanced solutions and working to bolster their IT competencies. The ultimate goal is to achieve efficient integration by fostering communication and information exchange among supply chain partners.

This study provides direction for the maritime industry regarding SCI. The logistics systems, including the maritime transportation, has evolved beyond mere cargo movement to become a value-added driven chain focused on meeting customer needs (Paixao and Marlow 2003). In the maritime industry, there has been a focused effort to meet the demand for end-to-end or door-to-door services. This involves implementing strategies to integrate the supply chain, with the goal of enhancing the efficiency and effectiveness of the maritime supply chain. In this context, the theoretical background and empirical analysis model presented by this research offer validated relationships between IT and SCI for stakeholders in the maritime supply chain to consider when employing SCI strategies. Modern SCI strategies are based on active data exchange and communication through innovative IT, fostering mutual relationships between partners to achieve efficient and effective operation of the entire supply chain. The model derived from this study validates the need for mediating effects based on multi-dimensional IT competencies to enhance performance through SCI with various components, which are essential to facilitate improvement. The higher-order constructs in the model suggest specific components on which managers should concentrate when operationalising and investing in IT competency and

SCI strategies within their organisations. These constructs indicate that IT competency can be secured through the flexibility of the firm's IT infrastructure, managerial support grounded in an understanding of IT, the ability to utilise and expand IT capabilities, and the competence of well-trained skilled staff. By leveraging these resources, maritime organisations may focus on enhancing communication and information sharing among supply chain partners, fostering knowledge creation, and setting common goals for harmonious collaboration, which are all pivotal components in the successful achievement of SCI strategies. The insights from this research suggest a strategic path for maritime supply chain stakeholders to leverage their IT capabilities, emphasising that maritime organisations should integrate their IT investments with SCI strategies, rather than investing IT or SCI separately. According to the proposed research model, if practitioners grasp the mediating effect of IT competency in enhancing performance through the use of SCI, they will have the more opportunity to optimise and maximise the outcomes.

This research carries implications for maritime organisation practitioners grappling with decision-making regarding the adoption and utilisation of BCT. The cases outcomes from a systematic literature review provide an overview of the objectives and roles of BCT solutions launched in the practical field, while the conceptual framework presented throughout the review assists in determining where to focus strategic management efforts in the implementation of BCT. Maritime practitioners are aware that BCT is emerging as a trend within the maritime and shipping industry, yet their understanding of the technology remains limited (Balci and Surucu-Balci 2021). The conceptual framework presented by the research provides a detailed account of how BCT is adopted and utilised for document management, transaction management, and cargo/terminal/vessel operations, as well as the impact and benefits it offers. In the conceptual framework, the divided domains present a detailed view of the expected impacts of BCT adoption for each stakeholder within the maritime supply chain. Shipping liners can anticipate the effects of BCT in document management, transaction management, and cargo/vessel operation sectors. As evidenced by the cases from the systematic literature review, shipping liners aim to adopt BCT for paperless documentation and information exchange and management on a standardised platform, taking a leading position in the initiative. From the perspective of terminal operators, there is an interest in the physical aspect of data management, indicating that if BCT adoption is considered, more investment will be required in terminal and cargo operations. As intermediaries connecting other stakeholders, freight forwarders need to focus on creating benefits through the adoption and utilisation of BCT in managing data, transaction and documents across all domains.

Given those perspectives from different stakeholders, this study conducted an empirical analysis targeting shipping liners, terminal operators, port authorities and freight forwarders within the integration of the maritime supply chain. As these three key entities have different functions they focus on, as explored in the literature review, it is expected that the anticipated roles and impacts regarding the adoption and utilisation of BCT will be distinct. Therefore, it is believed that there will be benefits to adopting a strategic stance focused on the uses of BCT as presented in the conceptual framework. Although BCT is applied across three domains within the maritime supply chain, these domains are fundamentally integrated, influencing the flow of the entire maritime supply chain. For managers of organisations contemplating the use of BCT in actual practice, this framework can facilitate an understanding of the applications and significance of adopting BCT and assist in making informed decisions about its strategic implementation.

Furthermore, this study presents the empirically verified moderating effect of BCT adoption on the impact of maritime supply chain organisations' IT competency on SCI. This interaction between IT competency and BCU suggests that BCT serve as a strategic enabler, enhancing the organisation’s ability to synchronise, trace, and secure information flows across the supply chain. This is particularly critical in the maritime industry, where fragmented systems and multi-party coordination present persistent challenges. The moderated mediation effect underscores the importance of considering digital infrastructure maturity when evaluating the performance outcomes of IT capabilities. In practice, the results imply that maritime organisations cannot rely on IT competency alone. Rather, the value of IT investment is significantly augmented when supported by active utilisation of blockchain-based platforms, which not only enhance overall performance but also plays a crucial role in facilitating SCI. BCT support seamless data exchange, improve visibility and traceability across partners, and thereby strengthen the integration of processes within the maritime supply chain. The findings suggest that BCT, when applied to document management, transaction management, and cargo/vessel/terminal operations, can accelerate the achievement of SCI strategies based on organisational IT competency. The analysis results are significant in that they provide evidence of the actual influence of the technology during the period when BCT was actively being adopted in the maritime industry. As a result, it is expected that guidelines will be provided to enable them to successfully achieve an integration strategy.

7.4 Limitations and Future research

This study provides valuable insights into how IT competency in maritime organisation facilitate SCI and performance, and the impact of BCT on this relationship, yet it also has several limitations. One notable limitation pertains to the methodology of questionnaire survey, specifically the use of nonprobability sampling and a convenience method. As discussed in Section 5.2.2, it is generally desirable to target a random population to ensure the generalisation of research findings. However, due to practical constraints such as time and cost, this research adopted a nonprobability convenience sampling method to collect data. The sample collected through this approach may not accurately represent the population, which implies that the research findings could be inherently biased. As a result, this limitation restricts the generalisability of the study’s outcome. In addition, this study, while addressing the adoption of BCT, which is emerging on a global scale, focused on respondents from organisations located in South

Korea, which may not meet international standards. Therefore, to enhance the degree of generalisation, future research should adopt a more rigorous sampling method, using probability sampling to include a wider range of organisations in the maritime industry. Building on this perspective, the fact that all hypotheses in a study are supported could be recognised as a space for considering the limitations of the research. Future studies may need to more rigorously manage the research design to ensure that confirmation bias is not leading the hypotheses to be supported in a way that aligns with the researcher's intentions, or to verify that the hypotheses are sufficiently challenging and not so obvious as to suggest a lack of rigor in the research. Alternatively, there is a need for a thorough examination to determine whether there are any important variables not considered that could have an impact on the research findings.

Secondly, the analysis in this research is based on a cross-sectional design. While cross-sectional studies can identify the state at the time of the survey and report the association levels of the research model, they entail challenges in distinguishing long-term and persistent effects and establishing clear causal relationships. Therefore, the current data only present a snapshot of the impact of BCT on the relationship between IT competency, SCI, and performance. This represents a diagnosis of the current state, leaving questions about consistence and making it challenging to identify precise causal links. To address this, future research could analyse longitudinal data collected over a certain period to identify causal relationships between variables and provide insights into whether the influence of BCT is sustained. Additionally, this study has limitations stemming from its adoption of an objectivistic positivism perspective. While this is meaningful for measuring and analysing observed objective phenomena, it may undervalue the interpretation based on understanding and insights that a qualitative approach provides. Consequently, there is a lack of perspective on how practitioners might acknowledge, interpret, and reflect the results of the model validation presented in this research in actual strategies. Future studies deploying methods such as in-depth follow-up interviews are considered to compensate for these limitations.

The reliance of this study's model on measurements from previous research can be pointed out as another limitation. The measurement tool of the study was based on prior related research that had already been validated for reliability and validity, therefore no issues with the current study's validity and reliability were identified. However, the possibility of missing important variables cannot be excluded due to the lack of reflection of opinions from current practitioners and experts when developing questionnaire items. In particular, the indicators for IT competency and performance were referenced from the literature on supply chain management, which may not have reflected the specificities of organisations in the maritime supply chain. Moreover, in terms of performance, this study used perception-based measurement tools instead of objective accounting data to measure operational and financial performance. To analyse performance more objectively, the survey questions should include performance indicators that are compared with industry averages or actual measurements. Reflecting this, as mentioned earlier, future research should consider using qualitative methods such as interviews to construct the measurement tool to reflect a broader and more practical perspective.

The influence of BCT is a central issue in this study. However, a limitation that must be overcome is the lack of certainty regarding the extent to which awareness and adoption of BCT have proliferated throughout the maritime supply chain. While systematic literature review has confirmed that the development and launch of blockchain solutions are becoming a major trend in the maritime industry, with a significant number of companies participating in these solutions, there is a possibility that the practitioners, who are the primary subjects of this research, may not fully understand the concept and mechanisms of BCT and how it differs from existing databases they are using. Efforts were made to address this limitation by adding explanations to the questionnaire survey and detailing the items, however, there remains a possibility that the impact of this emerging technology may not be fully captured. Therefore, future research should consider approaches that involve setting and analysing a population that can yield more practical and applicable data. This could include distinguishing between job task familiar with BCT concepts and usage or comparing companies that actively utilise BCT against those that do not.

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APPENDICES

APPENDIX A. THE SYSTEMATIC LITERATURE REVIEW PUBLISHED IN A JOURNAL

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ABSTRACT

This research aims to establish the link between blockchain technology adoption in the maritime and shipping industry and its impact on maritime supply chain integration via a systematic review of both the academic and practice literature. In total 148 articles were identified and analysed. Blockchain applications identified from the literature are categorized into three domains: document management, transaction management, and cargo/vessel/terminal operations. An analysis of the benefits and challenges that influence the deployment of blockchain technology for maritime supply chain integration leads to the development of an integrated and extended Technology, Organization, and Environment (TOE) framework. This study is among the first to examine the current state of blockchain diffusion within the maritime supply chain, making a significant contribution to the field. The extended TOE framework offers guidance for future research and understanding of the relationship between blockchain adoption and maritime supply chain integration. It can be used to assist organisations in successfully adopting blockchain technology in their supply chain operations.

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Blockchain; distributed ledger technology, maritime; shipping; supply chain integration; supply chain; TOE framework

1. Introduction

Increasing competition, reducing freight earnings and frequent supply chain disruptions such as the COVID-19 pandemic are some of the greatest challenges the maritime and shipping industry has faced in recent years. These challenges drive supply chain partners to seek new ways to improve operational efficiency and value creation. Supply Chain Integration (SCI) in the maritime and shipping sector has become a predominant strategy in response to changing customer needs. Information and Communication Technology (ICT) is one of the most important elements for strengthening SCI. Advances in ICT have enabled firms to facilitate smooth and timely information sharing across the supply chain and thus collaborate effectively with supply chain partners. Real-time (or near_real time) data related to supply chain activities shared within supply chain partners contribute to efficient supply chain management and have a positive effect on performance.

In recent years, Blockchain Technology (BCT) has been identified as a potential solution to enable maritime SCI and improve efficiency in maritime logistics (Queiroz et al. 2019). Blockchain is a distributed ledger database for maintaining and tracking a permanent and immutable record of transaction data that has been executed, shared, replicated, maintained, and synchronised by participants in a decentralised network. According to Yaga et al. (2019, p. 12), blockchains can be defined as:

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> . . . .distributed digital ledgers of cryptographically signed transactions that are grouped into blocks. Each block is cryptographically linked to the previous one (making it tamper evident) after validation and undergoing a consensus decision. As new blocks are added, older blocks become more difficult to modify (creating tamper resistance). New blocks are replicated across copies of the ledger within the network, and any conflicts are resolved automatically using established rules.

The data in a blockchain is managed by the participating entities without the involvement of central authorities. BCT allows information to be safely stored, utilised, and shared in a distributed ledger based on peer-to-peer networks linked by cryptographic hashes (Scott et al. 2017). Access rights differ between permissionless (public) and permissioned (private) blockchain networks. A permissionless blockchain network is open to anyone who can both read the blockchain and issue transactions without permission from a central authority, which requires substantial resource for maintenance. In a private blockchain, network users must be authorised by a specific authority to publish blocks so that they are identifiable. Since each joined entity plays a role in maintaining the blockchain in a decentralised manner, the network does not require the expense or maintenance of resources as is the case with a public blockchain network. Given these characteristics, a permissioned blockchain is normally set up by business organisations.

The complexities of maritime communication have a negative impact on transaction efficiency. For example, a single shipment transaction could involve 28 distinct parties and around 200 different document exchanges, resulting in time delays, human error, and miscommunication. When shared via blockchain, encrypted data can be made accessible to every participant, addressing issues of trust, product traceability, process optimisation, and coordination and communication.

One notable maritime SCI blockchain initiative is TradeLens, a secure data-sharing and collaboration blockchain-based platform initially developed by Maersk and IBM (2022b). This platform aims to integrate each party in the supply chain including traders, freight forwarders, inland transportation, ports and terminals, ocean carriers, and customs and other government authorities—in order to provide secure end-to-end services. TradeLens later became an independent and neutral platform. Another notable example is the Global Shipping Blockchain Network (GSBN) (2022a), set up by shipping carriers including COSCO and OOCL and global terminal operators including Hutchison Ports and PSA.

Notwithstanding the diffusion of BCT applications, academic research into BCT applications in the maritime and shipping industry is still in its infancy. While a wide range of literature has been published examining the current state of BCT applications in the supply chain, there has been far less consideration in the maritime sphere. Conceptual and review analyses have been conducted providing a holistic overview of the application, challenges, and opportunities in a supply chain management (SCM) context (Dutta et al. 2020). Several studies highlight the role of BCT in SCM as a key technology for integrating the supply chain and create value for different supply chain stakeholders (Queiroz et al. 2019). This paper focuses on the adoption of BCT in the maritime and shipping industry and its relationship to maritime SCI using a systematic literature review.

The aim of this paper is to provide a synthesised view of BCT adoption in the maritime and shipping sectors, in the context of SCI by understanding and identifying key adoption factors using the Technological—Organisational – Environmental (TOE) framework. The TOE framework is an organisational-level theory used to identify and explain the three elements of a firm's context, technological, organisational, and environmental, which influence the adoption and implementation of innovative technologies (Baker 2012).

This study differs from previous systematic literature reviews in two ways. First, the focus of this study is on BCT adoption and its integration into the maritime supply chain. Second, in contrast to previous studies, which covered either academic sources or industry sources, this study conducts an analysis based on both academic and industry sources. Thus, a more critical review was possible by consolidating not only theoretical academic considerations but also practical evidence from industry.

This paper addresses knowledge gaps with regard to the current application areas of BCT in the maritime and shipping sectors, identifies BCT adoption factors for maritime SCI including benefits and challenges and suggests a conceptual framework where adoption factors are classified in the context of technology, organisation, and environment. The rest of the paper is organised as follows. Section 2 provides the theoretical background to the systematic literature review whilst Section 3 presents the details of the methodological approach. Section 4 discusses the research findings, and in section 5 a conceptual framework is proposed linking BCT adoption and maritime SCI. Section 6 concludes the paper, discussing the main contributions, limitations, and future research opportunities.

2. Theoretical background

2.1. Maritime supply chain integration

Supply chains have improved functionally both through internal integration to facilitate seamless flows through internal supply chains and external integration to encompass suppliers and customers (Stevens and Johnson 2016). Internal integration involves the planning and control systems of a company to integrate supply and demand along a company's own operations. External SCI refers to the extent to which the supply chain processes of a firm are integrated within the scope of upstream (customers) and downstream (suppliers) through focal companies (Flynn et al. 2010). Whilst early SCI focused on the linear relationships and flows between customers and suppliers, more recent developments emphasise a non-linear network approach to integration (Stevens and Johnson 2016).

The maritime supply chain is effectively a logistics system integrating the individual functions of maritime transport. The concept of integration is at the centre of maritime logistics in the physical, economic/strategic or organisational aspects. Figure 1 illustrates the flow of physical cargoes and information between maritime supply chain actors (Meersman et at. 2010). A shipper chooses a certain shipping company (a carrier) with or without mediation of freight forwarder or logistics service provider. A carrier opts for the port of call and the terminal operator to use either with or without the mediation of an agent. In addition, the owner of the goods may rely on a customs broker if the customs process is required.

Liner shipping companies play a key role as they are often the most integrated in maritime logistics chains. In a competitive global economy, shipping companies are required to provide integrated services to meet customers' demands for door-to-door services. The role of shipping firms as carriers has changed from merely being cargo transporters to strategic distribution partners, providing important visibility and connectivity in the maritime supply chain (Yuen et al. 2019). Firms are

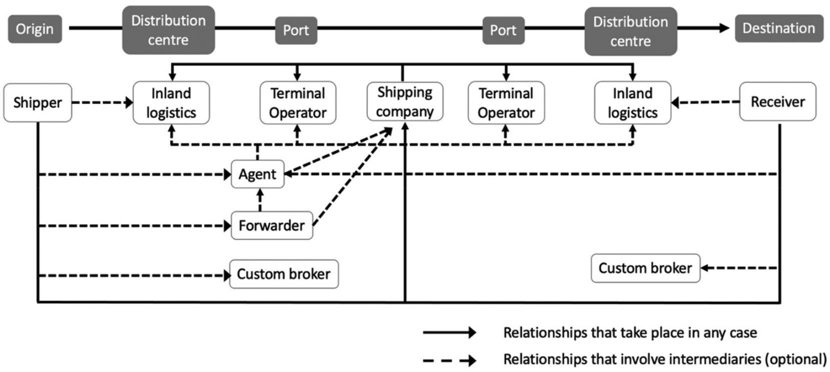

Figure 1. The maritime supply chain. Source: Adapted from (Meersman et al 2010).

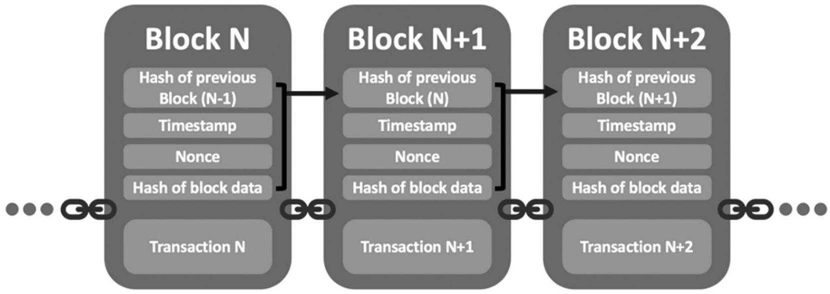

Figure 2. Blockchain structure overview. Source: Yaga et al. (2019)

making strategic efforts through inter-organisational relationships to achieve competitive advantage and improve performance. The nature and scope of shipping companies' operations has become a critical element in supply chain service performance with their new broader roles such as supply chain integrators and information disseminators (Wagner and Frankel 2000). Ports are another important supply chain actor, given that they are regarded as vital nodes in maritime supply chains. Studies have confirmed that port makes a positive impact on the effectiveness of the supply chain as a whole by reducing cost and cycle times, as well as improving productivity and delivery quality (Woo et al. 2013). Digitalisation efforts observed in seaports globally are an important development in the maritime supply chain.

2.2. Blockchain adoption and maritime SCI

The maritime industry is undergoing a digital transformation to improve global trade processes, with various advanced ICT systems such as the Internet of Things, big data analytics, cloud computing, and autonomous ships being adopted. However, blockchain technology (BCT) is increasingly viewed as a key digitalisation tool for the maritime supply chain (Dutta et al. 2020). BCT utilizes a decentralized network to maintain and track transaction data, with blocks in the chain linked by cryptographic hashes and all nodes having an identical copy (Figure 2). Once verified and validated by the parties involved in the transaction, blocks become immutable, ensuring transparency, traceability, security, and trust over the network. Data on a decentralised system can be accessed, monitored, stored, and updated by multiple participants, resulting in disintermediation of intermediaries and full visibility of transactions for supply chain members.

BCT enhances trust among supply chain partners because of its consensus mechanism. The mechanism verifies that transactions are coded into blocks according to cryptographic rules and places blocks in time sequence in the chain. Trust is established based on consensus within the blockchain and achieved with the consent of all participants. BCT also improves traceability within supply chain networks. The blockchain network provides proof of the provenance and authenticity of products to every participant in the transactions in real-time. Given shared information, it not only enhances visibility of tracking information related to the movement of products transmitted from the IoT sensors but also ensures the integrity of transaction information (Blossey et al. 2019). These features have the potential to improve the performance of the maritime and shipping sectors.

Tsiulin et al. (2020) suggests a conceptual framework of BCT implementation in shipping and port management. Here, reviewed projects are classified into three domains: document management, financial processes, and device connectivity. The main concept of the framework is applied and modified in order to classify the domain to which the BCT is applied. Document management is used to represent a domain involving documentation processes. Financial activity is expanded to transaction management which includes all types of contracts and transactions in the maritime

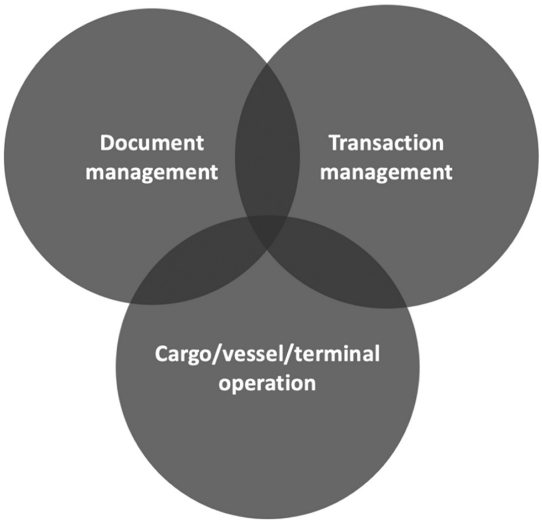

Figure 3. Blockchain domains in the maritime supply chain. Source: Adapted from Tsiulin et al. (2020)

supply chain. In addition, device connectivity is reoriented to cargo/vessel/terminal operation where connection between devices is required. Based on the modified conceptual framework, the application domains are classified as follows: document management, transaction management, and cargo/vessel/terminal operation (Figure 3). Each application area does not operate in isolation, being linked to each other to enhance information sharing in the entire maritime supply chain, and thus improve integration.

BCT has the potential to trigger the digitalisation of documentation used in maritime and shipping transport. The maritime industry has failed to fully digitalise document processes because of the differences between individual systems at each point of the supply chain and reliance on manual processes (Tsiulin et al. 2020). This delay in the transition to digitalisation has caused inefficiency in communication between stakeholders, hindering smooth information exchange, leading to wasted time and increased costs in the maritime transportation process. BCT enables digitalisation of documentation, improves real-time information exchange, and provides a unified approach in the context of document management.

From the perspective of supply chain participants, a contract of shipment involves a wide range of parties in different transaction processes. The intervention of intermediaries and replicated administration processes complicates transactions and negatively affects trust between stakeholders (Li et al. 2018). BCT provides a platform to execute contracts in supply chain transactions. Smart contracts, which are established on a decentralised blockchain network, execute transaction protocols automatically with increased accuracy, security, and trust with resulting transparency, traceability, and efficiency (Koirala et al. 2019). Furthermore, BCT applies not only to documentation and transactions but also to the physical movement of cargo across the maritime supply chain. BCT plays a key role in connecting both the physical and information dimensions. It provides the functionality to store and distribute information generated from sensors and devices such as RFID on containers, on board vessels, and from terminal equipment (Ahmad et al. 2021). The data is linked to the smart contract contributing to maximising the efficiency of the supply chain and optimising the planning of cargo handling across the supply chain including the port terminal (Panayides and Song 2008).

2.3. Extended TOE framework

Several notable theoretical models have been developed to investigate the factors influencing the adoption and implementation of innovative technologies from an individual user's point of view, namely: Technology Acceptance Model, Task Technology Fit, Diffusion of Innovation, Unified Theories Acceptance, and Use of Technology (Ullah et al. 2021). However, the TOE framework is a theory that explores and explains the significant impact on the adoption of ICT innovations in organisations, providing a comprehensive approach at the firm-level (Oliveira et al. 2014). Using a multi-dimensional analysis, the framework assesses the essential factors that organisations should consider when adopting innovative technology. BCT is a core technology in communication and information sharing in the supply chain network. In other words, not only the internal organisational structure and technology but also external connectivity and technology are important in facilitating BCT. This paper applies the TOE framework to consider internal and external characteristics of the organisation in adopting BCT.

The TOE framework has been used in previous research to understand the determinants of the adoption of innovative technology in the context of SCI. Further, the effect of factors in the adoption of advance technologies such as RFID and IoT in the supply chain has been investigated using the TOE framework. The technological context includes the characteristics and availability of technologies that are already in use, as well as those of technological innovation (Baker 2012). The organisational view includes the organisational context that incorporates the firms' structure, the resources, and intra-firm communications. The environmental context refers to the considerations that affect an organisation's business operation, such as markets, industries, and the regulatory environment.

In this study, the environmental view is extended to cover two exogenous dimensions: environmental categories external to the supply chain and organisational and inter-organisational factors. The adoption of BCT in the maritime supply chain aims for efficient data sharing between stakeholders. Given this fact, the relationship between organisations in blockchain-based information sharing is identified as a vital environmental factor in BCT application in the supply chain. Inter-organisational factors involve relation-specific issues across organisations and have been widely considered as a key element in information sharing in a supply chain context (Zeng et al. 2021).

3. Methodology

3.1. Systematic literature review

A systematic literature review was used in order to collect and explore literature addressing the theme of BCT application in the maritime supply chain. BCT application research has been regarded as in the emergent stage in its evolution, especially in the maritime and shipping industries. Exploratory research conducted using a systematic literature review is appropriate when a social phenomenon is at a developmental stage (Petticrew and Roberts 2006). A systematic literature review is different from traditional narrative reviews and is more replicable, scientific, and transparent, minimising bias through exhaustive literature searches. Systematic review is a scientific method designed to locate, appraise, and synthesise large bodies of information by investigating and exploring the frontiers of research for the establishment of background knowledge (Petticrew and Roberts 2006). The method contributes to providing a more objective review than traditional reviews by reducing bias in selection and the inclusion of literature in answering a specific research question.

Systematic literature reviews in SCM have increased rapidly and evolved to increase the rigour, transparency, and contribution by adopting guidelines from other disciplines (Durach et al. 2017). However, research on BCT is a relatively new field where the concept of the encryption network, namely bitcoin, was first established in 2008. Furthermore, the SCM domain associated with BCT is still under development but rapidly advancing, especially in the maritime and shipping sectors, where papers published in journals are scarce. Here, an integrated review of the application of BCT in these sectors in the context of SCI has not been undertaken. There exist literature studies focusing on the BCT topic in SCM and providing fragmentary evidence. For instance, Dutta et al. (2020) applied a systematic literature review in order to highlight the opportunities, societal impacts, and challenges of using BCT in supply chain operations across several industries such as shipping, manufacturing, automotive, finance, agriculture, and food. Queiroz et al. (2019) attempted to explore the main BCT application in SCM integration context, and the disruptions and challenges in adopting BCT by following a systematic review approach. Pournader et al. (2020) adopted a more methodical systematic literature review by using co-citation analysis (part of network analysis) to identify four main clusters, namely, technology, trust, trade, and transparency/traceability.

A review of BCT uses cases arising from practice was also conducted. Given that academic literature tends to lag behind practical developments in ICT studies and rapid developments and experiments in industry, this undertaking was necessary, providing a more comprehensive review of the state of the art BCT developments as well as academic thinking, sensemaking, and theorisation of the phenomena. This approach was adopted by Wang et al. (2019); however, while they considered BCT development in the supply chain generically, the focus here is specifically on the effect of BCT on SCI in the maritime and shipping sectors.

This study adopts the systematic review guideline proposed by Denyer and Tranfield (2009) and Durach et al. (2017) in the field of management and SCM, respectively. The review guideline involves five major stages: (1) defining and formulating the research question; (2) locating studies by determining the required characteristics of primary studies; (3) selecting and evaluating the pertinent literature; (4) analysing and synthesising the literature; (5) reporting and using results.

3.2. Formulating the research questions

The purpose of this study is to identify key factors affecting maritime SCI following the introduction of BCT using a systematic literature review. To this end, this paper explores the current state-of-the-art of BCT applications in the maritime and shipping sectors based on academic and practical evidence and identifies its benefits and challenges. Consequently, by synthesising the results, the research determines the major factors influencing maritime SCI in BCT adoption from the TOE perspective. The research questions are therefore formulated as follows:

- What are the main current BCT applications in the maritime and shipping industry?
- What are the main benefits and challenges of BCT adoption in the maritime supply chain?
- What are the key factors of BCT adoption that support maritime supply chain integration?

3.3. Research strategy

The systematic literature review process included three aspects: search terms, the databases used, and inclusion and exclusion criteria. Based on the defined research questions, the initial search strings included three key dimensions: ‘Blockchain’, ‘maritime shipping’, and ‘supply chain integration’. In order to identify appropriate search terms and reduce error, the iterative multi-step process for an effective keyword structure presented by Davarzani et al. (2016) was used (Figure 4). The keywords were determined as ‘Maritime’ OR ‘shipping’ OR ‘liner’ OR ‘port’; ‘Blockchain’ OR ‘block-chain’ OR ‘distributed ledger’. Keywords related to supply chain were excluded from the search string because the search results contained irrelevant articles that were broader than the maritime and shipping sectors or covered only minor aspects. From the literature related to maritime shipping and blockchain, outcomes related to SCI were manually checked and selected for the systematic literature review.

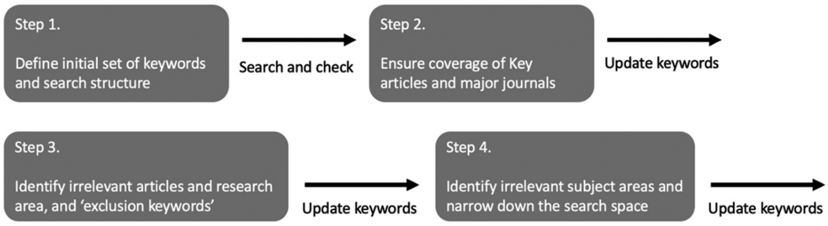

Figure 4. Multistage process to define keyword structure. Source: Davarzani et al. (2016)

The pilot search was conducted using the Scopus and Web of Science (WoS) databases. Scopus is the largest database containing abstract and citations of peer-reviewed literature (Burnham 2006). All search outcomes resulting from the WoS search overlapped with those of Scopus, therefore this study used Scopus database solely for "title, abstract, keywords" search.

Despite the reliability of peer-reviewed publications with a managerial impact in the research field under examination, peer-reviewed publications were not considered as inclusion criteria to ensure the quantity of materials considering that BCT research is in its infancy. Only papers published in full text in English were selected. Conference proceedings covering technological aspects were also included in order to understand how technological logic is related to the information sharing processes in SCI. The exclusion criteria encompassed conference reviews and book chapters which lack a rigorous peer review process (Lim et al. 2019).

Information sources such as professional and practitioner journals or web resources can be used to identify recent developments or topical themes in the context of policy, legislation, and technological advances that the academic literature does not provide. BCT application in the maritime sector has been discussed since 2017 and it is still at an early stage where academic studies based on empirical data are generally insufficient to conduct a systematic literature review. In order to supplement the gap between academic and practitioner evidence, Lloyd's List, which provides news and analysis across the global shipping industry, was used as a data source for practical evidence. Only blockchain was used as a search term since the result encompassed all relevant articles. Container, bulk, tankers and gas market were selected as the target field and sections included technology and innovation; ports and logistics; ship operation; safety; finance; regulation; and environment. The inclusion and exclusion criteria are detailed in Table 1.

3.4. Study selection and evaluation

Using the combination of refined key terms, an initial search identified 171 articles. Based on inclusion and exclusion criteria, non-accessibility to full text, conference reviews, book chapters, and non-English papers were filtered at this stage. The outcomes were refined based on the consideration of inclusion and exclusion criteria. Furthermore, the scope of the papers was filtered by reviewing the context of titles and

Table 1. Inclusion and exclusion criteria.

Academic sources	
Inclusion criteria	Access to full text
	A study which is mainly about blockchain application in maritime supply chain
Exclusion criteria	Conference reviews, book chapters
	Non-English
	A study which is marginally related to blockchain application in maritime supply chain
Practical sources	
Market	Container; bulk; tankers and gas
Section	Technology and innovation; ports and logistics; ship operation; safety; finance; regulation; environment

Source: Authors.

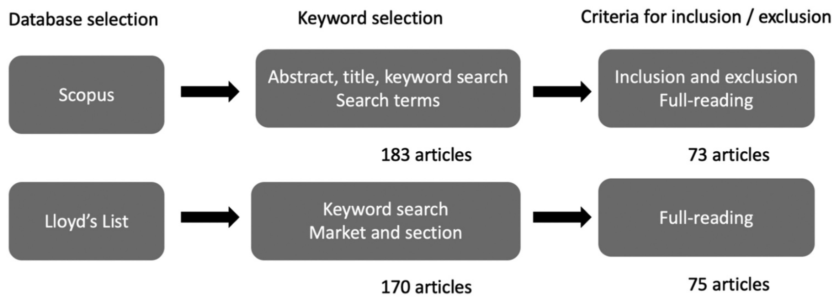

Figure 5. Process of systematic literature review. Source: Authors.

abstract with the keywords to ensure relevance and quality. Abstracts give a brief but broader summary of the publication that titles do not reflect. Articles in the primary search include keywords of blockchain application and maritime and shipping, however, articles covering irrelevant subjects such as retail, food, and manufacturing were excluded. At this stage, 73 articles were selected for the review.

Lloyd's List was used to search for the latest blockchain developments in practice. It provides a well-established and sophisticated search engine by sectors and issues. Shipping information and newspapers covering maritime sector issues published by Lloyd's List have been used as a database for analysis in maritime studies. One hundred and seventy articles were found in the search results in Lloyd's List and after assessment those related to BCT application in maritime supply chain were extracted where they reported the launch and development of blockchain programs, initiatives, projects, consortiums in the business fields of shipping liners, ports, forwarding, and software companies a total of 75 articles were identified. The complete filtering and selection procedure is illustrated in Figure 5. The list of identified papers and articles through review analysis is complied in the appendices for reference.

4. Research findings and discussion

This section provides a descriptive overview of information about articles from the Scopus search. Analysis and synthesis of important evidence in relation to BCT application in the maritime supply chain are represented in the following subsections.

4.1. Descriptive analysis

4.1.1. Number of publications

Papers in which Blockchain emerged in the maritime sector have seen a rise in numbers since their first appearance in 2017. In total 73 papers were identified between 2017 and 2021, the number of publications has grown annually since 2017, with 33 articles published in 2021, highlighting the emerging and growing interests in the research field. In terms of type of publications, the majority of academic papers consist of journal articles (59%), while the remainder are conference papers (41%) (Figure 6). In the same period, the largest number of practical articles relevant to the topic of BCT in liner shipping sector were published between 2018 and 2019. Most attention to the blockchain occurred in 2018 when various blockchain initiatives had been launched. Since then, as the BCT consortium was formed by major players in the industry, the development of small- and medium-sized projects has decreased, and the number of publications has decreased simultaneously. Broadly, industry discussion on blockchain started in 2016, and then academic interest, increased as organisations such as shipping companies and maritime authorities participated in the development of BCT (Table 2).

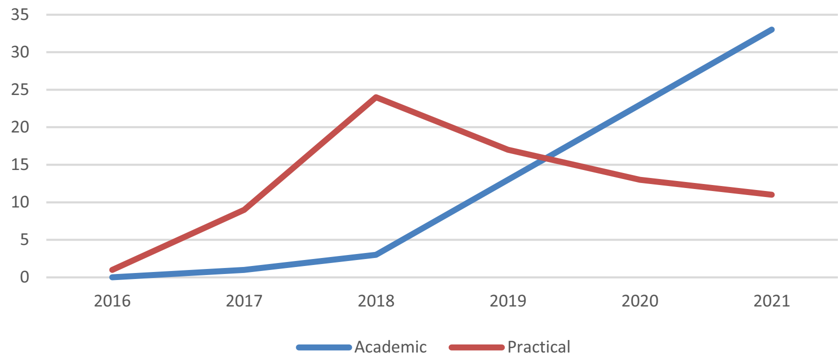

Figure 6. Number of publications per year. Source: Authors.

Table 2. Number of publications per year.

	Academic				
Year	Journal article	Conference	Total	Practical	Total
2016	0	0	0	1	1
2017	0	1	1	9	10
2018	1	2	3	24	27
2019	10	3	13	17	30
2020	16	7	23	13	36
2021	16	17	33	11	44
Total	43	30	73	75	148

Source: Authors.

4.1.2. Theoretical approach

The papers analysed in this study are grouped according to the theory-building types they follow. This study adopted a classification scheme used in the field of operations management research suggested by Wacker (1998) which differentiates between analytical and empirical approaches. The analytical approach includes deductive methods for theory building to logically derive conclusions through reasoning, whereas the empirical approach uses inductive methods to derive general principles using data from external organisations. Each approach is divided into three sub-categories; the analytical approach includes conceptual, mathematical, and statistical methods, while the empirical approach consists of experimental, statistical, and case studies.

Table 3 shows the distribution of studies of BCT applications in the maritime and shipping sectors classified according to Wacker's framework (Wacker 1998). Two-thirds of studies employed an analytical approach, primarily using analytical conceptual methodologies. This pattern is different from studies in the container shipping field, including shipping operations, shipping management, and shipping economics, which apply deductive approaches using statistical methods (Lau et al. 2013), while there are similarities with studies in the fields of port management and SCM, where analytical conceptual methodologies are the most popular research design adopted (Alexandridis et al. 2018). In terms of research methods, most studies conduct conceptual and review research which belongs to analytical analysis, aiming to illustrate developed concepts for new insights to existing problems. Contrary to analytical research, empirical approaches analysed external data such as case study, survey, interview, and observation. Due to the immaturity of BCT applications in industry, the use of empirical methods is relatively less than analytical

Table 3. Distribution of theoretical approach.

Theoretical building		Number of papers	Research methodological approach	Number of papers
Analytical	Analytical conceptual	32	Conceptual research	22
			Review	10
	Analytical mathematical	5	Math modelling	5
	Sub total	37		37
Empirical	Empirical case study	17	Case study	13
			survey	3
			Observation	1
	Empirical statistical	5	Quantitative empirical	5
	Sub - total	22		22
Other		14	Design science	14
Total		73		73

Source: Authors.

Table 4. Theoretical lens of papers.

Theoretical Lens	Contribution	References	No. of papers
Dynamic capability theory	Define and see the maritime supply chain as a dynamic hypercompetitive business environment	Lambouriere and Corbin (2020)	1
TAM (Technology Acceptance Model)	Assess the intention to use BCT from the perspective of perceived ease of use and usefulness of BCT	Yang (2019); Tan and Sundarakani (2020)	2
BOCR model (Benefits, Opportunities, Costs, and Risk)	Identify key BCT adoption factors as benefits, opportunities, costs, and risk.	Ho and Hsu (2020)	1
Game Theory	Mathematical comparison by different situation of BCT adoption	Pu and Lam (2021); Wang et al. (2021); Zhong et al. (2021)	3
TOE (Technology – Organisational – Environmental)	Identify key BCT adoption factors in the context of Technological, organisational, environmental	Orji et al. (2020)	1
Total			8

Sources: Authors.

methods. A number of conference papers with a focus on technical design were identified, which helps in understanding the use of BCT. Although not all articles include theory, various theoretical lenses' have been employed in conducting research. In line with the result of the analysis in previous section, it has been observed that theories of technology adoption such as the Technology Acceptance Model or Technological-Organisational-Environmental (TOE) framework are widely adopted considering the early stage of BCT development (Table 4).

4.2. Blockchain in maritime supply chain research and typical use cases

The research scope to which BCT is applied is split into various areas within the maritime supply chain and is detailed in Table 5. The majority of articles cover BCT adoption across the entire chain rather than focusing on certain supply chain players or sectors. For instance, Pu and Lam (2020). Lambourdiere and Corbin (2020), and Liu et al. (2021b), developed a conceptual framework to provide a holistic view of BCT application in the maritime sector, which encompasses major maritime supply chain stakeholders including ship operators, ports, governance, freight forwarders, shippers, consignees, terminals, insurers, back offices and tech management companies. Tsiulin et al. (2020) and Bavassano et al. (2020) reviewed literature focusing on BCT applications in the maritime sector and identified important factors in the implementation of BCT. Li and Zhou (2020) investigated how BCT is applied in supply chains in the maritime and shipping sectors, considering

Table 5. Blockchain application cases.

Company types	Lead company	Name of project	Main partners	Participating members	Year	Role and aim
Shipping liner	MOL		NYK Kawasaki, and NTT Data	14 members	2017	Trade data sharing platform to streamline procedure and reduce costs
	Hyundai Merchant Marine		Oracle, Samsung SDS, IBM Korea, Busan Port authority	38 members	2017	Blockchain consortium for shipment booking and cargo delivery
	APL		Kuehne+Nagel, InBev, Accenture,		2018	Solution to eliminate shipping documents and save logistics costs
	Pacific International Lines		PSA International and IBM Singapore		2018	Blockchain-based electronic bill of lading to cut the traditional paper trail and streamline the process
	Maersk	TradeLens	IBM	300 members	2018	Open and standardised platform for interaction through real-time access to shipping data and shipping document, including IoT and sensor data
	Ocean Alliance carriers	GSBN (Cargo Release)	Bank of China, DBS Bank, HSBC		2019	Blockchain-based open platform to connect stakeholders and allow them to digitise and organise dangerous goods documentation
	China Merchants Energy Shipping	Britc	China Merchants group		2021	Reliable platform for a shipping service platform, a documentation and contract system, as well as an information-sharing centre in dry bulker and tanker industry
Port	Authorities at the Port of Antwerp		T-mining, PortXL programme		2017	Platform to optimise efficiency in the container handling logistics chain by eliminating physical paperwork
	ABU Dhabi Ports unit Maqta Gateway	Sisal	Maritime SC		2018	Blockchain system providing seamless and secure link between stakeholders across the trade community with encrypted documentation
	Port of Rotterdam Authority		Samsung logistics and ABN Amro		2018	Open, independent and global platform for paperless integration of physical, administrative and financial streams within international chain
Software companies	Marine Transport International		Solas VGM		2017	Programme leveraging the legal requirements
	ShipNext		300 cubits		2018	Selling digital token for secured and reliable transactions in cryptocurrencies
	300 Cubits		Westports, LPR		2018	Deposit system using BCT and TEU token to address the problem of cargo 'no-shows' and 'rollovers'
	EY and Guardtime	INSURWAVE		4 members	2018	Digital platform for marine hull insurance
	CARGOSMART		Oracle		2018	Solution for supply chain parties to auto-fill repeated and verified information
	CargoX				2018	Blockchain-based electronic bill of lading
	Wave BL		Hapag-Lloyd, Zim, MSC		2020	Blockchain-based electronic bill of lading
	BunkerChain	TrustTrade	Singapore's Infocomm Media Development Authority		2021	Real time visibility and control of the physical bunkering process with full audit trail
Insurance	LLOYD'S Register Foundation	MBL consortium	Blockchain Labs for Open Collaboration (BLOC)	8 members	2018	Tracking the risks and challenges associated with the declaration and handling of dangerous goods
Bank	BNP Paribas and HSBC Singapore				2018	Digitised letter of credit transaction and digitalisation of trade finance

Source: authors, consolidated from Lloyd's List articles.

the movement of cargo, document exchange, and contract execution among shipping liners, ports, and forwarding companies. Jensen et al. (2019) explored the role, evolution, and adoption of TradeLens. Gaisdal et al. (2018) explored relevant areas from Implementing BCT in the maritime supply chain based on the main drivers and barriers of digital innovation identified. In contrast, Nguyen et al. (2020) identified the risks for BCT application and examined the causal relationships between them by level of risk through network analysis. Balci and Surucu-Balci (2021) identified barriers to BCT adoption in the maritime industry and examined their relationship.

Other papers identified the role of BCT in improving port logistics operations and terminal processes (Hensey et al. 2019; Liu and Wu 2020; Ahmad et al. 2021; Liu et al. 2021a; Sangeerth and Lakshmy 2021). Wang et al. (2021) examined the impact of BCT application in logistics capability related to logistics transparency and customs clearance efficiency. In addition, Tsiulin and Reinau (2021) determined and examined the scenario of what strategy port authorities would take for BCT application.

Many articles focus on blockchain-based smart contracts applied to transaction and documentation used in the maritime supply chain, for instance, bills of lading and e-invoicing are representative of such documentation (Todd 2019; Wunderlich and Saive 2019; Narayanam et al. 2020). Peronja et al. (2020) compared how the freight rate would differ when a smart contract is applied to a bill of lading and executed by decentralised automation. Pranav et al. (2020) and Alkhoori et al. (2021) proposed a system design for blockchain-based smart contracts in the shipment process. Irannezhad and Faroqi (2021) also proposed a conceptual platform which creates transactions through smart contracts enabled by integrated IoT and blockchain systems. The IoT system including the management of smart containers is applied using a blockchain-based solution (Xu et al. 2018; Alkhoori et al. 2021). Pu and Lam (2021a) showed that BCT applications have effects on emission reduction from digitalising shipping document.

In the financial sector, Pečcarić et al. (2020) found an alternative method for executing reimbursement loan transactions used in maritime transport trades as a form of payment implemented by smart contracts and BCT. Philipp et al. (2019) identified the advantages of using blockchain smart contracting systems in the context of a charter-party contracting process. Tan and Sundarakani (2020) evaluated the impact of BCT-based smart contracts in improving the efficiency of freight consolidation processes. The method of calculating freight rates in the spot market through the conclusion of a contract using a smart contract also has an impact. Sampath et al. (2020) proposed a decision-making technique in collaborative shipping marketplace for spot shipments for the participants of shippers and carriers using a decentralised blockchain. Zhong et al. (2021) examined decision-making regarding freight rates in container shipping when container liners entered as member nodes.

BCT applications for vessel operation are a further research domain. Perera and Czachorowski (2019) discussed the logic of smart contracts using operational information from GPS signal from vessel. Petković and Vujović (2019) proposed a scheme for the use of a BCT system for improving the security of authentication in autonomous vessels. Vujičić et al. (2020) discussed the role of BCT platforms in monitoring grey water discharge in vessels to enhance sustainability.

On the other hand, articles from Lloyd's list present BCT application cases in the maritime industry. Table 5 illustrates the application cases by the types of organisations. In practice, since 2017, major shipping liners, as the main players in ocean transportation, have developed and launched individual blockchain-based platforms. In general, various blockchain platforms aim to digitise paperwork and connect relevant stakeholders across maritime supply chains on standardised platforms (Braakman 2020). The platforms improve efficiency by smoothing information sharing in real-time and streamlining processes while reducing costs, saving time, and improving transparency, visibility, and security. Representatively, TradeLens of Maersk (Baker 2020) and GSBN of the Ocean alliance (Shen 2021b,c) are continuously attracting members and striving to achieve maritime SCI through these platforms. In the dry bulk and tanker industry, a movement towards a blockchain platform by China Merchant energy shipping has also appeared (Shen 2021a).

Port authorities are introducing BCT to promote efficient information sharing among various port users. Authorities at the Port of Antwerp (Tan 2017) and Rotterdam (Baker 2018a) and Abu Dhabi port unit Maqta gateway (Wee 2018a) introduced BCT to eliminate physical paperwork and enable real-time information sharing to improve operational safety and end-to-end integration in an open ecosystem.

Financial organisations that implement financial transactions in the maritime supply chain are participating in blockchain solutions. Lloyd's Register Foundation worked with Blockchain Labs for Open Collaboration, a digital solution provider, to launch Maritime Blockchain Labs in 2019 to explore ways to use BCT in a maritime ecosystem and to foster innovation and collaboration between blockchain users and shipping players (Clayton 2018). Commercial banking companies, BNP Paribas and HSBC collaborated to digitalise financial transaction in the maritime supply chain using BCT (Baker 2018a). In addition, software companies have been entering the market by developing blockchain platforms and providing solutions for maritime companies. These include Marine Transport International, ShipNext, 300 Cubits, EY and Guardtime, CARGOSMART, CargoX, Wave, Oracle, and BunkerChain (Baker 2012,2018; Bakhsh 2018; Shen 2018; Wee 2018; Baker 2018; Osler 2020; Wee 2021).

4.3. Blockchain application domains and benefits

As discussed above, BCT is being applied to different areas of the maritime supply chain and plays various roles. The blockchain domain can be divided into three major categories by functionality as mentioned in Section 2.2., document management, transaction management, and cargo/vessel/terminal operation. The functionalities and features of BCT in each domain identified from the previous literature of BCT applications in the maritime supply chain are detailed in Table 6 and discussed below.

4.3.1. Document management

The introduction of BCT to manage various types of information used in maritime supply chain processes brought significant changes in 1) document digitalisation, 2) real-time information exchange and accessibility, 3) data management, and 4) document unification.

1) Maritime organisations can minimise costs for paperwork through digitalisation and improve efficiency by shortening the processing time of documentation by reducing delay (Nærland et al. 2017; Gausdal et al. 2018; Jabber and Bjørn 2018; Jensen et al. 2019; Wunderlich and Saive 2019; Yang 2019 l Li and Zhou 2020; Pečarić et al. 2020; Perkušić et al. 2020; Peronja et al. 2020; Pu and Lam 2020; Tsiulin and Reinau 2021). 2) In addition, not only can the system achieve enhanced flexibility through smoother and seamless exchange of data related to documents, shipments, and transaction (Lambourdiere and Corbin 2020; Pranav et al. 2020; Tsiulin et al. 2020b; Ahmad et al. 2021; Bae 2021; Liu et al. 2021; Sangeerth and Lakshmy 2021), but also, instantly resolve disputes regarding shipments, invoices, purchases, and returns through real-time access to information (Ho and Hsu 2020; Li and Zhou 2020; Narayanam et al. 2020).

2) The permitted information shared across the entire supply chain in (near) real-time includes ownership data, time stamping, location data, and other product-specific data, and provides full visibility and transparency to all relevant parties providing end-to-end data access (Jabber and Bjørn 2018; Allen et al. 2019; Perera and Czachorowski 2019; Yang 2019; Jović et al. 2020; Kaska and Tolga 2020; Lambourdiere and Corbin 2020; Liu and Wu 2020; Pu and Lam 2020; Wang et al. 2021). Data managed in a distributed ledger are immutable to database changes or damage and are trackable and traceable, therefore, the chance of fraud and attack is reduced (Petković and Vujović 2019; Ho and Hsu 2020, Irannezhad 2020; Tan and Sundarakani 2020; Ahmad et al.

Table 6. Blockchain application domains and benefits factors.

Blockchain domain	Factors	References
Document management	Document digitalisation	Nærland et al. (2017); Gausdal et al. (2018); Jabbar and Bjørn (2018); Jensen et al. (2019); Jović et al. (2019); Wunderlich and Saive (2019); Yang (2019); Li and Zhou (2020); Pečarić et al. (2020); Perkušić et al. (2020); Peronja et al. (2020); Pu and Lam (2020,2021a); Tsiulin and Reinau (2020) MOL; Authorities at the Port of Antwerp; Hyundai Merchant Marine; Maersk (TradeLens); PIL; APL; LLOYD'S Register Foundation; CargoX; ABU Dhabi Ports unit Maqta Gateway (Sisal); Ocean Alliance carriers (GSBN); Port of Rotterdam Authority
	Real time information	Lamdourdiere and Corbin (2020); Pranav et al. (2020); Tsiulin et al. (2020b); Ahmad et al. (2021); Bae (2021); Liu et al. (2021b); Sangeerth and Lakshmy (2021); Ho and Hsu (2020); Li and Zhous (2020); Narayanam et al (2020) MOL; Marine Transport International; LLOYD'S Register Foundation; ABU Dhabi Ports unit Maqta Gateway (Sisal); Ocean Alliance carriers(GSBN)
	Data management	Jabbar and Bjørn (2018); Allen et al. (2019); Perera and Czachorowski (2019); Yang (2019); Jović et al. (2020); Kaska and Tolga (2020); Lambourdiere and Corbin (2020); Liu and Wu (2020); Pu and Lam (2020); Wang et al. (2020); Petković and Vujović (2019); Ho and Hsu (2020); Irannezhad (2020); Tan and Sundarakani (2020); Ahmad et al. (2021); Maerenković et al. (2021) Authorities at the Port of Antwerp; Marine Transport International; LLOYD'S Register Foundation; ABU Dhabi Ports unit Maqta Gateway (Sisal)
	Document unification	Jović et al. (2019); Pu and Lam (2020); Tsiulin et al. (2020a) Maersk (TradeLens)
Transaction management	Decentralisation	Gausdal et al. (2018); Petković and Vujović (2019); Philipp et al. (2019); Li and Zhou (2020); Papathanasiou et al. (2020); Pečarić et al. (2020); Perkušić et al. (2020); Pranav et al. (2020); Tan and Sundarakani (2020); Tsiulin et al. (2020a); Nasih et al. (2019); Pu and Lam (2020); Tsiulin et al. (2020b); Marenković et al. (2021) MOL; Maersk (TradeLens); CARGOSMART
	Consensus mechanism	Nasih et al. (2019); Pedersen et al. (2019); Perkušić et al. (2020); Lambourdiere and Corbin (2020); Peronja et al. (2020); Sampath et al. (2020); Marenković et al. (2021); Sangeerth and Lakshmy (2021) PIL; CARGOSMART; Ocean Alliance carriers(GSBN)
	Automated transaction	Nærland et al. (2017); Jugović (2019); Philipp et al. (2019); Segers et al. (2019); Pečarić et al. (2020); Tan and Sundarakani (2020); Irannezhad and Faroqi (2021); Zhong et al. (2021) Hyundai Merchant Marine; PIL
	Data management	Philipp et al. (2019); Liu and Wu (2020); Pu and Lam (2020); Nærland et al. (2017) Marine Transport International; Hyundai Merchant Marine; EY and Guardtime (INSURWAVE); Ocean Alliance carriers(GSBN)
	Platform standardisation	Jensen et al. (2019); Jović et al. (2019); Jugović et al. (2019); Yang (2019) Hyundai Merchant Marine; Maersk (TradeLens); EY and Guardtime (INSURWAVE); Ocean Alliance carriers(GSBN); Port of Rotterdam Authority; BNP Paribas and HSBC Singapore
Cargo/vessel/ terminal operation	Cargo management	Xu et al. (2018); Jugović et al. (2019); Yang (2019); Liu and Wu (2020); Narayanam et al. (2020); Papathanasiou et al. (2020); Peronja et al. (2020); Ahmad et al. (2021); Hasan et al. (2019); Pang et al. (2020); Pu and Lam (2020); Tan and Sundarakani (2020); Alkhoori et al. (2021); Merenković et al. (2021); Munim et al. (2021); Zhong et al. (2021) Hyundai Merchant Marine; Maersk (TradeLens); LLOYD'S Register Foundation; Ocean Alliance carriers(GSBN)
	Terminal operation optimisation	Hansan et al. (2019); Henesey et al. (2019); Jović et al. (2019); Liu and Wu (2020); Ahmad et al. (2021); Tsiulin and Reinau (2021); Wang et al. (2021a); Vujičić et al. (2020) Authorities at the Port of Antwerp
	Connectivity with IoT	Allen et al. (2019); Perera and Czachorowski (2019); Philipp et al. (2019); Pang et al. (2020); Tan and Sundarakani (2020); Tsiulin et al. (2020b); Ahmad et al. (2021); Irannezhad and Faroqi (2021); Munim et al. (2021)
	Vessel data management	Petković and Vujović (2019)

Source: Authors.

2021). 4) In a shared blockchain system for maritime supply chain transaction participants use and exchange standardised documents (Jović et al. 2019). The use of standardised documents improves transaction speed and efficiency by removing the problem of document duplication when document exchange among stakeholders (Pu and Lam 2020; Tsiulin et al. 2020a).

4.3.2. Transaction management

The conversion to smart contracts combined with the BCT solves the problems of complexity and inefficiency in the current transaction systems in the maritime supply chain. Blockchain factors affecting transaction management include 1) decentralisation of the supply chain, 2) consensus mechanism for transactions, 3) automated transactions, 4) data management, and 5) platform standardisation.

1) In a blockchain, the data is spread across all parties preventing monopoly of data. As a consequence, the role of a central authority or intermediary to keep all data is eliminated so that the transaction process is simplified (Gausdal et al. 2018; Petković and Vujović 2019; Philipp et al. 2019; Li and Zhou 2020; Papathanasiou et al. 2020; Pečarić et al. 2020; Perkušić et al. 2020; Pranav et al. 2020; Tan and Sundarakani 2020; Tsiulin et al. 2020a). Accordingly, the number of peer-to-peer communications is minimised and the speed of execution of trade contracts accelerated (Nasih et al. 2019; Pu and Lam 2020; Tsiulin et al. 2020).

2) As the transaction proceeds with the consent of the participants, trust is established between participants within enhanced supply chain coordination (Lambourdiere and Corbin 2020; Peronja et al. 2020; Sampath et al. 2020; Sangeerth and Lakshmy 2021). 3) The algorithm combined with smart contract increases efficiency by automating certification. Tasks such as payment approval, transaction reporting, document passing, and freight rate calculation which are required for transactions, namely an invoice and Bill of Lading are simplified (Nærland et al. 2017; Jugović et al. 2019; Philipp et al. 2019; Segers et al. 2019; Pečarić et al. 2020; Tan and Sundarakani 2020; Irannezhad and Faroqi 2021; Zhong et al. 2021). 4) The encrypted transaction information stored in blockchain helps to decrease the occurrence of fraud and ensure security and privacy (Philipp et al. 2019; Liu and Wu 2020; Pu and Lam 2020). The ability for other parties to track history and conditions of transactions in real time can pose a great impact on visibility and traceability (Nærland et al. 2017). 5) These transactions are managed within a standardised platform contributing to easy data access and management (Jensen et al. 2019; Jović et al. 2019; Jugović et al. 2019; Yang 2019).

4.3.3. Cargo, vessel, and terminal operation

The main areas of application in this category include 1) cargo management, 2) terminal operation optimisation, 3) connectivity with IoT and 4) vessel data management.

1) Shipping companies can facilitate the efficient planning of operations by tracking cargo in real time using BCT (Xu et al. 2018; Jugović et al. 2019; Yang 2019; Liu and Wu 2020; Narayanam et al. 2020; Papathanasiou et al. 2020; Peronja et al. 2020; Ahmad et al. 2021). The data including not only condition and location of cargo but also the disappearance of shipments are open and accessible to all relevant parties during the entire delivery process. Parties verify the state of cargo at each point in the supply chain, which is then recorded on the blockchain. When cargo moves across the maritime supply chain, a smart contract automatically validates the authenticity ensuring the safety and integrity of the items based on the consensus (Hasan et al. 2019; Pang et al. 2020; Pu and Lam 2020; Tan and Sundarakani 2020; Alkhoori et al. 2021; Munim et al. 2021; Zhong et al. 2021).

2) Real-time data about cargo also help terminals to prepare optimal stowage planning by providing the exact time of arrival and location of cargo, which reduces the potential for congestion (Hansan et al. 2019; Henesey et al. 2019; Jović et al. 2019; Liu and Wu 2020; Ahmad et al. 2021; Tsiulin and Reinau 2021; Wang et al. 2021). The automated and optimised process results in both a reduction in labour costs and improved time management for organising cargo and improving the

cycle time with decreased lead times and advanced container utilisation, as well as improving environmental sustainability (Vujičić et al. 2020).

3) BCT is complementary with IoT devices such as RFID and GPS attached to containers, equipment in terminals, and vessels. Shipment tracking is enabled by the use of sensors, monitoring or management, or data collection from IoT uses. The tracking data is stored and shared in the secure storage provided by the blockchain (Allen et al. 2019; Perera and Czachorowski 2019; Philipp et al. 2019; Pang et al. 2020; Tan and Sundarakani 2020; Tsiulin et al. 2020; Ahmad et al. 2021; Irannezhad and Faroqi 2021; Munim et al. 2021). 4) Vessel operational data which is shared and stored on a distributed consensus network can be used for autonomous ship control (Petković and Vujogić 2019).

4.4. Blockchain application challenges

Although BCT can bring benefits and opportunities, there are challenges and barriers that need to be understood and prepared in order to ensure its successful adoption and implementation. The main issues identified are detailed in Table 7 and discussed below.

4.4.1. Relationship among participants

Adopting BCT means that an organisation participates in a blockchain-based platform with other parties, and the relationship between participants is an important factor in its introduction. Traditional stakeholders in the maritime sector are often reluctant to share proprietary data with competitors, so it is hard to get buy-ins from all relevant stakeholders (Perkušić et al. 2020; Tsiulin and Reinau 2021). In addition, consensus and trust between participants is required as to who will be the central registry that manages the process of validating and proving transactions on an integrated platform. The threat of losing control over operational information means that establishing trust among all parties involved is complex (Tan and Sundarakani 2020). For example, no matter how open the TradeLens platform is, Maersk remains the dominant organisation, which means that other participants have to adopt any changes to the platform. Such monopoly issues will not be easy for a legal competition framework to adequately deal with (Munim et al. 2021). This may be the reason why Tradelens later became an independent and neutral blockchain platform.

4.4.2. Standardisation

The ultimate goal of maritime organisations in adopting BCT is to achieve a shared platform, and standardisation of data is essential. However, this can cause confusion and errors because multiple documents must be updated by multiple parties in one transaction (Papathanasiou et al. 2020). For instance, one shipment or trade in ocean transport includes 20 or 30 different business parties and involves more than 30 documents being exchanged within different information systems and communication protocols operated by individual organisations. Setting a common industry standard from different businesses and attracting other stakeholders is thus a significant challenge in BCT adoption (Pečarić et al. 2020; Tan and Sundarakani 2020).

4.4.3. Cost

Cost is the most fundamental factor to consider in a company's strategy (Gausdal et al. 2018). A wide range of incidental costs related to the initial BCT development and implementation, as well as ongoing maintenance, arise. There are also additional expenditures for manpower-training and switching to a new system (Zhou et al. 2020). In addition, firms need to account for the maintenance costs arising from high levels of energy consumption if they participate in a permissioned blockchain. Further investigation into whether the economic value created by a decentralised supply chain compared to the investment cost is beneficial is thus required (Irannezhad 2020).

Table 7. Blockchain application challenges factors.

Blockchain application challenges	References
Relationship among participants	Perkušić et al. (2020); Tsiulin and Reinau (2021); Tan and Sandarakani (2020); Balci and Surucu-Balci (2021); Munim et al. (2021)
Standardisation	Irannezhad (2020); Liu et al. (2021b); Munim et al. (2021); Papathanasiou et al. (2020); Pečarić et al. (2020); Tan and Sundarakani (2020)
Cost	Gausdal et al. (2018); Zhou et al. (2020); Irannezhad (2020)
Regulation	Irannezhad (2020); Pečarić et al. (2020); Todd (2019); Ho and Hsu (2020); Liu et al. (2021b); Allen et al. (2019); Papathanasiou et al. (2021); Balci and Surucu-Balci (2021)
Security	Tan and Sundarakani (2020); Munim et al. (2021); Christidis and Devetsikiotis (2016); Pečarić et al. (2020); Liu et al. (2021b); Ho and Hsu (2020)
Infrastructure and technological issues	Gausdal et al. (2018); Munim et al. (2021); Irannezhad (2020); Liu et al. (2021b); Munim et al. (2021)
Industrial culture and skills	Gausdal et al. (2018); Jensen et al. (2019); Tan and Sundarakani (2020); Irannezhad (2020); Papathanasiou et al. (2020); Zhou et al. (2020); Ho and Hsu (2020); Balci and Surucu-Balci (2021)

Source: Authors.

4.4.4. Regulation

The absence of solid and clear rules for information sharing or property rights to data are being addressed as challenges to BCT implementation (Irannezhad 2020; Pečarić et al. 2020). The features of a decentralised ledger make it difficult for public institutions to control the industry (Todd 2019; Ho and Hsu 2020; Liu et al. 2021). Furthermore, information sharing across multiple countries using BCT raises the problem of which jurisdiction's laws and regulations should be applied (Allen et al. 2019; Papathanasiou et al. 2020; Ahmad et al. 2021).

4.4.5. Security

In terms of an end-to-end supply chain facilitated in a BCT-based open platform, especially in permissionless blockchains, the possibility of leakage of user's information remains when a private document is revealed to third parties (Tan and Sundarakani 2020; Munim et al. 2021). Maintaining a system that ensures network security and data protection is a significant factor to consider (Christidis and Devetsikiotis 2016l Pečarić et al. 2020; Liu et al. 2021). Abuses of the technology by an organisation/individual such as manipulating transactions and creating fake transactions also need to be prevented (Ho and Hsu 2020).

4.4.6. Infrastructure and technological issues

Other challenges are related to the capacity of IT infrastructure and the complexity of the permissioned blockchain. As blockchain transaction expands globally, the energy required to process the data transmitted between parties for validation and confirm the validity is considerable. The IT infrastructure of the nodes participating in the verification process should be able to manage high energy intensity which expends a significant amount of processor power. Processors need to meet the expectations for speed under high load and storage space for nodes (Gausdal et al. 2018l Munim et al. 2021). Environmental concerns related to energy consumption, which results in a significant carbon footprint, are also problems to be overcome (Irannezhad 2020; Liu et al. 2021; Munim et al. 2021). Given that most of the blockchain initiatives use permissioned BCT, rather than permissionless BCT, their mining and consensus protocols tend to be different (for instance using Proof of Stake, rather than Proof of Work deployed by Bitcoin network) and are less energy intensive. There are active efforts in practice and academia in developing various BCT consensus mechanisms in order to improve performance whilst addressing environmental concerns.

4.4.7. Industrial culture and skills

The conservative nature of shipping industry is highlighted as another barrier to BCT adoption. Maritime businesses are reluctant to invest in the technology because of risk uncertainty and scepticism about sharing information through a technology with competitors (Gausdal et al. 2018; Jensen et al. 2019). Stakeholders' hesitation and resistance to change until other stakeholders participate in the blockchain platform represent challenges to innovation within the shipping industry (Tan and Sundarakani 2020). In addition, the lack of experts and the burden of new recruitment and self-training also act as major factors in decision-making (Irannezhad 2020; Papathanasiou et al. 2020; Zhou et al. 2020). Low consumer acceptance will negatively affect stakeholders' willingness to move to new systems (Ho and Hsu 2020). Only a small number of practitioners expect BCT to become the most significant driver of change in the shipping industry.

5. Discussion and development of theoretical model

The preceding section of this paper focused on defining the areas where Blockchain Technology (BCT) is beneficially applied in maritime supply chains, as well as the challenges encountered during the adoption of BCT in maritime supply chains. Through this exploration, it was established that BCT facilitates the integration of maritime supply chains by improving the sharing of information among maritime stakeholders in a more secure, transparent, and efficient manner.

In this section, we integrate the key factors identified from both the benefits and challenges of BCT adoption in maritime supply chain and grouped into TOE categories. Given that the BCT adoption in maritime supply chain is highly related to the integration of the supply chain, an additional dimension, i.e. inter-organisational context is added, which considers relationships between stakeholders. Factors included in each context were identified through a benefits and challenges analysis (Tables 8). Factors belonging to each context were constructed by matching the characteristics of benefits and challenges identified in this study to determinants presented in the previous literature. The following subsections provide detailed descriptions of each element. An integrated framework is proposed subsequently (Figure 7).

5.1. Technological context

Expected benefits – Expected benefits refers to factors which result in improved performance of maritime supply chain entities by using BCT. The determinants of expected benefits are similar to relative advantages, perceived usefulness, and performance expectancy in the user adoption context (Gökalp et al. 2020). The digitalised document and automated transaction processes improve the efficiency of the maritime supply chain by reducing delay and saving cost. Simplified transactions in the decentralised system accelerate the speed of the process by minimising point-to-point communication without the use of intermediaries. In addition, the optimal operation of cargo handling, vessel movement, and terminal operations is enabled by tracking the location and condition of containers in real-time. Visibility and transparency are another core benefits of BCT adoption in information sharing. Enhanced visibility and transparency of information which is shared to all participants of the blockchain system enables for entities to respond in real-time regarding the data they are related.

Cost – Economic aspects play a key role in determining the implementation of BCT (Jović et al. 2020). Saving cost for labour, paperwork, and human errors by reducing the inefficiency of paper-based processes, eliminating administrative costs, and optimising the process through real-time shared information will drive the decision to adopt BCT. On the other hand, expenditure for enhancing recruitment and training, investment in developing new skills, and switching cost from existing system significantly and negatively affect the willingness to adopt BCT.

Security and privacy – Security is one of the most relevant considerations for BCT adoption, both in terms of benefits and challenges (Clohessy et al. (2020). Encrypted and immutable data managed

Table 8. Benefits and challenges factors of BCT, and TOE factors.

Extended TOE	Subcategory	Elements defined	Benefits/ Challenges	Application areas
Technological	Expected benefits	Improved Efficiency	Benefit	Document digitalisation; decentralisation; consensus mechanism; cargo management; terminal optimisation;
		Traceability and trackability	Benefit	Data management; cargo management;
		Simplification	Benefit	Decentralisation; automated transaction;
		Real-time access and sharing	Benefit	Real-time information; data management; connectivity with IoT; vessel data management;
		Visibility and transparency	Benefit	Data management; cargo management; platform standardisation
	Cost	Cost reduction	Benefit	Document digitalisation; terminal operation optimisation;
		Increased expenditure	Challenge	Cost;
	Security and privacy	Immutability	Benefit	Data management; cargo management;
		Information Leakage	Challenge	Security;
	Compatibility	With other technology	Benefit	Connectivity with IoT;
	Complexity	Technical complexity	Challenge	Complexity;
Organisational	Organisation's readiness	Readiniess	N	N
	Organisation's size and type	Size	N	N
		Type	N	N
Environmental	Regulation	Regulatory issues	Challenge	Regulation;
	Market circumstance	Market circumstance	Challenge	Industrial culture and skills;
	Environment	Sustainability	Benefit	Document digitalisation; terminal operation optimisation; vessel data management;
		Energy consumption	Challenge	Infrastructure and technological issues;
Inter-Organisational	Trust	Trust enhancement	Benefit	Consensus mechanism;
		Week trust	Challenges	Relationship among participants;
	Standardisation	Standarised platform	Benefit	Platform standardisation;
	Monopoly	Monopoly	Challenge	Relationship among participants;

Source: Authors.

in a distributed ledger reduces the occurrence of fraud and attack, ensuring security and privacy. However, the possibility of the leakage of private information remains a risk given the openness of a shared ledger.

Compatibility – Compatibility is defined as the ease of integration of BCT on relevant platforms and existing technologies such as IoT and ERP (Orji et al. 2020). Organisations are more likely to adopt BCT if they determine that the technology is compatible with their IT infrastructure. BCT makes a positive contribution to improving the efficiency and optimisation of maritime supply chains if integrated with IoT technologies that are already utilised in containers, vessels, and terminal operations.

Complexity – Complexity is the degree to which an organisation finds it difficult to understand and use BCT technology (Malik et al. 2021). BCT is a complex technology which tends to operate across multiple countries and continents. Therefore, legal compliance to meet the requirement of various laws is challenging. Despite this complexity of the technology, lack of expertise in BCT application in the maritime supply chain is also a significant problem.

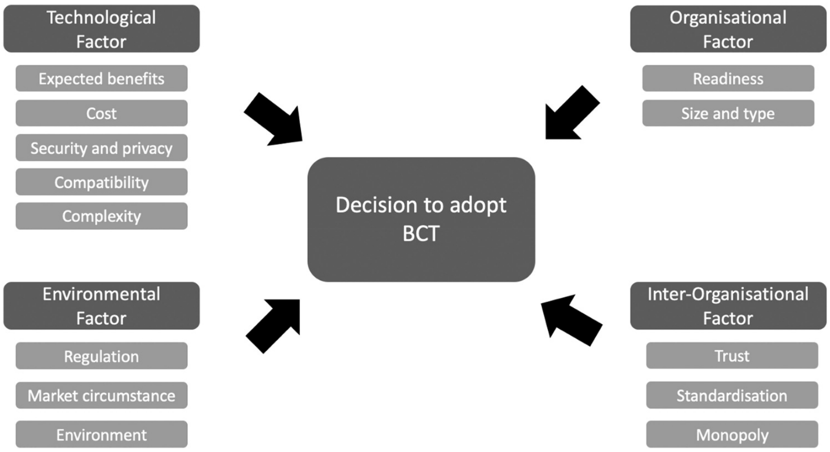

Figure 7. Extended TOE framework. Source: Authors.

5.2. Organisational contexts

Organisations' readiness – Organisational readiness is a consideration that reflects an organisation's capacity to adopt innovative technologies and resources to facilitate the technology including human, financial, and IT infrastructure resources (Clohessy et al. 2020). Current internet speed and data storage can be insufficient to satisfy fundamental requirements to maintain the blockchain network, which requires relatively high costs and energy. Human resources for securing and training skilled manpower and financial resources for substantial investment are also factors when an organisation decides BCT adoption.

Organisations' size and types – organisation's size impacts IT innovation adoption (Lee and Xia 2006). According to the industrial use case analysis as discussed in Section 4.2, it is found that major companies with a large volume of vessels and market share are leading blockchain platforms which tend to attract more participants. Furthermore, the strategy to develop and apply BCT is different depending on the business type, namely shipping liners, port authorities, freight forwarders, and other sectors.

5.3. Environmental contexts

Regulation – This determinant refers to policy and regulations committed by governments and public authorities, which affect innovation diffusion (Zhu et al. 2006). BCT usage is related to transaction and information, and therefore, an absence of a regulatory environment protecting users' properties may discourage adoption, while government support may speed up the adoption process. In addition, the existence of a standard regulatory framework that will unify the individual laws that are currently applied for each organisation, country, and continent is a major consideration.

Market circumstances – Organisations reevaluate how they adopt and use technology in response to market dynamics (Clohessy et al. 2020). The conservative nature of business parties in the maritime supply chain is a factor that negatively affects the introduction of new technologies to the market. Consumers' perception of BCT is an important factor in determining whether companies will participate or not. In addition, special market conditions, such as the pandemic, also influence the adoption of BCT.

Environment – Saving energy and reducing waste are factors to consider in realising green energy. The fully digitised documentation in the maritime supply chain contributes to environmental protection by reducing waste from paper use. Optimised operation of hardware and equipment on vessels and terminals through the use of BCT also helps to strengthen the sustainability of the maritime and shipping sectors. However, carbon emission due to high energy consumption from BCT processors is an issue that needs to be addressed.

5.4. Inter-organisational contexts

Trust – The definition of this factor is that the willingness of a party depends on another party taking a particular action based on its expectations (Gökalp et al. 2020). The BCT's features of visibility and transparency contribute to the improvement in the level of trust among maritime supply chain parties. The consensus mechanism in the distributed system ensures trust by reducing uncertainty about counterparties and improves cooperation through the maritime supply chain network. Organisations, however, are still not entirely confident in giving competitors a competitive advantage by providing essential information and proprietary data.

Standardisation – Market standards emerged as a significant consideration from an interorganisational perspective in BCT adoption (Clogessy et al. 2020). By managing transactions using a unified document on a standardised platform, stakeholders expect to strengthen SCI and improve efficiency. Nevertheless, for the many business parties of maritime supply chain that are still operating individual IT systems and communication protocols, the common industry standard of BCT platform can be a motive to participate in cooperation with other stakeholders, whereas the immature stage of standard development has a negative effect on the introduction of BCT.

Monopoly – Large and leading organisation in information systems and technology influence other organisations' adoption choice (Zeng et al. 2021). As BCT grows as a central technology of the maritime supply chain network, the power of a handful of entities who validate and prove transactions can become a threat to participants. The adoption decisions made by small- and medium-size enterprises following the technology are influenced by leading companies' policy regarding information control.

6. Conclusion and future direction

The growing importance of BCT as an emerging driver to SCI was the motivation to conduct this research. Previous literature has discussed research in the context of logistics and supply chains by both developing conceptual models or frameworks and conducting empirical research to examine the relationship between BCT adoption and its impact on performance as well as associated risks. Nevertheless, only a few papers have attempted to identify application areas and features of BCT in the maritime sphere. This gap in the literature hinders the development of theoretical understanding for BCT adoption in maritime supply chains. To address this gap, a systematic literature review was conducted in this study to establish an extended TOE framework. The framework provides a holistic view on the integration of maritime supply chains through the adoption of BCT, consolidating both academic perspective and practical developments in the industry. The main findings of this study as the answers to the research questions are summarised as follows.

What are the main current BCT applications in the maritime and shipping industry? Via a systematic literature review of both academic and practical literature, this study identified a number of application areas which can broadly be categorised into three areas: 1) document management, 2) transaction management, and 3) cargo, vessel, and terminal operation. Particularly, BCT has been introduced by various maritime organisations in the form of platforms as an integrator for different participants in the supply chain.

What are the main benefits and challenges of BCT adoption in the maritime supply chain? Through an analysis of the current status of BCT application, this review identified the benefits and challenges associated with its adoption, as detailed in Sections 4.3 and 4.4. BCT, as an emerging technology, offers significant advantages in the areas of data storage, management, and sharing. Its benefits are particularly salient in the context of the maritime supply chain, which is characterized by a multitude of participants and complex trade relationships. However, the adoption of BCT is impeded by various barriers, including political, environmental, relational, and technological factors that pose challenges to its widespread adoption in the market.

What are the key factors of BCT adoption that support maritime SCI? The results of the systematic literature review enabled the identification, analysis, and categorisation of the factors that impact BCT adoption in the maritime supply chain. These factors were grouped into a list of constructs, which revealed that the technology's primary considerations centered around the integration of the maritime supply chain, particularly in terms of enhancing connectivity and communication among key stakeholders. These constructs then form the extended TOE framework.

Therefore, through exploring the answers to the three research questions and the development of the extended TOE framework, our study provides valuable insights to both academia and practitioners. First, the findings contribute to expanding knowledge of BCT by articulating the state-of-the-art for BCT application and developments in the maritime supply chain. Whilst many studies explore the use of BCT in supply chains in general, this study focuses specifically on the maritime sector—an under-investigated area. This review analysis also differs from many literature studies in that the review is conducted from both theoretical and practical perspectives by consolidating academic and practical sources.

The academic aspect provides a detailed exposition of BCT's technical characteristics and its potential applications, while the practical review explores the actual deployment and adoption of BCT by companies and industries. By integrating these two perspectives, an extended Technology-Organization-Environment (TOE) theoretical framework was developed that provides a comprehensive overview of the latest BCT deployments in maritime supply chains. The proposed TOE framework has important implications for future blockchain-related research as it offers a theoretical background that can guide empirical investigations. Further research could adopt large-scale surveys or multiple case studies to test and validate the framework, thereby advancing our understanding of BCT adoption in the maritime supply chain.

This study has important implications for practitioners in the maritime industry who are currently grappling with the decision to adopt and apply blockchain technology in the face of rapid digital transformation. The key factors identified in the proposed extended TOE framework have significant managerial and policy implications for supply chain stakeholders in the industry. The framework can aid managers in prioritising the benefits and challenges of BCT adoption as a platform, which can help guide decision-making regarding BCT adoption. Furthermore, knowledge of the benefits and challenges associated with BCT application can enhance the likelihood of successful adoption by practitioners. Thus, this work is of significant value to maritime organisations as they navigate the complexities of BCT adoption and strive to remain competitive in a rapidly evolving digital landscape.

Finally, our research is not without limitations. Despite the systematic literature review process, it is possible that some articles may have been missed during the selection process. Furthermore, due to the rapid pace of developments in the application of BCT in maritime supply chains, there may be innovative use cases and practices that were not captured by this review. As such, further research and exploration are warranted to stay current with the latest advancements in the field of BCT adoption in maritime supply chains.

There are many exciting avenues for future research in the field of BCT adoption in maritime supply chains. For instance, there is a need to examine the impact of BCT on the broader ecosystem of maritime logistics and supply chain management, including its potential to disrupt traditional business models and create new opportunities for innovation and growth. It is also worthwhile to use modelling approaches to quantify the impact of blockchain on maritime supply chain performance such as lead time, cost, and inventory levels. This can help decision-makers understand the financial implications of BCT adoption and make informed decisions about whether and how to implement BCT solutions. Finally exploring the integrative use of blockchain with other digital technologies in maritime supply chains can be an exciting avenue for future research. As the maritime industry continues to embrace digitalisation, there is a growing need to integrate different technologies to achieve greater efficiencies and improve supply chain performance.

Disclosure statement

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Appendix 1

Reviewed articles

Authors	Year	Journal	Type of paper	Theoretical building Type1	Theoretical building Type2	Research method
Kristoffer Nærland, Christoph Müller-Bloch, Roman Beck, Søren Palmund	2017	ICIS 2017: Transforming Society with Digital Innovation	conference	N	N	technological
Anne H. Gausdal, Karen V. Czachorowski, Marina Z. Solesvik	2018	Sustainability	journal paper	empirical	empirical case study	case study
Karim Jabbar, Pernille Bjørn	2018	Proceedings of the 2018 ACM Conference on Supporting Groupwork	conference	empirical	empirical case study	observation
Lei Xu, Lin Chen, Zhimin Gao, Yanling Chang, Eleftherios Iakovou, Weidong Shi	2018	2018 IEEE International Symposium on Technologies for Homeland Security, HST 2018	conference	N	N	technological
Robert Philipp, Gunnar Prause, Laima Gerlitz	2019	Transport and Telecommunication	journal paper	empirical	empirical case study	case study
Thomas Jensen, Jonas Hedman, Stefan Henningsson	2019	MIS Quarterly Executive	journal paper	empirical	empirical case study	case study
Segers, Lennard, Ubacht, Jolien, Rukanova, Boriana, Rukanova, Boriana	2019	ACM International Conference Proceeding Series	conference	empirical	empirical case study	case study
Asger B. Pedersen, Marten Risius, Roman Beck	2019	MIS Quarterly Executive	journal paper	analytical	analytical conceptual	conceptual research
Miro Petković, Vice Mihanović, Igor Vujović	2019	Journal of Applied Engineering Science	journal paper	analytical	analytical conceptual	conceptual research
Paul Todd	2019	International Journal of Law and Information Technology	journal paper	analytical	analytical conceptual	conceptual research
Darcy W.E. Allen, Chris Berg, Sinclair Davidson, Mikayla Novak, Jason Potts	2019	Asia and the Pacific Policy Studies	journal paper	analytical	analytical conceptual	conceptual research
Alen Jugović, Juraj Bukša, Alex Dragoslavić, David Sopta	2019	Scientific Journal of Maritime Research	journal paper	analytical	analytical conceptual	conceptual research
Marija Jović, Marko Filipović, Edvard Tijan, Mladen Jardas	2019	Scientific Journal of Maritime Research	journal paper	analytical	analytical conceptual	review
Lokukaluge P. Perera, Karen Czachorowski	2019	OCEANS 2019 - MARSEILLE	conference	N	N	technological
Haya Hasan, Esra AlHadhrami, Alia AlDhaheri, Khaled Salah, Raja Jayaraman	2019	Computers & Industrial Engineering	journal paper	N	N	technological
Lawrence Henesey, Yulia Lizneva, Mahwish Anwar	2019	21st International Conference on Harbor, Maritime and Multimodal Logistics Modeling and Simulation, HMS 2019	conference	N	N	technological (simulation)
Chung-Shan Yang	2019	Transportation Research Part E	journal paper	empirical	empirical statistical	survey
Tien-Chun Ho, Chien-Lung Hsu	2020	Journal of Marine Science and Technology	journal paper	empirical	empirical statistical	quantitative empirical
Eric Lambourdiere, Elsa Corbin	2020	Worldwide Hospitality and Tourism Themes	journal paper	analytical	analytical conceptual	conceptual research
Angeliki Papathanasiou, Rosanna Cole, Philip Murray	2020	European Management Journal	journal paper	empirical	empirical case study	case study
Cuicui Liu, Shaoying Wu	2020	Journal of Physics: Conference Series	conference	empirical	empirical case study	case study

(*Continued*)

Authors	Year	Journal	Type of paper	Theoretical building Type1	Theoretical building Type2	Research method
Yusheng Zhou, Ying Shan Soh, Hui Shan Loh, Kum Fai Yuen	2020	Marine Policy	journal paper	empirical	empirical case study	case study
Stefan Wunderlich, David Saive	2020	International congress on blockchain and applications	conference	analytical	analytical conceptual	conceptual research
Mario Pečarić, Ivan Peronja, Mislav Mostarac	2020	Scientific Journal of Maritime Research	journal paper	analytical	analytical conceptual	conceptual research
Shuyi Pu, Jasmine Siu Lee Lam	2020	Maritime Policy & Management	journal paper	analytical	analytical conceptual	conceptual research
Safia NASIH, Sara AREZKI, Taoufiq GADI	2020	ACM International Conference Proceeding Series	conference	analytical	analytical conceptual	conceptual research
Ivan Peronja, Kristijan Lenac, Roko Glavinović	2020	Scientific Journal of Maritime Research	journal paper	analytical	analytical conceptual	conceptual research
Sergey Tsiulin, Kristian Hegner Reinau, Nikolay Goryaev	2020	2020 Global Smart Industry Conference (GloSIC)	conference	analytical	analytical conceptual	conceptual research
P Pranav, Ah Saikiran, MM Mukul, B Ravishankar, Vn Shailaja	2020	Proceedings of the International Conference on Mainstreaming Block Chain Implementation (ICOMBI) 2020	conference	analytical	analytical conceptual	conceptual research
Srdjan Vujiˇci´c, Nermin Hasanspahi´c, Maro Car, Leo Campara	2020	Journal of Marine Science and Engineering	journal paper	analytical	analytical conceptual	conceptual research
Perkušić, M., Jozipović, Š., Piplica, D.	2020	Transactions on Maritime Science	journal paper	analytical	analytical conceptual	conceptual research
Ling Li, Honggeng Zhou	2020	Information Systems and e-Business Management	journal paper	analytical	analytical conceptual	review
Sergey Tsiulin, Kristian Hegner Reinau, Olli-Pekka Hilmola, Nikolay Goryaev, Ahmed Karam	2020	Review of International Business and Strategy	journal paper	analytical	analytical conceptual	review
Marija Jovi´c, Edvard Tijan, Dražen Žgalji´c, Saša Aksentijevi´c	2020	Sustainability	journal paper	analytical	analytical conceptual	review
Elnaz Irannezhad	2020	Transportation Research Procedia	journal paper	analytical	analytical conceptual	review
Giorgio Bavassano, Claudio Ferrari, Alessio Tei	2020	Research in Transportation Business & Management	journal paper	empirical	empirical case study	survey
Yue Pang, Danshi Wang, Dongdong Wang, Luyao Guan, Chunyu Zhang, and Min Zhang	2020	2020 IEEE World Congress on Services (SERVICES)	conference	N	N	technological
Krishnasuri Narayanam, Seep Goel, Abhishek Singh, Yedendra Shrinivasan	2020	2020 IEEE International Conference on Blockchain (Blockchain)	conference	N	N	technological
Wee Kwan Albert Tan, Balan Sundarakani	2020	Journal of Global Operations and Strategic Sourcing	journal paper	empirical	empirical case study	case study
Ifeyinwa Juliet Orji, Simonov Kusi-Sarpong, Shuangfa Huang, Diego Vazquez-Brust	2020	Transportation Research Part E	journal paper	empirical	empirical statistical	quantitative empirical
Huiling Zhong, Fa Zhang, Yimiao Gu	2021	Transportation Research Part E	journal paper	analytical	analytical mathematical	math modelling
Junjin Wang, Jiaguo Liu, Fan Wang, Xiaohang Yue	2021	Transportation Research Part B	journal paper	analytical	analytical mathematical	math modelling

(*Continued*)

Authors	Year	Journal	Type of paper	Theoretical building		Research method
				Type1	Type2	
Shuyi Pu, Jasmine Siu Lee Lam	2021	International Conference on Industrial Engineering and Engineering management (IEEM)	conference	analytical	analytical mathematical	math modelling
G¨okcay Balci, Ebru Surucu-Balci	2021	Transportation Research Part E	journal paper	empirical	empirical case study	case study
Oliver Weisshuhn, Christian Greiner and Allan Ramdhony	2021	Proceedings of the 18th International Conference on e-Business, ICE-B 2021	conference	empirical	empirical case study	case study
Hvolby, H.-H., Steger-Jensen, K., Bech, Svensson, C., Neagoe, M.	2021	Procedia Computer Science	conference	empirical	empirical case study	case study
Sergey Tsiulin, Kristian Hegner Reinau	2021	Transportation Research Procedia	journal paper	empirical	empirical case study	case study
Suprateek Sarker, Stefan Henningsson, Thomas Jensen & Jonas Hedman	2021	Journal of Management Information Systems	journal paper	empirical	empirical case study	case study
Claudia A. Duran, Manuel Cargas, Christian Fernández-Campusano, And Alejandro Navarrete	2021	IEEE Access 9	conference	analytical	analytical conceptual	conceptual research
Hecai Han, Zhengjiang Liu, Xinjian Wang and Songyan Li	2021	journal of physics: conference series	conference	analytical	analytical conceptual	conceptual research
Hankun Shi and Xuelin Wang	2021	journal of physics: conference series	conference	analytical	analytical conceptual	conceptual research
Shaokun Liu	2021	IOP Conference Series: Earth and Environmental Science	conference	analytical	analytical conceptual	conceptual research
Elnaz Irannezhad, Hamed Faroqi	2021	Maritime Policy & Management	journal paper	analytical	analytical conceptual	conceptual research
Sven Marenković, Edvard Tijan, Saša Aksentijević	2021	44th International Convention on Information, Communication and Electronic Technology (MIPRO)	conference	analytical	analytical conceptual	Conceptual research
Nitin K. Tyagi, Mukta Goyal	2021	Concurrency Computation	journal paper	analytical	analytical conceptual	conceptual research
Jiaguo LIU, Huimin ZHANG, Huida ZHAO	2021	journal of systems science and information	journal paper	analytical	analytical mathematical	math modelling
Shuyi Pu, Jasmine Siu Lee Lam	2021	Transportation Research Part D	journal paper	analytical	analytical mathematical	meth modelling
Melis Kaska, A. Cagri Tolga	2021	International Conference on Intelligent and Fuzzy Systems	conference	empirical	empirical statistical	quantitative empirical
Hee-sung Bae	2021	Sustainability	journal paper	empirical	empirical statistical	quantitative empirical
Nebojsa Radonic, Mikkel Boding Kildetoft	2021	Forty-First International Conference on Information Systems, India 2020	conference	empirical	empirical case study	quantitative empirical
Raja Wasim Ahmad, Haya Hasan, Raja Jayaraman, Khaled Salah, Mohammed Omar	2021	Research in Transportation Business & Management	journal paper	analytical	analytical conceptual	review
Jiaguo Liu, Huimin Zhang & Lu Zhen	2021	International Journal of Production Research	journal paper	analytical	analytical conceptual	review

(*Continued*)

Authors	Year	Journal	Type of paper	Theoretical building		Research method
				Type1	Type2	
Dimah H. Alahmadi, Fatmah Abdulrahman Baothman, Mona M. Alrajhi, Fatimah S. Alshahrani, and Hawazin Z. Albalawi	2021	Journal of Intelligent Systems	journal paper	analytical	analytical conceptual	review
Ziaul Haque Munim, Okan Duru, Enna Hirata	2021	Journal of Marine Science and Engineering	journal paper	analytical	analytical conceptual	review
Son Nguyen, Peggy Shu-Ling Chen and Yuquan Du	2021	International Journal of Physical Distribution & Logistics Management	journal paper	analytical	analytical conceptual	review
Nexhat Kapidani, Sanja Bauk, and Innocent E. A. Davidson	2021	journal of marine science and engineering	journal paper	empirical	empirical case study	survey
Sangeerth, P.S and Lakshmy, K.V	2021	Proceedings of the Sixth International Conference on Inventive Computation Technologies	conference	N	N	technological
Omar Alkhoori, Abduraouf Hassan, Omar Almansoori, Mazin Debe, Khaled Salah, Raja Jayaraman, Junaid Arshad, Muhammad Habib Ur Rehman	2021	IEEE Access	conference	N	N	technological
Chunming Tang, Yuyu Ma, Xiang Yu	2021	E3S Web of Conferences	conference	N	N	technological
Mandrea Tesei, Domenico Lattuca, Alexander Tardo, Luca Di Mauro, Paolo Pagano, Marco Luise, Paulo C. Bartolomeu, Joaquim Ferreia	2021	IEEE Open Journal of Vehicular Technology	conference	N	N	technological
Kameshwaran Sampath, Sai Koti Reddy Danda, Ken Kumar	2021	2020 IEEE International Conference on Blockchain (Blockchain)	conference	N	N	technological
Qing Hu, H, and Qing, Wenshuo Han, H, and Wenshuo, Hao Zhang, Z, and Hao	2021	4th International Conference on Data Science and Information Technology	conference	N	N	technological
Warlley Paulo Freire, Wilson S. Melo Jr, Vinicius D. do Nascimento, Alan Oliveira de S´a	2021	International Workshop on Metrology for the Sea; Learning to Measure Sea Health Parameters (MetroSea)	conference	N	N	technological (simulation)

Appendix 2

Reviewed articles from Lloyd's List

Editor	Date	Title	Link
Katherine Espina	13.07.2016	PSA unboxed	https://lloydslist.maritimeintelligence.informa.com/LL022853/PSA-unboxed
Wei Zhe Tan	28.07.2017	Antwerp to use blockchain technology in container handling operations	https://lloydslist.maritimeintelligence.informa.com/LL108882/Antwerp-to-use-blockchain-technology-in-container-handling-operations
Georgie Furness-Smith	28.08.2017	MOL, NYK and K Line to develop trade data sharing platform using blockchain	https://lloydslist.maritimeintelligence.informa.com/LL111092/MOL-NYK-and-K-Line-to-develop-trade-data-sharing-platform-using-blockchain
James Baker	30.08.2017	MTI trials blockchain for VGM processing	https://lloydslist.maritimeintelligence.informa.com/LL111139/MTI-trials-blockchain-for-VGM-processing
James Baker	31.08.2017	Consolidation is driving digitalisation	https://lloydslist.maritimeintelligence.informa.com/LL111175/Consolidation-is-driving-digitalisation
Tae-Jun Kang	07.09.2017	HMM completes pilot blockchain voyage with reefer-laden boxship	https://lloydslist.maritimeintelligence.informa.com/LL111275/HMM-completes-pilot-blockchain-voyage-with-reefer-laden-boxship
Alan Bullion	28.09.2017	How blockchain could deliver safer global food supplies	https://lloydslist.maritimeintelligence.informa.com/LL111445/How-blockchain-could-deliver-safer-global-food-supplies
Tae-Jun Kang	06.11.2017	SM Line completes first pilot voyage using blockchain technology	https://lloydslist.maritimeintelligence.informa.com/LL112213/SM-Line-completes-first-pilot-voyage-using-blockchain-technology
Wei Zhe Tan	20.11.2017	Zim pilots electronic bills of lading on China to Canada voyage	https://lloydslist.maritimeintelligence.informa.com/LL1120105/Zim-pilots-electronic-bills-of-lading-on-China-to-Canada-voyage
Tae-Jun Kang	13.12.2017	MOL joins IBM for blockchain cross-border trade operations test	https://lloydslist.maritimeintelligence.informa.com/LL1120490/MOL-joins-IBM-for-blockchain-cross-border-trade-operations-test
James Baker	16.01.2018	Blockchain comes of age in shipping	https://lloydslist.maritimeintelligence.informa.com/LL1120865/Blockchain-comes-of-age-in-shipping
ANALYSIS	31.01.2018	Will 2018 be the year of shipping Initial Coin Offerings?	https://lloydslist.maritimeintelligence.informa.com/LL1121079/Will-2018-be-the-year-of-shipping-Initial-Coin-Offerings
Will Waters and Mike King	01.02.2018	Container shipping's first dedicated crypto currency launched	https://lloydslist.maritimeintelligence.informa.com/LL1121112/Container-shippings-first-dedicated-crypto-currency-launched
Wei Zhe Tan	02.02.2018	New box demand to buoy container manufacturing sector, says Teo	https://lloydslist.maritimeintelligence.informa.com/LL1121054/New-box-demand-to-buoy-container-manufacturing-sector-says-Teo
Wei Zhe Tan	22.02.2018	PIL, PSA and IBM complete blockchain trial	https://lloydslist.maritimeintelligence.informa.com/LL1121520/PIL-PSA-and-IBM-complete-blockchain-trial
Tae-Jun Kang	23.02.2018	Korea's shipping blockchain consortium gets more members	https://lloydslist.maritimeintelligence.informa.com/LL1121523/Koreas-shipping-blockchain-consortium-gets-more-members
Cichen Shen	15.03.2018	APL and K+N join the blockchain bandwagon	https://lloydslist.maritimeintelligence.informa.com/LL1121842/APL-and-KN-join-the-blockchain-bandwagon
Wei Zhe Tan	19.03.2018	Tech firm concludes pilot blockchain shipment	https://lloydslist.maritimeintelligence.informa.com/LL1121885/Tech-firm-concludes-pilot-blockchain-shipment
Richard Clayton	22.03.2018	Lloyd's Register Foundation to fund maritime blockchain project	https://lloydslist.maritimeintelligence.informa.com/LL1121941/Lloyds-Register-Foundation-to-fund-maritime-blockchain-project
Cichen Shen	25.04.2018	SMW: Hype around blockchain fails to impress	https://lloydslist.maritimeintelligence.informa.com/LL1122351/SMW-Hype-around-blockchain-fails-to-impress
Cichen Shen	25.04.2018	SMW: ONE sets out its digitalisation priorities	https://lloydslist.maritimeintelligence.informa.com/LL1122344/SMW-ONE-sets-out-its-digitalisation-priorities

(*Continued*)

Editor	Date	Title	Link
James Baker	18.05.2018	An INTTRA for blockchain?	https://lloydslist.maritimeintelligence.informa.com/LL1122657/An-INTTRA-for-blockchain
Trevor Heaver	10.07.2018	Managing maritime logistics in the cyber age	https://lloydslist.maritimeintelligence.informa.com/LL1123316/Managing-maritime-logistics-in-the-cyber-age
Nidaa Bakhsh	10.07.2018	Blockchain-based marine insurance platform tries to recruit users	https://lloydslist.maritimeintelligence.informa.com/LL1123030/Blockchain-based-marine-insurance-platform-tries-to-recruit-users
James Baker	17.07.2018	Shipowners see emissions technology as driver of change over next five years	https://lloydslist.maritimeintelligence.informa.com/LL1123429/Shipowners-see-emissions-technology-as-driver-of-change-over-next-five-years
Cichen Shen	19.07.2018	CargoSmart joins the list of blockchain middlemen	https://lloydslist.maritimeintelligence.informa.com/LL1123469/CargoSmart-joins-the-list-of-blockchain-middlemen
James Baker	09.08.2018	Maersk and IBM launch blockchain product	https://lloydslist.maritimeintelligence.informa.com/LL1123805/Maersk-and-IBM-launch-blockchain-product
James Baker	10.08.2018	A party for one ain't no fun	https://lloydslist.maritimeintelligence.informa.com/LL1123812/A-party-for-one-aint-no-fun
Vincent Wee	04.10.2018	PIL and IBM to develop electronic bill of lading	https://lloydslist.maritimeintelligence.informa.com/LL1124476/PIL-and-IBM-to-develop-electronic-bill-of-lading
Vincent Wee	22.10.2018	Abu Dhabi Ports partners MSC for blockchain pilot project	https://lloydslist.maritimeintelligence.informa.com/LL1124685/Abu-Dhabi-Ports-partners-MSC-for-blockchain-pilot-project
James Baker	06.11.2018	New kids on the blockchain	https://lloydslist.maritimeintelligence.informa.com/LL1124962/New-kids-on-the-blockchain
James Baker	06.11.2018	Leading carriers launch new blockchain platform	https://lloydslist.maritimeintelligence.informa.com/LL1124961/Leading-carriers-launch-new-blockchain-platform
James Baker	09.11.2018	Blockchain trials turn to finance	https://lloydslist.maritimeintelligence.informa.com/LL1125006/Blockchain-trials-turn-to-finance
Cichen Shen	17.01.2019	Qingdao Port joins blockchain consortium GSBN	https://lloydslist.maritimeintelligence.informa.com/LL1125897/Qingdao-Port-joins-blockchain-consortium-GSBN
Hwee Hwee Tan	31.01.2019	PIL pilots non-negotiable e-BL on lunar new year shipment	https://lloydslist.maritimeintelligence.informa.com/LL1126101/PIL-pilots-non-negotiable-e-BL-on-lunar-new-year-shipment
James Baker	07.02.2019	Blockchain needs standards for full adoption	https://lloydslist.maritimeintelligence.informa.com/LL1126171/Blockchain-needs-standards-for-full-adoption
James Baker	20.02.2019	Ports sector failing to take cyber security seriously	https://lloydslist.maritimeintelligence.informa.com/LL1126353/Ports-sector-failing-to-take-cyber-security-seriously
James Baker	17.04.2019	Zim joins Maersk's blockchain platform	https://lloydslist.maritimeintelligence.informa.com/LL1127110/Zim-joins-Maersks-blockchain-platform
Vincent Wee	29.04.2019	Ports must be part of global digital network	https://lloydslist.maritimeintelligence.informa.com/LL1127247/Ports-must-be-part-of-global-digital-network
James Baker	28.05.2019	CMA CGM and MSC to join TradeLens	https://lloydslist.maritimeintelligence.informa.com/LL1127655/CMA-CGM-and-MSC-to-join-TradeLens
James Baker	25.06.2019	Pilot project seeks to prevent misdeclared cargoes with blockchain	https://lloydslist.maritimeintelligence.informa.com/LL1128047/Pilot-project-seeks-to-prevent-misdeclared-cargoes-with-blockchain
Vincent Wee	12.07.2019	CargoSmart's GSBN settles on service agreements with industry leaders	https://lloydslist.maritimeintelligence.informa.com/LL1128369/CargoSmarts-GSBN-settles-on-service-agreements-with-industry-leaders
Cichen Shen	15.07.2019	Cosco Shipping may join digital standardisation group	https://lloydslist.maritimeintelligence.informa.com/LL1128380/Cosco-Shipping-may-join-digital-standardisation-group
Cichen Shen	27.09.2019	The Interview: Xu Lirong	https://lloydslist.maritimeintelligence.informa.com/LL1129331/The-Interview-Xu-Lirong
James Baker	30.09.2019	Blockchain pioneer suspends operations	https://lloydslist.maritimeintelligence.informa.com/LL1129358/Blockchain-pioneer-suspends-operations

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Editor	Date	Title	Link
James Baker	07.10.2019	Digital service providers begin to gain traction	https://lloydslist.maritimeintelligence.informa.com/LL1129443/Digital-service-providers-begin-to-gain-traction
Vincent Wee	06.11.2019	Hong Kong pushes forward with blockchain project for trade finance	https://lloydslist.maritimeintelligence.informa.com/LL1129854/Hong-Kong-pushes-forward-with-blockchain-project-for-trade-finance
James Baker	03.12.2019	Supply chain braces for next industrial revolution	https://lloydslist.maritimeintelligence.informa.com/LL1130235/Supply-chain-braces-for-next-industrial-revolution
David Osler	27.01.2020	New eBill of Lading promises greater security	https://lloydslist.maritimeintelligence.informa.com/LL1130789/New-eBill-of-Lading-promises-greater-security
Inderpreet Walia	27.02.2020	Progress made in digital shipping platform network	https://lloydslist.maritimeintelligence.informa.com/LL1131297/Progress-made-in-digital-shipping-platform-network
Cichen Shen	17.04.2020	Cosco, SIPG and Tesla in blockchain test	https://lloydslist.maritimeintelligence.informa.com/LL1131853/Cosco-SIPG-and-Tesla-in-blockchain-test
James Baker	16.05.2020	Roadmap leads way to digital bills of lading	https://lloydslist.maritimeintelligence.informa.com/LL1132399/Roadmap-leads-way-to-digital-bills-of-lading
David Osler	28.05.2020	DP World seeks to integrate all terminals with TradeLens	https://lloydslist.maritimeintelligence.informa.com/LL1132494/DP-World-seeks-to-integrate-all-terminals-with-TradeLens
Cichen Shen	07.07.2020	Cosco agrees blockchain technology deal with Alibaba	https://lloydslist.maritimeintelligence.informa.com/LL1132953/Cosco-agrees-blockchain-technology-deal-with-Alibaba
David Osler	01.09.2020	Time is right for electronic bills of lading	https://lloydslist.maritimeintelligence.informa.com/LL1133734/Time-is-right-for-electronic-bills-of-lading
August Braakman	05.10.2020	Is digital leviathan a risk to fair competition in shipping?	https://lloydslist.maritimeintelligence.informa.com/LL1134139/Is-digital-leviathan-a-risk-to-fair-competition-in-shipping
Richard Clayton	09.10.2020	Digitalisation: Do the numbers stack up?	https://lloydslist.maritimeintelligence.informa.com/LL1134212/Digitalisation-Do-the-numbers-stack-up
James Baker	15.10.2020	Carriers complete TradeLens integration	https://lloydslist.maritimeintelligence.informa.com/LL1134279/Carriers-complete-TradeLens-integration
Vincent Wee	11.11.2020	ICTSI joins Maersk's TradeLens platform	https://lloydslist.maritimeintelligence.informa.com/LL1134631/ICTSI-joins-Maersks-TradeLens-platform
August Braakman	05.01.2021	Will carriers control shipping's digitalisation?	https://lloydslist.maritimeintelligence.informa.com/LL1135288/Will-carriers-control-shippings-digitalisation
Cichen Shen	17.03.2021	Cosco-led blockchain shipping platform wins regulatory approvals	https://lloydslist.maritimeintelligence.informa.com/LL1136160/Cosco-led-blockchain-shipping-platform-wins-regulatory-approvals
Cichen Shen	11.05.2021	China Unicom joins TradeLens platform	https://lloydslist.maritimeintelligence.informa.com/LL1136723/China-Unicom-joins-TradeLens-platform
Cichen Shen	17.06.2021	TradeLens makes inroads in Chinese market	https://lloydslist.maritimeintelligence.informa.com/LL1137196/TradeLens-makes-inroads-in-Chinese-market
Cichen Shen	21.07.2021	Cosco-backed platform launches first application in China	https://lloydslist.maritimeintelligence.informa.com/LL1137629/Cosco-backed-platform-launches-first-application-in-China
Cichen Shen	25.08.2021	Logistics platform extends reach to Southeast Asia	https://lloydslist.maritimeintelligence.informa.com/LL1137992/Logistics-platform-extends-reach-to-Southeast-Asia
James Baker	10.09.2021	Hapag-Lloyd offers electronic bills of lading	https://lloydslist.maritimeintelligence.informa.com/LL1138131/Hapag-Lloyd-offers-electronic-bills-of-lading
Cichen Shen	15.09.2021	Major banks join blockchain shipping trade finance project	https://lloydslist.maritimeintelligence.informa.com/LL1138215/Major-banks-join-blockchain-shipping-trade-finance-project
Jacco De Jong	25.11.2021	Electronic bills of lading are disrupting the traditional supply chain	https://lloydslist.maritimeintelligence.informa.com/LL1139009/Electronic-bills-of-lading-are-disrupting-the-traditional-supply-chain

(*Continued*)

Editor	Date	Title	Link
NEWS	22.02.2018	Fujairah adopts blockchain to gather oil storage data	https://lloydslist.maritimeintelligence.informa.com/LL1121513/Fujairah-adopts-blockchain-to-gather-oil-storage-data
Anastassios Adamopoulos	03.02.2019	NYK and BHP bunker vessel with biofuel using blockchain	https://lloydslist.maritimeintelligence.informa.com/LL1126117/NYK-and-BHP-bunker-vessel-with-biofuel-using-blockchain
Vincent Wee	06.11.2019	Trafigura unveils blockchain trade platform in Singapore	https://lloydslist.maritimeintelligence.informa.com/LL1129853/Trafigura-unveils-blockchain-trade-platform-in-Singapore
Vincent Wee	23.01.2020	ICC signs deal to boost digitalisation of global trade and commerce	https://lloydslist.maritimeintelligence.informa.com/LL1130753/ICC-signs-deal-to-boost-digitalisation-of-global-trade-and-commerce
Cichen Shen	19.05.2020	Chinese tanker giants push for blockchain use in oil trade	https://lloydslist.maritimeintelligence.informa.com/LL1132397/Chinese-tanker-giants-push-for-blockchain-use-in-oil-trade
Vincent Wee	07.01.2021	Singapore gets first fully digitalised bunker trade	https://lloydslist.maritimeintelligence.informa.com/LL1135315/Singapore-gets-first-fully-digitalised-bunker-trade
Cichen Shen	20.10.2021	China Merchants launches commodity shipping platform	https://lloydslist.maritimeintelligence.informa.com/LL1138559/China-Merchants-launches-commodity-shipping-platform

APPENDIX B. ETHICAL APPROVAL FORM AND QUESTIONNAIRES

B1 Research ethics approval

Monday, November 18, 2024 at 23:42:16 Korean Standard Time

Subject: Your ethics application has been APPROVED: ID 1322; questionnaire survey
Date: Thursday, October 20, 2022 at 12:19:49 am Korean Standard Time
From: CARBS Research Office-Ethics
To: Sanghoon Shin

Dear Sanghoon Shin,

Research project title: The impact of blockchain application in maritime supply chain integration
SREC reference: 1322

The School Research Ethics Committee (SREC) reviewed the above application via its proportionate review process.

Ethical Opinion
The Committee gave a favourable ethical opinion of the above application on the basis described in the application form, protocol and supporting documentation.

Additional approvals
This letter provides an ethical opinion only. You must not start your research project until all any other approvals required for your research project (where relevant) are in place.

Amendments
Any substantial amendments to documents previously reviewed by the Committee must be submitted to the Committee via CARBS-ResearchEthics@cardiff.ac.uk for consideration and cannot be implemented until the Committee has confirmed it is satisfied with the proposed amendments.

You are permitted to implement non-substantial amendments to the documents previously reviewed by the Committee but you must provide a copy of any updated documents to the Committee via CARBS-ResearchEthics@cardiff.ac.uk for its records.

Monitoring requirements
The Committee must be informed of any unexpected ethical issues or unexpected adverse events that arise during the research project.

The programme director would include your research in end of project report. The Committee must be informed when your research project has ended. This notification should be made to CARBS-researchethics@cardiff.ac.uk within three months of research project completion.

Documents reviewed by the Committee
The documents reviewed by the Committee were:
Application ID: 1322
Link to applications list, where you can access the reviewed version.
CARBS Ethics Application Form October 2021 [version4].docx
Questionnaire.xlsx
SREC-New feedback form - July 2021 version(3).docx

Template Consent Form(1)(1).docx
Template Participant Information Sheet(1)(1).docx
ㅅㅡㅋㅡㄹㅣㄴㅅㅑㅅ 2022-08-26 ㅇㅗㅈㅓㄴ 3.20.30.png

Complaints/Appeals
If you are dissatisfied with the decision made by the Committee, please contact Dr Carmela Bosangit (BosangitC@cardiff.ac.uk) in the first instance to discuss your complaint. If this discussion does not resolve the issue, you are entitled to refer the matter to the Head of School for further consideration. The Head of School may refer the matter to the University Research Integrity and Ethics Committee (URIEC), where this is appropriate. Please be advised that URIEC will not normally interfere with a decision of the Committee and is concerned only with the general principles of natural justice, reasonableness and fairness of the decision.

Please use the Committee reference number on all future correspondence.

The Committee reminds you that it is your responsibility to conduct your research project to the highest ethical standards and to keep all ethical issues arising from your research project under regular review.

You are expected to comply with Cardiff University's policies, procedures and guidance at all times, including, but not limited to, its Policy on the Ethical Conduct of Research involving Human Participants, Human Material or Human Data and our Research Integrity and Governance Code of Practice .

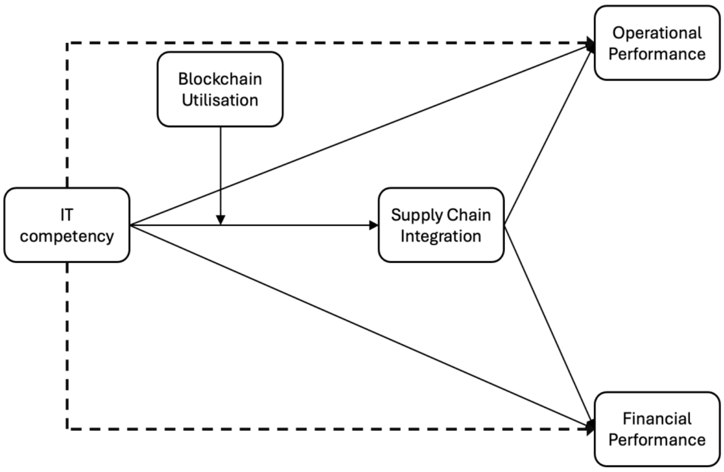
Yours sincerely,

Dr Carmela Bosangit
Chair of School Research Ethics Committee

B2. Questionnaire in English

Questionnaire

Thank you for your corporation.
This questionnaire aims to investigate the relationship between supply chain integration and IT competency of the organisation, and their impact on the performance with moderating effect of blockchain adoption in the mairitime supply chain. The survey consists of four sections, 1. Supply chain integration, 2. IT competitiveness, 3. Blockchain adoption, and 4. Performance.



This survey is conducted anonymously, and the results are statistically processed so that the personal and company responses are kept confidential. Also, the results of the investigation are used only for pure academic purposes. Your participation in this study is completely voluntary. There are under no obligation to participate in this survey. If you feel uncomfortable answering any questions, you may decline to answer any given question. It will take approximately 15 minutes to complete the questionnaire.
If you agree with this, pleas answer honestly as you normally feel. it will be a great help in the development of the shipping industry.

September, 2022

Researcher: Sanghoon Shin, Logistics Operation and Management,Cardiff University

Ⅰ. The following questions are about your integration with partners in the maritime supply chain. Following questions are related to the transition and logistics-related activities with main partners such as shipping liners, container terminals, forwarders, ports, and logistics companies in the maritime supply chain. please check the item that best suits your organisation.

	Questions	strongly disagree	neutral	strongly agree

1	Our firm and supply chain partners provide any information that might help within our maritime supply chain	1····2····3····4····5····6····7
2	Our firm and supply chain partners frequently exchange information within maritime supply chain	1····2····3····4····5····6····7
3	Our firm and supply chain partners have informed each other of changing needs in advance within our maritime supply chain.	1····2····3····4····5····6····7
4	Our firm and supply chain partners keep each other informed about events or changes that may affect our maritime supply chain.	1····2····3····4····5····6····7
5	Our firm and supply chain partners exchange accurate information within our maritime supply chain	1····2····3····4····5····6····7
6	Our firm and supply chain partners search and acquire new and relevant knowledge within our maritime supply chain	1····2····3····4····5····6····7
7	Our firm and supply chain partners assimilate and apply relevant knowledge within our maritime supply chain	1····2····3····4····5····6····7
8	Our firm and supply chain partners identify customer needs for our maritime supply chain	1····2····3····4····5····6····7
9	Our firm and supply chain partners discover new technology for our maritime supply chain	1····2····3····4····5····6····7
10	Our firm and supply chain partners learn the intentions and capabilities of other maritime supply chain in competition.	1····2····3····4····5····6····7
11	Our firm and supply chain partners have frequent contacts on a regular basis in our maritime supply chain	1····2····3····4····5····6····7
12	Our firm and supply chain partners have open and two-way communication in our maritime supply chain	1····2····3····4····5····6····7
13	Our firm and supply chain partners have informal communication in our maritime supply chain	1····2····3····4····5····6····7
14	Our firm and supply chain partners have many different channels to communicate through in our maritime supply chain	1····2····3····4····5····6····7
15	Our firm and supply chain partners have influence over each other’s decisions through discussion in our maritime supply chain	1····2····3····4····5····6····7
16	Our firm and supply chain partners pursue efficient multi-modal transport of container cargoes for our maritime supply chain	1····2····3····4····5····6····7
17	Our firm and supply chain partners stress the importance of collaboration within our maritime supply chain	1····2····3····4····5····6····7
18	Our firm and supply chain partners pursue the provision of value-added logistics services for our maritime supply chain	1····2····3····4····5····6····7
19	Our firm and supply chain partners pursue cost reduction throughout our maritime supply chain	1····2····3····4····5····6····7
20	Our firm and supply chain partners pursue reduced cycle times and enhanced inventory management for our maritime supply chain	1····2····3····4····5····6····7
21	Our firm and supply chain partners plan on emergent situations within our maritime supply chain	1····2····3····4····5····6····7
22	Our firm and supply chain partners plan on altering schedules and amending orders when customers demand them within our maritime supply chain	1····2····3····4····5····6····7
23	Our firm and supply chain partners manage the flow of cargoes within maritime supply chain	1····2····3····4····5····6····7
24	Our firm and supply chain partners plan on transport planning and scheduling transport within our maritime supply chain	1····2····3····4····5····6····7
25	Our firm and supply chain partners advise each other of any potential problems in meeting the shipper’s needs within our maritime supply chain	1····2····3····4····5····6····7
26	Our firm and supply chain partners develop systems to evaluate supply chain performance for our maritime supply chain	1····2····3····4····5····6····7
27	Our firm and supply chain partners deal with security and risks that may occur for our maritime supply chain	1····2····3····4····5····6····7

28	Our firm and supply chain partners develop systems to enable shippers to identify their cargoes' location for our maritime supply chain	1····2····3····4····5····6····7
29	Our firm and supply chain partners keep seamless transport flows even in a peak time for our maritime supply chain	1····2····3····4····5····6····7
30	Our firm and supply chain partners solve the problems together (i.e. delay and accidents in transport) for our maritime supply chain	1····2····3····4····5····6····7

Ⅱ. This question is related to IT competitiveness. For each of the following questions about your company's activities in the IT sector. please check the item that best suits your organisation.

	Questions	strongly disagree neutral strongly agree
1	Our organisation has established corporate rules and standards for hardware and operating systems to ensure platform compatibility	1····2····3····4····5····6····7
2	Our organisation has identified and standardized data to be shared across systems and business units	1····2····3····4····5····6····7
3	The manner in which the components of our information systems are organized and integrated allows for rapid changes	1····2····3····4····5····6····7
4	Our organisation's information systems are designed to support new business relationships easily	1····2····3····4····5····6····7
5	Our organisation's information systems are designed to rapidly accommodate changes in business requirements	1····2····3····4····5····6····7
6	Our organisation can implement IT in many business processes	1····2····3····4····5····6····7
7	Our organisation can implement IT in a large number of functional areas	1····2····3····4····5····6····7
8	The extent to which IT is used in our business processes (e.g., operation, management, and decision making) is great	1····2····3····4····5····6····7
9	Our organisation can integrate existing and new IT systems for business application	1····2····3····4····5····6····7
10	In our organisation, top managers are interested in using IT applications	1····2····3····4····5····6····7
11	In our firms, top managers consider IT applications as important	1····2····3····4····5····6····7
12	In our firms, top managers commit to support IT applications	1····2····3····4····5····6····7
13	Our IT personnel works well in cross-functional teams addressing business problems	1····2····3····4····5····6····7
14	Our IT personnel is encouraged to learn new technology	1····2····3····4····5····6····7
15	Our IT personnel is able to interpret business problems and develop appropriate technical solutions	1····2····3····4····5····6····7
16	Our IT personnel has the ability to work cooperatively in a project team environment	1····2····3····4····5····6····7
17	Our IT personnel is skilled in multiple technologies and tools	1····2····3····4····5····6····7

Ⅲ. This section is about the blockchain adoption. Please mark the number which indicates the situation of the company.

Blockchain is a new way of storing data. Blockchain can increase security by encrypting data and secure trust between users through decentralised system management. A decentralised system is the system where each participants has the authority to create information rather than a central body. The generated information is shared in real time with the consent of users to ensure transparency and promptness of the information.

The introduction of blockchain to the shipping industry where information asymmetry exists is expected to improve the security, reliability and transparency of transaction information, thereby solving the existing inefficient information management and problems in information exchange. Blockchain is applied to document management, transaction management, and cargo/ship/terminal device management in the shipping industry. Participants in transaction can easily check the current status and past history by tracking transport-related information which is immutable. This makes it possible for all actors in the supply chain to check information and process transportation procedures quickly and accurately. In addition, through IoT sensors, the temperature and weight of containers and status information of shipments can be managed with blockchain system. Representative examples include TradeLens from Maersk and GSBN from COSCO.

	Questions	strongly disagree neutral strongly agree
1	Our organisation invests resources to adopt BCT	1····2····3····4····5····6····7
2	Our organisation is using BCT to support document management by supporting digitalisation, real-time exchange, and standardisaion	1····2····3····4····5····6····7
3	Our organisation is utilising BCT to support transactions with supply chain partners in the decentralised and automated system	1····2····3····4····5····6····7
4	Our organisation is utilising BCT in the physical movement of cargo through vessel and port terminal	1····2····3····4····5····6····7

Ⅳ. This section is about the perfornance. Please mark the number which indicates the situation of the company.

	Questions	strongly disagree neutral strongly agree
1	Our organisation has improved the speed of supply chain operations	1····2····3····4····5····6····7
2	Our organisation has reduced transaction costs of supply chain operations	1····2····3····4····5····6····7
3	Our organisation and maritimes supply chain can improve the quality of services provided to customers	1····2····3····4····5····6····7
4	Our organisation and maritime supply chain can create value in supply chain integration	1····2····3····4····5····6····7
5	Our organisation and maritime supply chain can quickly respond to changes in market demand	1····2····3····4····5····6····7
6	The lead time for fulfilling customers' orders in our maritime supply chain (the time which elapses between the receipt of customer's order and the delivery of	1····2····3····4····5····6····7
7	Our organisation has improved its return on investment by efficient operation of maritime supply chain	1····2····3····4····5····6····7
8	Our organisation has improved its return on sales by efficient operation of maritime supply chain	1····2····3····4····5····6····7
9	Our organisation has improved its market share by efficient operation of maritime supply chain	1····2····3····4····5····6····7
10	Our organisation has improved its net income before tax by efficient operation of maritime supply chain	1····2····3····4····5····6····7
11	Our organisation has improved its cash flow from operations by efficient operation of maritime supply chain	1····2····3····4····5····6····7

V. This section is general Questions	
1	When was your organisation established?
2	What is your organisations' business type? ① Shipping liner ② Terminal operator ③ Freight forwarder ④ Port authority ⑤ Etc.
3	What is your organisation's nationality? ① Seoul ② Busan ③ Incheon ④ Other Korea ⑤ Asia ⑥ Europe ⑦ North America ⑧ Other
4	How many employess are in your organisation?
5	How old are you?
6	What is your task? ① Management ② Human resources ③ Sales and customer ④ IT support ⑤ Pruchasing ⑥Etc.
7	What is your position in your organisation? ① Staff ② Senior Staff ③ Manager ④ General manager ⑤ Executive director ⑥ CEO
8	How long have you worked in the organisation?

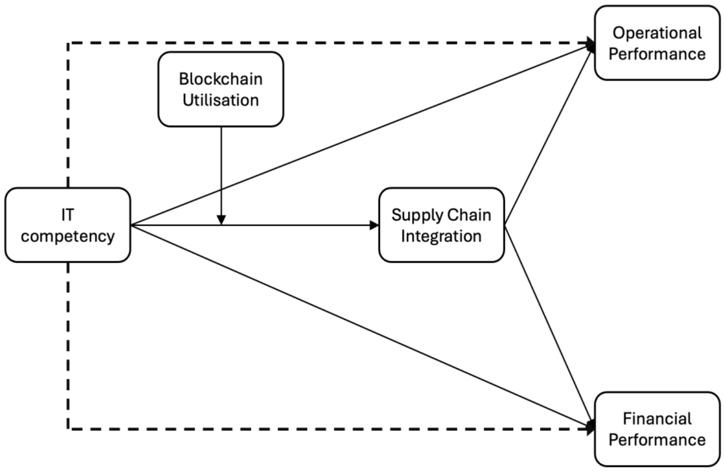
Thank you for answering.

B3. Questionnaire in Korean

Questionnaire

안녕하십니까? 귀사의 무궁한 발전을 기원합니다.

본 조사는 해운항만물류 SCM의 IT역량과 정보통합 그리고 Blockchain 도입 및 활용에 대하여 설문하여 해운항만물류산업의 경쟁력 강화에 기여하고자 시행합니다. 이 설문조사는 해운기업의 공급사슬통합과 IT 경쟁력, 기업의 성과간의 관계에 있어 블록체인의 도입의 조절효과를 검증하기 위하여 개발되었습니다. 이 설문조사는 1. 해운공급사슬망 통합, 2. IT 경쟁력, 3. 블록체인의 도입, 4. 기업성과의 4개 부분으로 구성되어 있습니다.



이 조사는 무기명으로 실시되고, 결과는 통계적으로 처리되므로 개인 및 기업의 응답내용은 절대 비밀이 보장됩니다. 또한 조사결과는 순수한 학술목적 이외에는 사용되지 않습니다. 당신의 참여는 완전히 자발적으로, 이 조사에 참여하여야할 의무는 없습니다. 만약 질문에 답하는것에 불편하시다면 답을 하지 않으셔도 괜찮습니다. 설문을 완성하는데 대략 15분 정도가 소요 될 것 입니다. 평소 느끼신 대로 솔직하게 빠지는 문항 없이 대답해 주시어 해운항만물류산업의 발전에 도움이 될 수 있도록 협조 부탁드립니다.

September, 2022

연구자: 신상훈, Logistics Operation and Management,Cardiff University

Ⅰ. 다음 문항들은 귀사와 해운항만물류공급사슬(maritime supply chain)내의 파트너들과의 협력에 관한 질문 입니다. 공급사슬(supply chain)내 유력한 주거래 해운선사, 컨테이너 터미널, 포워더, 항만, 물류업자 등의 파트너와의 거래 및 물류관련활동에 대한 아래 각 문항에 대해 가장 잘 맞는 해당항목의 번호 (1~7)를 기입해 주십시오.

	Questions	전혀 그렇지 않다 보통이 다 전적으로 그렇다

1

1	우리 회사와 파트너들은 해운공급사슬(maritime supply chain) 내에 도움이 될 수 있는 정보를 상호 제공합니다.	1····2····3····4····5····6····7
2	리 회사와 파트너들은 해운공급사슬(maritime supply chain) 내에서 자주 정보를 교환합니다.	1····2····3····4····5····6····7
3	우리 회사와 파트너들은 해운공급사슬(maritime supply chain) 내 파트너들 간 필요사항을 미리 전달합니다.	1····2····3····4····5····6····7
4	우리 회사와 파트너들은 우리 해운공급사슬(maritime supply chain)에 영향을 미칠 사건이나 변화에 대하여 서로 공유 합니다.	1····2····3····4····5····6····7
5	우리 회사와 파트너들은 해운공급사슬(maritime supply chain) 내에서 정확한 정보를 교환합니다.	1····2····3····4····5····6····7
6	우리 회사는 파트너들과 함께 해운공급사슬(maritime supply chain) 내에서 새로운 관련지식을 찾고 학습합니다.	1····2····3····4····5····6····7
7	우리 회사는 파트너들과 함께 해운공급사슬(maritime supply chain) 내 관련 지식을 완전히 이해하고 적용합니다.	1····2····3····4····5····6····7
8	우리 회사와 파트너들은 우리 해운공급사슬(maritime supply chain)의 고객요구를 확인합니다.	1····2····3····4····5····6····7
9	우리 회사와 파트너들은우리 해운공급사슬(maritime supply chain)을 위한 새로운 기술을 찾으려고 노력합니다.	1····2····3····4····5····6····7
10	우리 회사와 파트너들은 경쟁 해운공급사슬(maritime supply chain)의 나아갈 방향과 공급사슬(supply chain)운영 능력을 학습합니다.	1····2····3····4····5····6····7
11	우리 회사와 파트너들은 해운공급사슬(maritime supply chain) 내에서 정기적으로 자주 연락합니다.	1····2····3····4····5····6····7
12	우리 회사와 파트너들은 해운공급사슬 내에서 개방적이고 쌍방간의 의사소통을 하고 있습니다.	1····2····3····4····5····6····7
13	우리 회사와 파트너들은 해운공급사슬 내에서 비공식적인 의사소통을 하고 있습니다.	1····2····3····4····5····6····7
14	우리 회사와 파트너들은 해운공급사슬 내에서 다양한 의사소통 채널을 가지고 있습니다.	1····2····3····4····5····6····7
15	우리 회사와 파트너들은 해운공급사슬 내에서의 의견조율을 통해 서로 의사결정에 영향력을 미칩니다.	1····2····3····4····5····6····7
16	우리 회사와 파트너들은 우리 해운공급사슬을 위해 효율적인 복합운송(multi-modal) 관련 업무를 추구합니다.	1····2····3····4····5····6····7
17	우리 회사와 파트너들은 우리 해운공급사슬 내에서 협력의 중요성을 강조합니다.	1····2····3····4····5····6····7
18	우리 회사와 파트너들은 우리 해운공급사슬을 위해 부가가치를 창출을 위한 물류활동을 추구합니다.	1····2····3····4····5····6····7
19	우리 회사와 파트너들은 우리 효율적인 해운공급사슬 운영을 통해 비용절감을 추구합니다.	1····2····3····4····5····6····7
20	우리 회사와 파트너들은 우리 해운공급사슬을 위해 순환시간을 단축하고 재고관리를 강화합니다.	1····2····3····4····5····6····7
21	우리 회사와 파트너들은 우리 해운공급사슬 내에서 긴급상황에 대하여 함께 사전계획을 세웁니다.	1····2····3····4····5····6····7
22	우리 회사와 파트너들은 고객의 요청이 있을시, 해운공급사슬 내의 일정 변경 및 주문수정에 대한 대비계획을 함께 세웁니다.	1····2····3····4····5····6····7
23	우리 회사와 파트너들은 해운공급사슬 내에서 화물의 흐름을 관리합니다.	1····2····3····4····5····6····7
24	우리 회사와 파트너들은 우리 해운공급사슬 내에에 운송계획과 운송일정을 함께 계획합니다.	1····2····3····4····5····6····7
25	우리 회사와 파트너들은 우리 해운공급사슬 내에 잠재적 화주의 요구를 충족하기 위하여 서로 조언(advice)합니다.	1····2····3····4····5····6····7
26	우리 회사와 파트너들은 우리 해운공급사슬을 위하여 공급사슬의 성과를 측정하기 위한 시스템을 개발합니다.	1····2····3····4····5····6····7
27	우리 회사와 파트너들은 우리 해운공급사슬에 발생할 수 있는 보안 문제와 위험을 관리합니다.	1····2····3····4····5····6····7

28	우리 회사와 파트너들은 우리 해운공급사슬을 위하여 화주들이 화물의 위치를 확인할 수 있도록 시스템을 개발합니다.	1····2····3····4····5····6····7
29	우리 회사와 파트너들은 우리 해운공급사슬을 위하여 peak time에도 끊김없는 운송 흐름을 유지합니다.	1····2····3····4····5····6····7
30	우리 회사와 파트너들은 우리 해운공급사슬을 위하여 운송지연과 사고 등의 문제를 효과적으로 해결합니다.	1····2····3····4····5····6····7

Ⅱ. 이 질문은 IT 경쟁력과 관련된 질문입니다. 귀사의 IT 부문의 활동에 대한 아래 각 문항에 대해 가장 잘 맞는 해당항목의 번호 (1~7)을 기입해 주십시오.

	Questions	전혀 그렇지 않다 / 보통이다 / 전적으로 그렇다
1	우리 회사는 플랫폼의 호환성을 위해 하드웨어와 운영 시스템을 위한 기업규정과 기준을 수립하였습니다.	1····2····3····4····5····6····7
2	우리 회사는 시스템과 사업단위 간 공유되는 데이터를 정의하고 표준화 합니다.	1····2····3····4····5····6····7
3	우리 회사의 정보시스템은 빠른 변화에 대응 및 적응할 수 있도록 조직화 되고 통합된 정도가 높습니다.	1····2····3····4····5····6····7
4	우리 정보 시스템은 새로운 업무를 지원하기 쉽게 디자인 되어 있습니다.	1····2····3····4····5····6····7
5	우리 정보 시스템은 사업적 요구를 빠르게 수용 할 수 있도록 디자인 되었습니다.	1····2····3····4····5····6····7
6	우리 회사는 다양한 업무과정에 IT를 적용 할 수 있습니다.	1····2····3····4····5····6····7
7	우리 회사는 많은 종류의 기능적 영역에 IT를 적용 할 수 있습니다.	1····2····3····4····5····6····7
8	리 회사의 업무과정에 IT가 적용되고 있는 정도는 높습니다 (운영, 관리 및 의사결정)	1····2····3····4····5····6····7
9	우리 회사는 기존의 IT 시스템과 새로운 시스템을 통합하여 업무에 적용할 수 있습니다.	1····2····3····4····5····6····7
10	우리 회사에서, 최고 경영층은 회사에 IT를 적용하는 것에 관심이 많습니다.	1····2····3····4····5····6····7
11	우리 회사에서 최고 경영층은 회사에 IT를 적용하는 것을 중요하게 여기고 있으며 강조하고 있습니다.	1····2····3····4····5····6····7
12	우리 회사에서, 최고 경영층은 회사에 IT를 적용하는것에 헌식적으로 지원합니다.	1····2····3····4····5····6····7
13	우리 회사의 IT 인력은 다른 업무부서들과 문제해결을 위해 협력합니다.	1····2····3····4····5····6····7
14	우리 회사의 IT 인력은 새로운 기술을 학습하려고 노력합니다.	1····2····3····4····5····6····7
15	우리 회사의 IT 인력은 업무상의 문제를 이해하고 기술적인 해결책을 개발할 수 있습니다.	1····2····3····4····5····6····7
16	우리 회사의 IT 인력은 프로젝트 팀 환경에서 협력적으로 일할 수 있는 능력이 있습니다.	1····2····3····4····5····6····7
17	우리 회사의 IT 인력은 다양한 기술과 도구들을 사용할 수 있는 기술을 보유중입니다.	1····2····3····4····5····6····7

Ⅲ. 이 질문은 블록체인기술 도입과 관련된 질문입니다. 각 문항에 대해 가장 잘 맞는 해당항목의 번호 (1~7)을 기입해 주십시오. (전혀 그렇지않다=>1, 매우 그렇지않다=>2, 약간 그렇지않다=>3, 보통이다=>4, 조금 그렇다=>5, 매우그렇다=>6, 전적으로

블록체인은 데이터를 저장하는 새로운 방식의 기술입니다. 블록체인은 데이터를 암호화함으로서 보안성을 높이고 탈중앙화된 시스템 관리를 통해 이용자들간의 신뢰를 확보할 수 있습니다. 탈중앙화된 시스템이란, 중앙시스템이 정보를 관리 하는 것이 아닌, 각 참여자들이 정보를 생성하는데 권한을 가질 수 있음을 말합니다. 생성된 정보는 이용자들의 동의로 인해 실시간으로 공유되어 정보의 투명성과 신속성을 보장합니다.

정보의 불균형이 존재하는 해운산업에 블록체인이 도입되어 거래정보에 대한 보안성, 신뢰성, 투명성을 향상시켜 기존의 비효율적인 정보관리 및 교환의 문제를 해결할 것으로 기대됩니다. 블록체인은 해운산업의 각종 문서관리, 거래관리, 화물/선박/터미널 장치 관리에 적용되며 해운거래 참여자들이 위변조가 불가한 운송 관련 정보들을 추적하여 현재 상태와 과거의 이력을 쉽게 확일 할 수 있습니다. 이를 통해 공급망에 참여하는 모든 주체들이 정보를 확인하고, 운송 절차를 빠르고 정확하게 처리하는 것이 가능해집니다. 또한 IoT 센서를 통해 컨테이너의 온도와 무게, 선적 물품의 상태 정보 등도 블록체인으로 관리 할 수 있습니다. 대표적으로 Maersk 사의 TradeLens, COSCO의 GSBN이 있습니다.

	Questions	전혀 그렇지 않다 보통이 다 전적으로 그렇다
1	우리 회사는 블록체인 기술 도입 및 활용에 자원을 투자합니다.	1····2····3····4····5····6····7
2	우리 회사는 문서의 디지털화, 실시간 교환, 표준화를 통한 문서관리 지원하는데 블록체인 기술을 사용 중입니다.	1····2····3····4····5····6····7
3	우리 회사는 탈중앙화되고 자동화된 시스템에서 공급사슬의 파트너들과의 거래를 지원하는데 블록체인기술을 사용 중입니다.	1····2····3····4····5····6····7
4	우리 회사는 선박과 항만 터미널을 통한 화물의 물리적인 움직임과 관련하여 블록체인기술을 사용 중입니다.	1····2····3····4····5····6····7

Ⅳ. 이 질문은 성과와 관련된 질문입니다. 각 문항에 대해 가장 잘 맞는 해당항목의 번호 (1~7)을 기입해 주십시오.

	Questions	전혀 그렇지 않다 보통이 다 전적으로 그렇다
1	우리 회사가 속한 공급사슬의 업무처리 속도가 향상되었습니다.	1····2····3····4····5····6····7
2	우리 회사가 속한 공급사슬의 운영 비용이 감축되었습니다.	1····2····3····4····5····6····7
3	우리 회사가 속한 해운공급사슬은 고객에게 제공되는 서비스의 품질을 향상시킵니다.	1····2····3····4····5····6····7
4	우리 회사가 속한 해운공급사슬은 물류통합활동을 통해 부가가치를 창출합니다.	1····2····3····4····5····6····7
5	우리 회사가 속한 해운공급사슬은 시장 수요의 변화에 빠르게 반응합니다.	1····2····3····4····5····6····7
6	우리 회사가 속한 해운공급사슬에서 고객의 주문을 완료하는 조달기간 (고객의 주문의 접수와 화물의 인도 시간 사이)가 짧습니다.	1····2····3····4····5····6····7
7	우리 회사의 해운공급사슬의 운영을 통해 투자 대비 수익이 향상 되었습니다.	1····2····3····4····5····6····7
8	우리 회사의 해운공급사슬의 운영을 통해 우리 회사의 판매 대비 수익이 향상 되었습니다.	1····2····3····4····5····6····7
9	우리 회사의 해운공급사슬의 운영을 통해 우리 회사의 시장 점유율이 증대되었습니다.	1····2····3····4····5····6····7
10	우리 회사의 해운공급사슬의 운영을 통해 우리 회사의 세전 순수익이 향상 되었습니다.	1····2····3····4····5····6····7
11	우리 회사의 해운공급사슬의 운영을 통해 우리 회사의 운영으로 부터 현금유동성이 향상 되었습니다.	1····2····3····4····5····6····7

V. 다음 귀사 및 귀하에 대한 일반적 사항입니다.	
1	귀사의 설립연도는?
2	귀사의 업종은? ① 해운선사 ② 컨테이너 터미널 ③ 포워더 ④ 항만공기업 ⑤ 기타
3	귀사의 국적(본사 소재지) 지역은? ① 서울 ② 부산 ③ 인천 ④ 기타 대한민국 ⑤ 아시아 ⑥ 유럽 ⑦ 북아메리카 ⑧ 기타
4	귀사의 종업원수는?
5	귀하의 연령은?
6	귀하의 담당업무는? ① 경영전략, 기획 ② 총무, 인사 ③ 영업, 고객관리 ④ IT(정보기술) ⑤ 구매 및 생산 ⑥ 기타
7	귀하의 직급은? ① 사원 ② 주임, 반장, 계장, 대리 ③ 과장 ④ 부장, 차장 ⑤ 이사, 상무, 전무 ⑥ 사장
8	귀하의 현 회사 근무기간?

끝까지 설문에 응해 주셔서 감사합니다.

APPENDIX C. NONRESPONSE BIAS TEST RESULT

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
SCI_1	2485.5	5335.5	-1.415	0.157
SCI_2	2381.5	5231.5	-1.806	0.071
SCI_3	2464.0	5314.0	-1.486	0.137
SCI_4	2498.0	5348.0	-1.370	0.171
SCI_5	2314.0	5164.0	-2.078	0.038
SCI_6	2705.5	5555.5	-0.693	0.488
SCI_7	2885.0	5888.0	-0.010	0.992
SCI_8	2848.0	5698.0	-0.151	0.880
SCI_9	2754.0	5604.0	-0.507	0.612
SCI_10	2879.5	5882.5	-0.031	0.976
SCI_11	2215.0	5065.0	-2.563	0.010
SCI_12	2410.0	5260.0	-1.817	0.069
SCI_13	2687.0	5537.0	-0.767	0.443
SCI_14	2671.5	5521.5	-0.823	0.411
SCI_15	2644.5	5494.5	-0.927	0.354
SCI_16	2840.0	5690.0	-0.180	0.857
SCI_17	2555.5	5558.5	-1.265	0.206
SCI_18	2779.0	5782.0	-0.414	0.679
SCI_19	2862.5	5865.5	-0.095	0.924
SCI_20	2709.0	5559.0	-0.677	0.498
SCI_21	2753.0	5603.0	-0.514	0.607
SCI_22	2886.5	5889.5	-0.004	0.997
SCI_23	2836.0	5839.0	-0.195	0.845
SCI_24	2791.5	5794.5	-0.364	0.716
SCI_25	2566.0	5569.0	-1.231	0.218
SCI_26	2714.0	5564.0	-0.667	0.504
SCI_27	2829.5	5832.5	-0.222	0.824
SCI_28	2533.0	5383.0	-1.352	0.176
SCI_29	2633.0	5483.0	-0.971	0.332
SCI_30	2837.5	5840.5	-0.190	0.849

ITC_1	2876.5	5726.5	-0.042	0.966
ITC_2	2839.5	5842.5	-0.183	0.855
ITC_3	2778.0	5628.0	-0.419	0.675
ITC_4	2830.0	5833.0	-0.219	0.827
ITC_5	2677.0	5527.0	-0.799	0.424
ITC_6	2737.5	5740.5	-0.570	0.569
ITC_7	2788.5	5638.5	-0.376	0.707
ITC_8	2781.0	5631.0	-0.405	0.685
ITC_9	2869.5	5872.5	-0.069	0.945
ITC_10	2778.5	5781.5	-0.414	0.679
ITC_11	2850.5	5853.5	-0.140	0.888
ITC_12	2818.5	5821.5	-0.261	0.794
ITC_13	2771.0	5621.0	-0.443	0.658
ITC_14	2544.5	5547.5	-1.309	0.190
ITC_15	2744.5	5747.5	-0.543	0.587
ITC_16	2600.5	5603.5	-1.091	0.275
ITC_17	2601.5	5604.5	-1.087	0.277
BCA _1	2592.0	5518.0	-0.561	0.575
BCA _2	2545.0	5471.0	-0.745	0.456
BCA _3	2724.0	5352.0	-0.047	0.963
BCA _4	2712.5	5340.5	-0.092	0.927
PER_1	2693.0	5543.0	-0.740	0.459
PER_2	2687.5	5537.5	-0.768	0.442
PER_3	2659.0	5509.0	-0.870	0.384
PER_4	2607.0	5457.0	-1.070	0.285
PER_5	2750.5	5600.5	-0.523	0.601
PER_6	2830.0	5833.0	-0.220	0.826
PER_7	2870.0	5720.0	-0.067	0.946
PER_8	2719.5	5494.5	-0.501	0.617
PER_9	2820.5	5823.5	-0.257	0.797
PER_10	2783.0	5786.0	-0.404	0.686
PER_11	2843.5	5693.5	-0.170	0.865

APPENDIX D. PLS-SEM TEST RESULTS

- Factor loadings of the measurement model

	IS	KC	CC	GS	DH	JPM	FITI	ITA	MITK	ITPS	BCU	OPP	FNP
SCI1	0.846												
SCI2	0.892												
SCI3	0.855												
SCI4	0.838												
SCI5	0.837												
SCI6		0.866											
SCI7		0.818											
SCI8		0.805											
SCI9		0.849											
SCI10		0.828											
SCI11			0.852										
SCI12			0.869										
SCI13			0.822										
SCI14			0.845										
SCI15			0.817										
SCI16				0.815									
SCI17				0.849									
SCI18				0.831									
SCI19				0.797									

SCI20				0.794									
SCI21					0.806								
SCI22					0.827								
SCI23					0.82								
SCI24					0.827								
SCI25					0.779								
SCI26						0.783							
SCI27						0.814							
SCI28						0.794							
SCI29						0.804							
SCI30						0.812							
ITC1							0.792						
ITC2							0.864						
ITC3							0.9						
ITC4							0.848						
ITC5							0.857						
ITC6								0.921					
ITC7								0.921					
ITC8								0.886					
ITC9								0.878					
ITC10									0.955				
ITC11									0.968				
ITC12									0.949				
ITC13										0.908			
ITC14										0.93			
ITC15										0.926			

ITC16										0.938			
ITC17										0.885			
BCA1											0.92		
BCA2											0.97		
BCA3											0.97		
BCA4											0.96		
PERF1												0.88	
PERF2												0.86	
PERF3												0.9	
PERF4												0.89	
PERF5												0.88	
PERF6												0.85	
PERF7													0.94
PERF8													0.95
PERF9													0.92
PERF10													0.95
PERF11													0.94

- Analysis of Cross loading

	IS	KC	CC	GS	DH	JPM	FITI	ITA	MITK	ITPS	BCU	BCIA	OPP	FNP
SCI1	0.846	0.594	0.592	0.590	0.587	0.554	0.422	0.411	0.305	0.408	0.334	0.363	0.516	0.416
SCI2	0.892	0.657	0.699	0.649	0.633	0.626	0.425	0.386	0.293	0.366	0.347	0.335	0.565	0.464
SCI3	0.855	0.671	0.697	0.591	0.627	0.617	0.449	0.417	0.306	0.381	0.395	0.321	0.541	0.483
SCI4	0.838	0.652	0.678	0.559	0.609	0.575	0.411	0.390	0.278	0.369	0.322	0.301	0.550	0.498
SCI5	0.837	0.676	0.654	0.660	0.583	0.606	0.429	0.354	0.274	0.354	0.277	0.281	0.493	0.432
SCI6	0.631	0.866	0.667	0.584	0.570	0.600	0.421	0.393	0.304	0.361	0.346	0.327	0.561	0.522
SCI7	0.677	0.818	0.621	0.629	0.625	0.563	0.420	0.340	0.301	0.360	0.318	0.353	0.505	0.491
SCI8	0.669	0.805	0.649	0.629	0.654	0.625	0.424	0.440	0.312	0.402	0.291	0.296	0.551	0.481
SCI9	0.582	0.849	0.613	0.613	0.576	0.628	0.462	0.417	0.300	0.353	0.363	0.373	0.548	0.480
SCI10	0.616	0.828	0.601	0.727	0.604	0.596	0.453	0.421	0.375	0.427	0.316	0.404	0.523	0.480
SCI11	0.697	0.694	0.852	0.636	0.700	0.611	0.389	0.343	0.271	0.367	0.412	0.375	0.553	0.500
SCI12	0.744	0.700	0.869	0.645	0.681	0.631	0.442	0.359	0.273	0.416	0.368	0.335	0.583	0.517
SCI13	0.563	0.551	0.822	0.477	0.567	0.540	0.337	0.290	0.123	0.286	0.360	0.242	0.470	0.436

SCI14	0.641	0.619	0.845	0.531	0.591	0.593	0.377	0.342	0.208	0.344	0.381	0.286	0.543	0.507
SCI15	0.617	0.608	0.817	0.598	0.648	0.591	0.434	0.340	0.294	0.386	0.299	0.295	0.497	0.486
SCI16	0.646	0.642	0.601	0.815	0.668	0.582	0.472	0.340	0.347	0.342	0.415	0.388	0.515	0.493
SCI17	0.648	0.648	0.627	0.849	0.711	0.649	0.520	0.437	0.408	0.459	0.306	0.402	0.531	0.448
SCI18	0.581	0.644	0.559	0.831	0.615	0.659	0.516	0.476	0.384	0.455	0.290	0.371	0.536	0.487
SCI19	0.486	0.570	0.479	0.797	0.631	0.587	0.513	0.452	0.455	0.437	0.336	0.411	0.429	0.376
SCI20	0.541	0.608	0.539	**0.794**	**0.705**	0.594	0.425	0.373	0.378	0.347	0.312	0.377	0.465	0.414
SCI21	0.603	0.605	0.664	0.666	0.806	0.639	0.434	0.365	0.305	0.426	0.330	0.378	0.529	0.458
SCI22	0.591	0.581	0.634	0.646	0.827	0.619	0.424	0.370	0.311	0.422	0.405	0.377	0.505	0.436
SCI23	0.550	0.553	0.547	0.666	**0.820**	**0.706**	0.512	0.482	0.451	0.431	0.383	0.439	0.575	0.486
SCI24	0.600	0.587	0.588	**0.719**	**0.827**	0.618	0.497	0.411	0.359	0.361	0.339	0.387	0.586	0.485
SCI25	0.550	0.625	0.657	0.602	0.779	0.587	0.461	0.374	0.325	0.338	0.356	0.334	0.536	0.478
SCI26	0.534	0.598	0.580	0.537	0.572	0.783	0.471	0.417	0.329	0.349	0.415	0.399	0.596	0.585
SCI27	0.607	0.641	0.599	0.698	0.668	0.814	0.543	0.473	0.418	0.486	0.418	0.468	0.571	0.549
SCI28	0.501	0.512	0.473	0.545	0.582	0.794	0.563	0.483	0.445	0.402	0.422	0.513	0.541	0.469
SCI29	0.559	0.528	0.552	0.611	0.625	0.804	0.604	0.530	0.470	0.496	0.368	0.456	0.497	0.497

SCI30	0.594	0.615	0.623	0.623	0.685	0.812	0.587	0.557	0.430	0.496	0.418	0.430	0.577	0.519
ITC1	0.364	0.365	0.311	0.425	0.402	0.507	0.792	0.623	0.569	0.621	0.329	0.448	0.353	0.303
ITC2	0.373	0.394	0.359	0.505	0.450	0.575	0.864	0.645	0.608	0.649	0.394	0.525	0.457	0.348
ITC3	0.452	0.506	0.468	0.573	0.545	0.622	0.900	0.693	0.618	0.664	0.445	0.528	0.523	0.409
ITC4	0.453	0.463	0.444	0.488	0.522	0.614	0.848	0.740	0.598	0.578	0.514	0.527	0.542	0.460
ITC5	0.477	0.482	0.406	0.549	0.515	0.610	0.857	0.734	0.606	0.582	0.452	0.488	0.530	0.467
ITC6	0.434	0.461	0.385	0.440	0.459	0.551	0.753	0.921	0.655	0.667	0.483	0.495	0.509	0.391
ITC7	0.431	0.451	0.359	0.472	0.448	0.558	0.756	0.921	0.691	0.670	0.451	0.499	0.480	0.371
ITC8	0.404	0.404	0.336	0.460	0.431	0.554	0.707	0.886	0.693	0.693	0.423	0.535	0.449	0.378
ITC9	0.385	0.423	0.358	0.464	0.446	0.550	0.696	0.878	0.681	0.686	0.414	0.475	0.519	0.438
ITC10	0.293	0.310	0.227	0.413	0.380	0.464	0.637	0.697	0.955	0.673	0.430	0.552	0.402	0.329
ITC11	0.336	0.366	0.267	0.477	0.414	0.506	0.684	0.727	0.968	0.699	0.422	0.527	0.373	0.321
ITC12	0.346	0.412	0.303	0.484	0.447	0.521	0.693	0.736	0.949	0.737	0.446	0.552	0.435	0.397
ITC13	0.417	0.414	0.402	0.456	0.441	0.500	0.639	0.656	0.641	0.908	0.392	0.525	0.430	0.347
ITC14	0.417	0.447	0.421	0.468	0.475	0.509	0.664	0.680	0.678	0.930	0.411	0.537	0.451	0.394
ITC15	0.426	0.418	0.397	0.468	0.447	0.516	0.664	0.715	0.697	0.926	0.451	0.529	0.469	0.418

ITC16	0.393	0.405	0.369	0.453	0.437	0.508	0.685	0.686	0.684	0.938	0.463	0.574	0.453	0.394
ITC17	0.363	0.407	0.379	0.449	0.433	0.519	0.666	0.716	0.679	0.885	0.466	0.533	0.448	0.407
BCA1	0.359	0.336	0.342	0.406	0.419	0.456	0.492	0.482	0.480	0.484	0.916	0.818	0.489	0.441
BCA2	0.387	0.392	0.431	0.387	0.421	0.492	0.484	0.472	0.437	0.455	0.970	0.754	0.540	0.530
BCA3	0.380	0.385	0.437	0.375	0.434	0.501	0.482	0.471	0.416	0.452	0.974	0.755	0.532	0.519
BCA4	0.378	0.386	0.442	0.385	0.432	0.497	0.476	0.455	0.402	0.429	0.962	0.744	0.513	0.501
BCA5	0.375	0.418	0.379	0.460	0.454	0.535	0.575	0.513	0.518	0.552	0.791	0.947	0.534	0.466
BCA6	0.345	0.412	0.334	0.457	0.450	0.531	0.565	0.530	0.522	0.546	0.752	0.962	0.514	0.446
BCA7	0.379	0.418	0.362	0.474	0.463	0.548	0.584	0.554	0.563	0.589	0.767	0.981	0.512	0.456
BCA8	0.367	0.392	0.342	0.457	0.459	0.563	0.563	0.556	0.584	0.580	0.771	0.964	0.516	0.472
BCA9	0.343	0.387	0.349	0.448	0.456	0.545	0.564	0.526	0.554	0.570	0.787	0.969	0.522	0.456
PERF1	0.568	0.556	0.565	0.527	0.607	0.621	0.483	0.458	0.361	0.435	0.468	0.460	0.879	0.739
PERF2	0.558	0.563	0.562	0.502	0.553	0.592	0.521	0.481	0.380	0.391	0.539	0.496	0.858	0.740
PERF3	0.551	0.599	0.562	0.561	0.594	0.615	0.538	0.500	0.400	0.472	0.488	0.511	0.901	0.726
PERF4	0.547	0.568	0.565	0.557	0.578	0.603	0.493	0.467	0.361	0.424	0.471	0.464	0.893	0.746
PERF5	0.540	0.559	0.567	0.533	0.611	0.652	0.497	0.484	0.390	0.475	0.487	0.491	0.884	0.751

PERF6	0.528	0.556	0.502	0.523	0.609	0.575	0.473	0.470	0.329	0.384	0.406	0.413	0.852	0.715
PERF7	0.537	0.588	0.576	0.550	0.547	0.622	0.448	0.412	0.357	0.413	0.497	0.444	0.797	0.939
PERF8	0.533	0.563	0.573	0.546	0.582	0.639	0.463	0.431	0.372	0.430	0.492	0.461	0.816	0.947
PERF9	0.494	0.563	0.545	0.519	0.562	0.616	0.461	0.442	0.359	0.415	0.476	0.442	0.786	0.919
PERF10	0.506	0.536	0.532	0.499	0.538	0.615	0.458	0.415	0.332	0.395	0.498	0.459	0.790	0.952
PERF11	0.454	0.514	0.506	0.439	0.482	0.580	0.379	0.349	0.299	0.350	0.489	0.429	0.746	0.940

APPENDIX E. PLS-SEM TEST RESULT FOR HOC

- Discriminant validity Fornell & Larker Criterion

	SCI	ITC	BCU	OPP	FNP
SCI	0.878				
ITC	0.609	0.899			
BCU	0.489	0.535	0.956		
OPP	0.723	0.567	0.543	0.878	
FNP	0.656	0.476	0.522	0.839	0.94

- Discriminant validity HTMT

	SCI	ITC	BCU	OPP	FNP
SCI					
ITC	0.642				
BCU	0.509	0.566			
OPP	0.767	0.603	0.569		
FNP	0.683	0.498	0.538	0.878	