Exploring the impact of port-centric information integration on port performance: the case of Qingdao Port

Abstract

Digital technologies are dramatically reshaping the maritime industry and transforming how ports operate in a global transport system. To remain competitive and improve its productivity, a port needs to build its digital capability and become a 'smart' port. Despite its increasing importance, port digitalisation is largely under-researched. Our research explores how information integration afforded by the recent development of Port Centric ICT systems (PCIS) may impact port performance. A survey was conducted in Qingdao Port, the seventh-largest comprehensive port in the world. A partial least squares structural equation modelling (PLS-SEM) analysis was conducted. Our model focuses on testing the mechanism of information integration on port performance among the port community members; that is, both internal information integration and external information integration and their direct and indirect impact on port performance. Our main contribution lies in that our study identifies two clear pathways for developing a port's digitalisation processes to achieve competitive advantages: a) the mediated path, where port performance will improve if information integration is coupled with port community operational capability (PCOC); b) the direct path, where the innovative use of PCIS leads to radical ideas, new business models and transformative changes.

Keywords: port community, information integration, port−centric ICT system, PLS-SEM, survey, digitalisation

1. Introduction

A seaport has evolved from a simple trans-shipment point to become a critical node in maritime shipping and global supply chains. There is an increasing need for ports to fulfil various supply chain partners' requirements. Herz and Flamig (2014) proposed a 'port-SCM' philosophy, whereby 'seaports should add value to shippers by aligning their own business activities with shippers' supply chain management (SCM) strategies and requirements'. Hence, port actors should work with shippers to achieve maximum benefit for the whole supply chain. Mangan et al. (2008) used the concept of 'port-centric logistics' for the first time to describe the transition in ports from being a simple trans-shipment hub to a critical logistics node providing a variety of services and activities and supporting the wider supply chain ecosystem. They also described the changing role of ports in supply chains with the emergence of 'port-centric logistics' and identified new trends in the port sector: first, significant reforms concerning port deregulation and changes in the public/private ownership of the ports sector; second, the emergence of Global Port Operators (GPOs) and the need for integration to reduce container terminal costs; and third, intensified inter-port competition and the recognition of ports' role in the overall competitiveness of national economies. These new trends in the port sector led to an increase in non-core port activities that bring higher profit margins, hence port operators are more eager to actively promote comprehensive value-added services in a more active manner.

As a result, a port must engage and interact with a wide range of stakeholders for effective value creation and the complex provision of port services. The stakeholders range from public authorities and customs, to terminal operators, shipping lines, importers, exporters, in-land transport operators, and freight-forwarding companies. This range of stakeholders is referred to hereafter as *port community members*. The effective exchange of information between and within a port and its community members is critical in order to effectively facilitate the physical movement of cargo in and out of a port. Indeed, information and communication technology (ICT) has emerged to become a key catalyst in port management and development (Gordon et al., 2005; Mondragon et al., 2017; Harris et al., 2015; Bensassi et al., 2015). The increasing digitalisation is not only driven by efficiency gains (e.g., reducing cargo transit time and port congestion), but also by safety, security, and environmental concerns (Mattei 2020). Enabled by recent technological advances, such as cloud computing, wireless vehicular network, artificial intelligence, blockchain and the Internet of Things, there is increasing digitalisation observed in ports for process automation and effective communication (Wang et al., 2019;

Nguyen et al., 2020). An ICT system can be defined as any organised combination of hardware, software, communications networks, and data resources that collects, transforms and disseminates information within and between organisations. To streamline its information exchange activities with all the stakeholders within its ecosystem, a port needs a standardised communication platform for timely, reliable and low-cost information sharing. This leads to the concept of port-centric ICT system (PCIS). Despite the importance of PCIS in facilitating effective information sharing and interactions between port community members, our understanding of the implications of PCIS is rather limited. Our research aims to fill this gap by exploring how PCIS influences port performance.

Although it has been well established that information integration leads to better organisational performance (Melville et al., 2004), more effective transport operations (Giannopoulos et al., 2017; Harris et al., 2015) and supply chain management (Flynn et al., 2010; Cheng et al., 2011; Prajogo et al., 2012; Han et al., 2017; Yu et al., 2017), our understanding is rather limited as to how the complex information integration in a port community may impact port performance. This gap is made evident by a literature review on seaport research studies (Woo et al., 2012), showing that most studies focus on port management and strategy, competition and performance, terminal operation, spatial analysis, and port policy. Only a handful of papers discuss how ports adopt advanced IT to improve ports in certain areas (Kiaetet et al., 2000; Lee-Partridge et al., 2000; Lee et al., 2016). Yet none have examined the issue from a multiple stakeholder perspective. Another notable work is by Carlan et al. (2016), who have developed a cost and benefit framework, however the framework has not been empirically validated.

Acciaro and Sys (2020) and Acciaro et al. (2018) assert that there is a lack of insights about the processes and mechanisms that make innovation successful in the port industry and substantial misalignment exists between a focal company's strategy and its innovation success. Our research seeks to uncover the casual link between digital technology and port performance and identify the potential pathways how PCIS influences port performance. In this paper, we develop a structural equation model approach to deal with the complex relationship afforded by PCIS involving both external and internal information integration. We test both the direct and indirect impact of information integration on port performance in three dimensions: operational, business and industrial performance. Our research identifies that internal information integration does affect port performance but mainly via the intermediary of port community operational capability (PCOC), whilst external information integration impacts port performance both directly and indirectly via PCOC. Therefore, our study offers significant insights into articulating cause and effect from information integration to port performance. Our study is one of the first attempts that uses survey data from multiple stakeholders in a port community to explain and validate the link between PCIS and port performance. Understanding how PCIS may impact port performance is also of great value in practice. While digitalisation is gaining increasing attention in the port and shipping industries, many are unclear as to how to develop pathways to capture the opportunities and benefits afforded by digital technologies. Our study identifies two specific pathways that offer practical insights into contributing factors and how these factors should be configured to achieve competitive advantages.

The rest of the paper is organised as follows. Section 2 contextualises our research in the theoretical background. A conceptual model is presented, which informs our research hypotheses and survey design, with the main constructs operationalised for the benefit of our survey research. Section 3 presents the details of our methodological approach. Section 4 reports our survey results and the empirical analysis of survey data. Finally, Section 5 concludes our research by discussing its theoretical and managerial implications and acknowledging research limitations and future research opportunities.

2. Theoretical background and research hypotheses development

2.1. Port Centric ICT system

A PCIS is a web-enabled platform providing a single point of interaction between a port and its community members (Yip et al., 2016; 2021). Traditionally the communication between port community numbers tends to be dyadic. The information linkages are costly to build (e.g., via EDI) and fragmented, causing delays and inefficiencies. In a PCIS, all the information exchange in the ports now runs through a single hub, allowing information to be submitted once but then recused and shared amongst relevant public and private stakeholders. As illustrated by Figure 1, a PCIS consolidates several disparate systems into a centralised platform; thus, the information flows are simplified and optimised, leading to greater efficiency.

A port community system is a typical port-centric ICT system that connects multiple systems operated by port community members, enabling intelligent and secure exchange of information between public and private stakeholders in order to improve the competitive position of the ports' communities (Carlan et al., 2016). Portbase in the Netherlands, APCS in Belgium and Portic in Spain are well-known examples in practice. Another similar concept to PCIS is single window system which also emphasises a single point of interaction between multiple stakeholders but does not restrict its application in the context of port (Takis et al., 2016). PCIS, if integrated with networks of embedded sensors, autonomous transportation, blockchain technology, mobile devices and apps, and other digital technologies, will provide competitive advantages and transform a traditional port into the so-called next generation 'smart port' (Riedl et al., 2018).

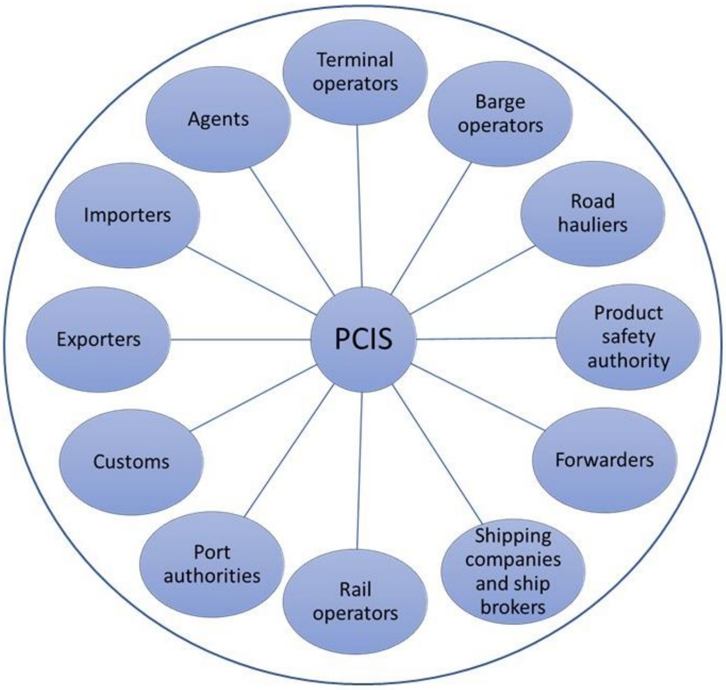

Figure 1: A generic model of port centric ICT system (PCIS)

2.2. The conceptual model - linkage between PCIS and port performance

While the concept of 'port-centric logistics' and the importance of ports to the wider supply chain have received growing recognition, the practicability of this concept has rarely been studied. With logistics and transport networks becoming increasingly complicated and the competition on costs and service performance ever stronger, ICT has been widely recognised as a key enabler (Perego et al., 2010). A port-centric ICT system serves as a central hub, which integrates and streamlines the information flows between a port and its community members. We hereby propose a framework in order to evaluate its impact on port performance (Figure 2).

Recent developments such as cloud computing in ICT provide new opportunities to connect a port and its users in a cost-effective way and have the potential to change how a port provides services to its multi-stakeholders (Berns et al., 2017). In this study, we assert that a PCIS plays a key role in internal integration information within a port and its community, and external information integration within port-related shipping supply chains. Port information integration will then enhance port community operational capability and improve port performance. Based on previous literature, this research proposes a conceptual model, as shown in Figure 2. We identify valid measures for related measurement items and adapt existing scales to measure internal information integration (III) (Wong et al.,2011; Fawcett et al., 2007; Zhao et al., 2011; Flynn et al., 2010; Cardi et al., 2014), external information integration (EII) (Flynn et al., 2010; Ward and Zhou, 2006; Zhao et al., 2011; Wong et al., 2011), port community operational capability (PCOC) (Rai et al.,2006; Wong et al.,2011) and port performance (PP) (Wong et al., 2011; Flynn et al., 2010; Rai et al.,2006; Vernon, F., 2008). The network of relationships among the variables in the model and the rationale for the proposed linkages are discussed in detail in the following sections.

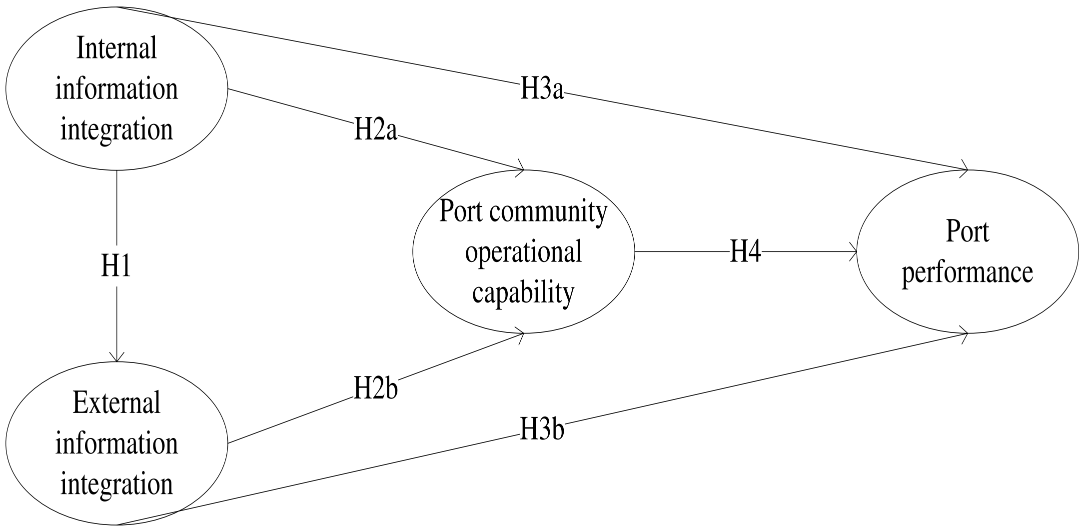

Figure 2. The conceptual model

2.3. Research hypotheses development

2.3.1. PCIS and information integration

Supply Chain Integration (SCI) is a well-explored topic in SCM and many have discussed the value of ICT in SCI (Popp, 2000; Fawcett et al., 2007; Cheng et al., 2011; Ngai et al., 2011). Flynn et al. (2010) argued that SCI is characterised by two complementary activities: internal and external integration. Both measure SCI and play complementary roles along the SCI process. In the supply chain literature, Internal integration (II) denotes the degree of functions within an organisation work collaboratively so as to resolve conflicts and achieve common goals (Pagell, 2004; Heim and Peng, 2010). External integration (EI) denotes the degree to which an organisation develops external relationships from multiple perspectives, in order to facilitate possible solutions to supply chain challenges. The external integration includes three key areas: namely, customer-supplier cooperation/partnership, cross-organisational information sharing and inter-company coordination of plans/activities (Narasimhan and Kim, 2002; Gunasekaran et al., 2004; Sahin and Robinson, 2005; Swink et al., 2007). Internal/external information integration is a key enabler in order to achieve internal/external supply chain integration. Most studies examine supply chain information integration from two aspects: information technology connection (technical aspect) and information sharing & trust (social aspect) (Prajogo and Olhager, 2012).

Given that our focus is on PCIS, our definition of *Internal Information Integration* (III) goes beyond the scope of a single organisation. We denote III to indicate information integration among port community members within a PCIS, for instance between a terminal operator and a shipping line. Whilst for *External Information Integration (EII),* we refer it as each port community member's information integration with outside organisations (i.e., those which are *not* part of the PCIS). Figure 3 illustrates the boundary of EII and III in the context of PCIS.

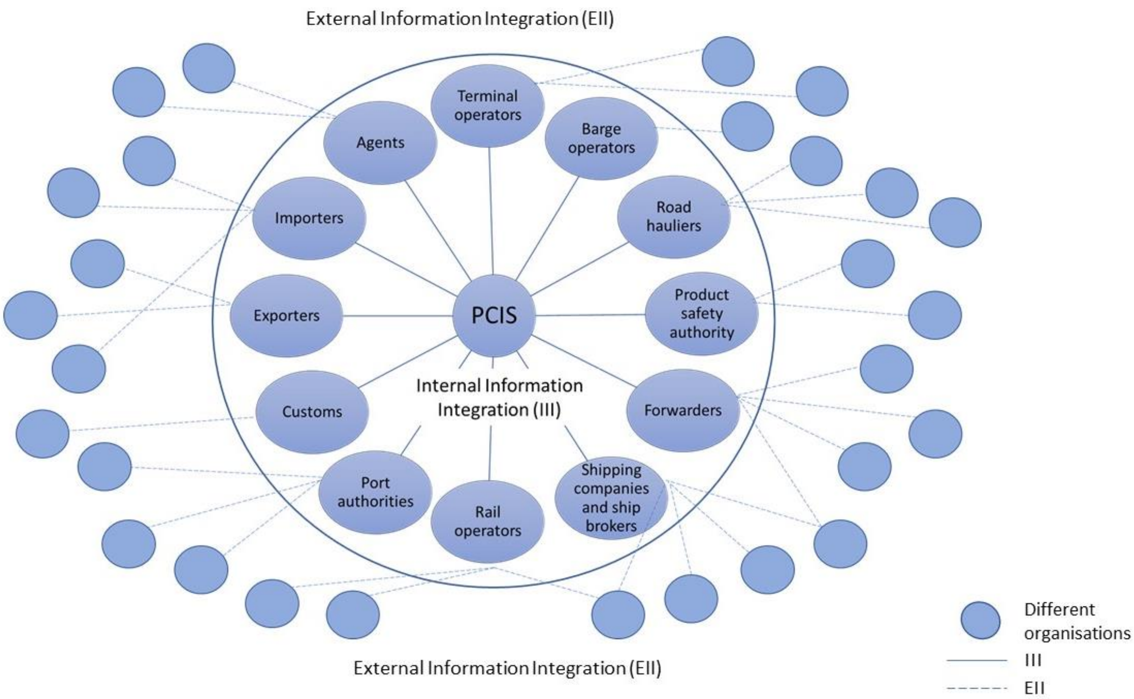

Figure 3: Illustration of Internal Information Integration (III) and External Information Integration (EII) in the context of PCIS (source: authors)

Subsequently we propose measures of internal and external information integration in a port-based supply chain, according to previous studies, as captured in Table 1. We then articulate and develop our first hypothesis accordingly.

Table 1. Prior research on measurement scales: information integration

Internal Information Integration (III)	**Prior studies**
Data and enterprise application integration are in place among internal functions to enhance coordination.	Wong et al. (2011), Fawcett et al. (2007), Zhao et al. (2011), Flynn et al. (2010),
We have good information visibility across functions and member organisations within our port.	Cardi et al. (2014)
All relevant decision-making information shared within our port is accurate and trustworthy.	Wong et al. (2011), Fawcett et al. (2007)
All relevant decision-making information is shared within our port is frequent and timely.	Fawcett et al. (2007)
Our IT infrastructure is capable of meeting our current business needs.	Wong et al. (2011)
PCIS plays a pivotal role in facilitating information sharing within our port.	Zhao et al. (2011)
PCIS plays a pivotal role in supporting cross functional and community member cooperation**.**	Zhao et al. (2011)
PCIS plays a pivotal role in supporting cross functional **teamwork** for process improvement or service innovation**.**	Zhao et al. (2011)

Table 1. (cont'd)

External Information Integration (EII)	**Prior studies**
Electronic information shared between our community members and external stakeholders is standardized.	Rai et al. (2006)
PCIS allows us to exchange information with our external private stakeholders outside our port community, such as shipping companies and freight forwarders, in a timely and accurate manner.	Flynn et al. (2010) Rai et al. (2006), Han et al. (2017)
PCIS allows exchanging information with external public stakeholders outside our port community, such as custom clearance and the port authority, in a timely and accurate manner.	Han et al. (2017)
PCIS allows our community members to exchange information efficiently in a timely and accurate manner.	Ward and Zhou (2006), Zhao et al. (2011)

PCIS allows us to easily build and alter our information linkages to our existing supply chain partners, such as shipping companies and freight forwarders.	Zhao et al. (2011), Wong et al. (2011)
PCIS allows us to easily build and alter our information linkages to new supply chain partners.	Ward and Zhou (2006), Zhao et al. (2011), Han et al. (2017)
PCIS enables us to actively explore innovative ways of using ICT in offering new products or services to our supply chain partners.	Han et al. (2017)

High-level connectivity enhances coordination and allows frequent, accurate and timely information sharing for effective decision making (Fawcett et al., 2007). Han et al. (2017) found that the IT infrastructure plays a pivotal role in supporting inter-organisational information connectivity and collaborative relationships. Internal integration means information sharing between internal functions and is important to support cross-functional cooperation. Companies leveraged their internal integration to gain a competitive advantage over their peers (Zhao et al., 2011), while transparency and the quality of information flows will lead to reduced transaction costs and a reduced lead time (Popp, 2000). Arai et al. (2006) studied digitally enabled supply chain integration and emphasised the importance of data consistency and cross-functional application integration. Through III, various departments and functional areas within a firm can operate as part of an integrated and systematic firm, sharing information, jointly planning and designing their processes, and supporting cross-functional teamwork for process improvement or service innovation (Maiga et al., 2015). A PCIS brings port community members together via the digital infrastructure and acts as the backbone for information exchange in the port. Using the PCIS, companies can benefit from a multitude of intelligent services for simple and efficient information exchange, both between companies and between the public and private sectors. This enables all participating community members to optimise their logistics processes, thereby improving their own competitive position and that of the ports (Yip et al., 2021).

III and EII are positively correlated (Ward and Zhou, 2006). Maiga et al. (2015) showed that internal information system integration is positively associated with external information system integration; both positively impacting cost and quality performance. While integration is an information intensive process, it is characterised by two complementary activities occurring along the process: internal and external integration. The supply chain integration is enabled by the internal integration. A partially internally integrated organisation may obtain some benefits from external integration. However, in terms of delivery and flexibility performance, benefits are possible in the presence of sound internal integration. Schoenherr and Swink (2012) applied the relational and resource-based views of firms and confirmed that internal integration enables and reinforces external integration. Without internal integration, the information and data shared with service supply chain partners will not be accurate and timely (Flynn et al. 2010). By providing access to the central infrastructure and facilitating the ability to link data flows under the right condition, a PCIS enables its community users to move towards integrated planning for cross supply chains, real time planning of transport, making adjustments based on the latest status and predicting how logistics will develop. We therefore propose:

H1: PCIS enabled internal information integration positively affects information integration with external stakeholders.

2.3.2. PCIS and port community operational capability

Rai et al. (2006) defined the supply chain process integration as the degree to which a company has integrated the flow of information, materials and finances with its supply chain partners. First, information flow involves the share of operational, tactical and strategic information of a company and its supply chain partners. Second, physical flow involves the global optimisation with its supply chain partners to manage the stock and flow of materials and finished goods. Last, financial flow involves the exchange of financial resources between supply chain partners and is driven by workflow. The flow concepts are well accepted in the supply chain management literature (Stevens, 1989; Gunasekaran et al., 2001; Chopra and Sodhi, 2004).

In the context of the port-centric supply chain, a port is not simply a service provider for physical freight movements: it has a far greater scope inducing complex and sophisticated service activities. It follows the similar functions of a typical supply chain focal actor as indicated by Rai et al. (2006). Therefore, a port community operational capability can be referred to as a port community's ability to manage its physical, information and financial flows. Port-centric logistics focus on the management of cargo, ships and vehicles and the associated information and financial flows (Table 2).

Table 2. Prior research on measurement scales: port community operational capability

Port community operational capability		Prior studies
Financial Flow	Costs associated with billing, payment processing and dispute handling are reduced.	Rai et al. (2006)
	The invoicing and receivables cycle time is shortened while payments are accelerated.	
	The availability of financial information for decision-making is improved.	
Information Flow	Information concerning shipment and cargo tracking is visible at all steps across port and port users.	Wong et al. (2011), Rai et al. (2006)
	Integrated information systems are used to share data/information with port users.	
Physical Flow	Cargo flows through the port more efficiently.	Rai et al. (2006)
	The transferring of cargo from one mode to another is improved.	

Information integration and supply chain integration can be considered the most important constituents of an integrative supply chain strategy (Kim, 2017). Prajogo et al. (2012) suggested that IT capabilities and information sharing are the two most important categories of integrative IT, with both having a positive impact on logistics integration. Some authors believe that integrative information technology has a positive impact on supply chain integration (Kim, 2017; Huo et al., 2016). Information integration plays a critical role in the port supply chain management.

Woo et al. (2013) studied the integration of seaports into supply chains and found that it has a positive impact on both the effectiveness and the efficiency of seaport performance. They also suggested that supply chain integration within a port operating company enables the company to adopt and implement a strategy that integrates functions within the port and with its partners. Integrated IT infrastructures enable firms to develop better supply chain process integration, whereby firms can unbundle information flows from physical flows and share information with their supply chain partners, which leads to increased visibility, improved demand planning and streamlined movement of physical products (Rai et al., 2006). In line with previous studies, we propose that III and EII enabled by PCIS, positively influences a port community's operational capability, as shown in H2a and H2b.

H2a: PCIS-enabled internal information integration positively affects port community operational capability.

H2b: PCIS-enabled external information integration positively affects port community operational capability.

2.3.3. Port information integration and port performance

There are a handful of studies on the impact of supply chain integration on performance. Wong et al. (2011) studied the outcomes of information integration on performance in supply chain management (SCM) and how information integration contributes to better performance outcomes. They specified performance as operational performance and cost performance. Regarding customer-oriented operational performance, the information integration improves service quality for customers in SCM. To relate it to the port's operational performance in our paper, we adapt it to consider the flexibility and responsiveness of a port in satisfying external stakeholders' needs. Regarding cost performance in SCM, information integration lowers the cost of coordinating with various stakeholders in port supply chains. To translate this into the port environment, we propose that information integration lowers the cost of port terminal operational activities; that is, cargo handling.

Flynn et al. (2010) studied how supply chain integration influences performance by applying contingency and configuration theories. They defined internal integration and customer/supplier integration as external integration. They also identified operational performance as the flexibility in reacting to customers' needs, lead time, customer service level, and business performance. We measure the impact of information integration on business performance in a port after using the ICT system: the port's increase in revenue is greater than its competitors.

There is increasing awareness of the importance of supply chain visibility. ICT plays an essential role in obtaining real-time visibility across all tiers within the supply chain (Cardi et al., 2014; Vernon, 2008). Rai et al. (2006) studied the impact of digitally enabled supply chain integration capabilities on firm performance. We adapt their work in order to define data consistency in a port, as the common data definitions are consistent in stored data across port users, and cross-functional application integration in a port as port-centric ICT system allows real-time communication between port and port users. Here, we also emphasise a time-based operational performance (Droge et al., 2004) in a port.

Further, industrial performance in a port means that information integration enables the port to compete more effectively in the marketplace, reaching new markets and increasing market demand. Table 3 shows the measurement scales of port performance in this paper. We continue with an overview of the foundations of multiple levels of performance.

Table 3. Prior research on measurement scales: port performance

Port Performance		**Prior studies**
Operational Performance	The effectiveness of port operations (i.e., service quality and price) is improved.	Wong et al. (2011), Flynn et al. (2010), Rai et al. (2006)
	The efficiency of port operations (i.e., cargo handling time) is improved.	
Business Performance	After using the port-centric ICT system, the port's increase in sales is greater than its competitors.	Wong et al. (2011), Flynn et al. (2010), Vernon, F. (2008)
	After using port-centric ICT system, the port's increase in profit is greater than its competitors.	
Industrial Performance	The demand for the products of the port industry is growing and will continue to grow.	
	More firms in the port industry will use ICT systems.	

The implementation of the port-centric ICT system in the port supply chain allows ports to acquire information about its service providers and customers, which in turn improves the capability of information integration and process integration, thus influencing port performance (Tseng et al., 2015). Zhao et al. (2002) indicated that information coordination and sharing in the whole supply chain allows supply chain partners to increase their performance. In the manufacturing industry, Internal information system integration and external information system integration can lead to the optimal inventory amount and customer service. , They also have a positive impact on cost and quality performance (Maiga, 2015; Titah et al., 2016). Wong (2011) considered the integration of information between intra-organisational functions and inter-organisational functions to be important contributing factors that improve organisational competitiveness and performance. The scope of information integration research has been expanded from an intra-firm to an inter-firm perspective. Nicolás Gonzálvez-Gallego (2015) stated that only a few papers have studied the separate impact of internal ICT capabilities and external ICT capabilities on performance. Dong et al. (2009) believed that information technology has played a direct and indirect role on performance improvement. In this study, we suppose that both internal and external information integration have significant effects on port performance. We consider the direct and indirect impact of internal and external information integration on port performance.

Previous studies have indicated that customer integration has a positive impact on operational performance under the condition of good information quality (Yu, Chavez, et al., 2015). Tseng et al. (2015) found that increasing collaboration and communication between manufacturers and their supply chain partners can reduce transaction costs and improve firm performance. In line with the aforementioned studies, we propose that internal and external information integration have a positive impact on port performance through H3a and H3b, and that port community operational capability has a positive impact on port performance through H4 (see below).

H3a: PCIS-enabled internal information integration positively affects port performance.

H3b: PCIS-enabled external information integration positively affects port performance.

H4: Port community operational capability positively affects port performance.

3. Research methodology

3.1. Questionnaire design and measures

As shown in Tables 1-3, we identify valid measures for related items based on the literature. When there are no reliable and valid existing measures, we have developed new measures which are derived from both our academic understanding and empirical observation via our field visits and interviews. We use a five-point Likert scale to measure all items, with higher scores indicating that the extent to which a respondent agrees with the measurement items will be stronger. It also indicates that a respondent considers that stronger information integration relates to better port community operational capability and port performance.

The questionnaire in our research is conducted based on a rigorous literature review. Since most of the current literature on PCIS focuses on European ports and is rarely written by

Chinese researchers, we have developed an English version of the questionnaire. Next, a professor specialising in Operations Management translated the questionnaire into a Chinese version. To ensure the reliability of the questionnaire, another professor specialising in Operations Management translated the Chinese version back into English. The translated English version was compared against the original English version for consistence. Some adjustments were made on the Chinese version so that the original meaning of the questions in English expressions was retained. Before the full-scale launch of the survey, the pilot test of the finalised Chinese version was conducted within 15 companies. When the respondents filled out the questionnaire, they could discuss the survey questions face-to-face with researchers to clarify the meaning of the questions. The survey items are listed in Appendix B.

3.2. Subject for studying – Qingdao Port

Data for this study were mainly collected from a survey questionnaire in the port of Qingdao, China. The survey questionnaire is distributed by the Wenjuanxing survey data base in January 2019. This survey database is an online crowdsourcing platform in China that provides functions equivalent to Amazon Mechanical Turk. Qingdao Port was selected for the following reasons. First, motivated by the lack of practical insights of PCIS from ports in the Asian market, more attention is paid to the developing countries. China's ports have developed markedly in recent years and are now playing an increasingly significant role in the world's trade and economy. China hosts seven out of the top 10 busiest (in terms of volume) ports in the world. The port of Qingdao is a representative case of ports in China. Established in 1892, it is the world's seventh-largest comprehensive port and China's second-largest port for international trade. Qingdao Port is wholly state-owned enterprise and has been listed in Hong Kong stock market since 2014. The expected empirical result of survey data from Qingdao Port is transferrable to other ports in China, as they are managed and operated under a similar governance structure. Thus, our findings offer valuable insights to the development of ports in Asia and worldwide.

Second, Qingdao Port has a long history in PCIS deployment, and its integrated information system is well developed. Qingdao Port has invested heavily in automation and digitalisation in recent years, with the ambition of becoming a large data-based smart port. Its new Qianwan container terminal became Asia's first fully-automated container terminal in 2017: a single crane can handle 42.23 containers per hour (holding the world record at the time of writing), which is over 50% higher than the global average. Therefore, research insights gained via the survey of this port will be informative for other ports worldwide, given that the Qingdao Port has established its competitive position in the global logistics network via its digitalisation efforts.

The information systems in Qingdao Port include Qingdao Port Logistics e-Commerce Platform, Qingdao Port e-Commerce Network, and Qingdao Port Logistics Information Network. Among them, the Qingdao Port Logistics e-Commerce Platform is a PCIS that can provide internal and external information integration. The PCIS in Qingdao Port serves as a single point of connection which brings together various port community members into a single platform. Through the integration of port industry resources (freight forwarders, shipping agents, terminal operators, shipping companies, inland transporters (road, rail and barge), importers, exporters, etc.), the port can communicate more effectively with members of the port community.

3.3. Data collection

Following the generic PCIS model as in Figure 1, our target respondents are the users of PCIS and the port community members, such as freight forwarders, shipping agents, terminal operators, shipping companies, inland transporters (road, rail and barge), shippers (importers and exporters), and so on. For each randomly selected member in the port community, our sample comprised of those holding the positions of CEO/president, vice president, director, senior manager, and those who were knowledgeable about the port’s internal and external information processes within a port community and how a port operates. The job title and years of working experience indicates that the respondents have sufficient knowledge and expertise, with the ability to offer reliable observations and information about the information integration practices in Qingdao Port. The respondents are competent to assess the performance of Qingdao Port from their own organisation’s perspective. Given that they are active users of the port services, they are able to comment on the operational performance of a port i.e. quality, price and cargo dwell time. Respondents are also able to comment on the business performance of Qingdao Port, as information such as sales and profit can be accessed via publicly available documents, for instance its annual report. Finally, the respondents are competent to offer a valid assessment about the industrial performance of the port, given that they are key actors in the industry and are actively using or engaging with other ports in the maritime industry.

Out of 117 organisations that we contacted, we distributed a total of 351 questionnaires and received 93 usable ones. This results in a response rate of 26.5%, which can be considered as satisfactory in this type of survey-based study (Frohlich, 2002). A profile of the respondents is presented in Table 4, indicating that they represent a variety of industries related to the port industry. Most respondents have been in their position for more than five years; thus, are knowledgeable about the information we required.

Table 4. Profile of respondents

Characteristic	**Number of respondents**	**Percentage of respondents (%)**
Job title		
CEO/President	13	13.98
Director	19	20.43
Senior manager	28	30.11
Supervisor	15	16.13
Clerk/Operator	18	19.35
Years of working experience	Number of respondents	Percentage of respondents
1-5 years	6	6.45
6-10 years	9	9.68
11-15 years	34	36.56
16-20 years	29	31.18
over 20 years	15	16.13
Distribution of firms in sample by the port industry	Number of firms in sample	% of sample
Freight forwarding	14	15.05
Shipping agents	15	16.13
Terminal operators	7	7.53
Shipping companies	16	17.20
Inland transporter (road, rail)	17	18.28
Shippers (importers, exporters)	7	7.53
Port authorities	9	9.68
Consignees	8	8.60

3.4. Partial least squares (PLS) SEM method

This study adopts the PLS-SEM method based on the following applicable conditions, including sample size, nature of our research and statistical power. In terms of the sample size, the PLS-SEM method can offer solutions with smaller sample sizes when models comprise many constructs and a large number of items. Even if the size of the data is limited, PLS-SEM can show the high robustness results because it uses ordinary least squares regression which are not sensitive to a small sample size (Reinartz et al., 2009; Sarstedt et al., 2016; Hair et al., 2019). Due to the relatively small sample size in our study (<200), the PLS-SEM method is chosen as the research tool. The main aim of this study is to evaluate the extent to which part of the research model (information integration) influences the other part of the model (port community operational capability and port performance), therefore our study is exploratory and theory building in nature, instead of being confirmatory and theory testing. For the latter, LIRSEL (another type of SEM), a parameter-oriented approach tends to more appropriate (Peng and Lai 2021, Hair et al., 2013).

In terms of the statistical power, the PLS-SEM method has the higher degree of statistical power compared to covariance-based structural equation method (CB-SEM) (Reinartz et al., 2009), meaning that the PLS-SEM method is more likely to identify the significant relationships in the model. Thus, this study adopts the PLS-SEM method based on above applicable conditions of the PLS-SEM method.

In addition, despite some reservations (Rönkkö et al., 2016), PLS has become increasingly accepted, entails practically no bias compared to the other methods of SEM and has been applied in increasingly more studies (Sarstedt et al., 2016). We have adopted the SmartPLS 3.0 software to analyse the data. We use the bootstrapping technique to calculate parameter coefficient estimates and t-value with 500 subsamples from the original dataset and no sign changes, including mediating effecting analysis.

4. Empirical analysis and results

4.1. Measurement and model assessment

In this section, reliability and validity tests were conducted: internal consistency reliability, indicator reliability, convergent validity, and discriminant validity. Internal consistency reliability refers to the degree of consistency of multiple indicators to measure the same concept. Composite reliability and Cronbach's alpha values can be used to test internal consistency reliability by the method of partial least squares. Composite reliability and Cronbach's alpha values were above the commonly used threshold value 0.700 that is accepted (Nunnally and Bernstein, 1994). In this study, Cronbach's alpha values range from 0.873 to 0.909, while composite reliability ranges from 0.902 to 0.927 (see Table 5): all satisfying the threshold value.

Indicator reliability refers to how many of the variations in measure indicators are explained by the concept. In the reflective model, outer loadings estimated the relationship between an indicator and the construct concept. The value of outer loadings indicates an indicator's absolute contribution to its belonged construct concept. Hair et al. (2013) considered that the values of outer loadings equal to or higher than 0.708 are desirable. In our study, all items' outer loading values are higher than 0.708, except for III6 (0.680) in internal information integration and EII7 (0.605) in external information integration. In conclusion, 26 of the 28 reflective indicators have an outer loading of more than 0.708, demonstrating that this study has an acceptable indicator reliability.

Convergent validity refers to the degree to which a measure indicator correlates with other alternative measure indicators of the same concept. Hu and Bentler (1999) indicated that all average variance extracted (AVE) values are higher than the cut-off value of 0.500, providing support for convergent validity. In our case, AVE values ranged from 0.537 to 0.646. Thus, the model was acceptable, indicating that our constructs have convergent validity.

Table 5. The fitting results of the Structural Equation Model

Latent variables	Number of indicators	Internal consistency reliability		Indicator reliability	Convergent validity
		Cronbach's alpha	Composite reliability	Loadings	AVE
III	8	0.876	0.902	0.680 to 0.790	0.537
EII	7	0.873	0.903	0.605 to 0.831	0.572
PCOC	7	0.909	0.927	0.781 to 0.824	0.646
PP	6	0.889	0.914	0.711 to 0.842	0.640

Note: III Internal information integration, EII External information integration, PCOC Port community operational capability, PP Port performance, AVE Average variance extracted.

Discriminatory validity is also evidence of the validity of the construct, which means that when different latent variables are measured using different methods, the construct concepts should be able to be distinguished. It also means the degree to which measures of different latent variables are unique. First, the discriminant validity of the constructs can be assessed by comparing the square root of the average variance extracted (AVE) and the correlation between any pair of them, as suggested by Fornell and Larcker (1981). The square root of the AVE estimates was found to be almost greater than the squared correlation between any pair of them (see Table 6), suggesting that the measurement items share a common variance with their hypothesized constructs more than with the other constructs, which also provides an acceptable evidence of discriminant validity. Second, we looked at the cross loading, which states that each construct concept shares a larger variance with its own measure indicators than with other measure indicators. Thus, an indicator's outer loadings should be higher than all its cross loadings with other constructs. Appendix A shows that our model meets the cross-loading requirements.

Table 6. Discriminant validity assessment (Fornell-Larcker Criterion).

	III	EII	PCOC	PP
III	0.733			
EII	0.833	0.756		
PCOC	0.651	0.690	0.804	
PP	0.435	0.543	0.659	0.800

Note: III Internal information integration, EII External information integration, PCOC Port community operational capability, PP Port performance. The number in the diagonal is the square root of the average variance extracted.

Coupled with the validity assessment, we examined the multicollinearity due to relatively high correlations among some variables. As presented in Table 7, the variance inflation factor (VIF) values for alallhe constructs are at acceptable levels; that is, below five, indicating the absence of multicollinearity (Diamantopoulos and Siguaw, 2006).

Table 7. Variable Inflation Factor (VIF) analysis result.

Latent	EII	PCOC	PP

variables			
III	1.000	3.262	3.386
EII		3.262	3.720
PCOC			1.981

Note: III Internal information integration, EII External information integration, PCOC Port community operational capability, PP Port performance.

4.2. Structural model assessment: hypothesis testing

Following the reliability and validity test on the measurement model, the bootstrap procedure has been used to assess the structural model. Standard error and t-statistics are obtained through bootstrapping in order to evaluate the significance of the hypothesis. Table 8 and Figure 2 show the results of the hypothesis testing.

Empirical results support five of the six hypotheses. The results show that internal information integration has a positive impact on external information integration (H1). The link between internal information integration and port performance show that H3a is not supported, while H3b, the link between external information integration and port performance, is supported. Further, the results reveal a statistical significance between internal information integration and port community operational capability (H2a), and statistically significant effects between external information integration and port community operational capability (H2b). With regard to port performance, the results indicate that port community operational capability positively impacts port performance (H4).

Table 8. Summary of the findings.

Hypotheses		Original sample	Sample mean	Standard deviation	t statistics	p values	Outcome
H1	III → EII	0.833	0.840	0.032	26.054	***	Supported
H2a	III → PCOC	0.251	0.246	0.137	1.830	*	Supported
H2b	EII→ PCOC	0.481	0.494	0.133	3.627	***	Supported

H3a	III → PP	-0.199	-0.204	0.129	1.543	NS	Not supported
H3b	EII → PP	0.314	0.314	0.147	2.138	**	Supported
H4	PCOC→PP	0.572	0.582	0.108	5.301	***	Supported

Note: III Internal information integration, EII External information integration, PCOC Port community operational capability, PP Port performance. ***p<0.001, ** p<0.05, * p<0.1, NS: Non-significant.

Table 9 summarises the non-mediated model and mediated model tested by PLS analysis. This table presents the standard path coefficient, t value and explained variance (R-squared) to evaluate the statistical significance by the bootstrapping method. It also shows the results with and without the mediated variables of port community operational capability, in order to highlight the mediating role of port community operational capability in the relationship between information integration and port performance.

Table 9. Effects and variance explained for all endogenous variables.

Effect of endogenous variables on hypothesis	Path coefficient β (t value)		Variance explained (R-squared)	
	Non-mediated model	Mediated model	Non-mediated model	Mediated model
Effect on EII			0.696	0.693
H1: III → EII	0.836***(25.490)	0.833***(26.054)		
Effects on PCOC				0.495
H2a: III → PCOC		0.251*(1.830)		
H2b: EII → PCOC		0.481*** (3.627)		
Effects on PP			0.278	0.461
H3a: III → PP	-0.052(0.332)	-0.199 (1.543)		
H3b: EII → PP	0.585*** (3.976)	0.314** (2.138)		
H4: PCOC→PP		0.572***(5.301)		

Note: III Internal information integration, EII External information integration, PCOC Port community operational capability, PP Port performance. ***p<0.001, ** p<0.05, * p<0.1, NS: Non-significant.

According to the empirical testing of our model, III of PCIS significantly affects EII (β=0.833, p<0.001). The result explains 69.3% of the EII variance indicating strong prediction accuracy (Hair et al., 2013). This indicates that information sharing and integration within a port will increase the level of information integration with external stakeholders in the port-SCM. This finding also suggests that the best approach to information integration starts from within-firm information integration and then builds up with between-firm information integration. Moreover, this finding supports our proposition that internal information can be seen as an important enabler of full port supply chain integration by the formation of strategic alliances with the port and port users.

Regarding the effects of PCIS on PCOC, the results support H2a (β=0.251, $p<0.1$) and H2b (β=0.481, $p<0.001$), which indicates that III and EII of PCIS significantly affect PCOC, explaining 49.5% of variance. An advanced level of integrated IT infrastructure is positively associated with the capability of a port to integrate business processes internally and externally with port users. Although the information platform in enhancing port operational capability (including financial flows, information flows and physical flows) was not well addressed in prior research, our finding indicates that there is a clear positive impact of PCIS on port community operational capability.

In terms of the impacting factors of port performance, the test identified that 46.1% of the variances of PP are explained by PCIS and PCOC, which indicates a strong prediction accuracy (Hair et al., 2013). EII and PCOC significantly affect PP directly, but III does not affect it directly. However, III does affect PP via either PCOC or EII. This indicates that III indirectly affects PP. This model suggests that III needs an intermediary to achieve an impact on PP.

In order to further address this issue, the non-mediation model was tested to obtain more information for comparison with the mediation model (Iacobucci et al., 2007). The results are presented in Table 9. The direct effect of III on PP decreased (β=-0.052 to β=-0.199) in the mediation model. Additionally, its effect on PCOC (β=0.251, $p<0.1$) and PCOC's effect on PP (β=0.572, $p<0.001$) are significant. This implies that III is positively associated with PP but only via PCOC. The effect of III on PP via EII can be explained in a similar way.

While comparing the direct and indirect impact of PCIS on port performance, we observed that the prediction accuracy (R-squared) of port performance increased from 27.8% to 46.1% in the mediation model in Table 9. This indicates that the mediation model has a strong predictive power and a high level of accuracy (Hair et al., 2013). This finding suggests that PCOC affects PP significantly, which means that a port community with better business process integration among customers and suppliers will perform better than its competitors in its efficiency and effectiveness.

Table 10 Specific indirect effects

Path analysis	Original sample	Sample mean	Standard deviation	t statistics	p values
III→EII→PCOC	0.400	0.411	0.110	3.646	***
III→EII→PP	0.261	0.255	0.127	2.063	**
III→EII→PCOC→PP	0.229	0.242	0.081	2.827	**
III→PCOC→PP	0.144	0.142	0.084	1.716	*

Note: III Internal information integration, EII External information integration, PCOC Port community operational capability, PP Port performance. ***p<0.001, ** p<0.05, * p<0.1, NS: Non-significant.

Table 10 shows specific indirect effects among III, EII, PCOC and PP. The indirect effects of each impact path are shown in Table 10. Table 10 shows that III affects PP via three paths; that is, via EII, via EII and PCOC, and via PCOC. It clearly demonstrates that although III cannot affect PP directly, it has three different approaches to affect PP. Moreover, the path coefficient indicates that the most effective of these three paths is via EII to affect PP ($\beta=0.261$, $p<0.05$). This is in line with the majority of previous studies on the manufacturing supply chain, that IT infrastructure, with both internal and external information integration, contributes more to firm performance than only internal information integration. Another interesting finding is that although III has a significantly positive impact on PCOC ($\beta=0.251$, $p<0.1$) in the mediation model, its indirect path (via EII to PCOC) shows a greater effect on PCOC ($\beta=0.400$, $p<0.001$) than the direct effect ($\beta=0.251$, $p<0.1$). This demonstrates clear evidence that information integration within a firm only has less effect than information integration among all port community members, from the perspective of enhancing operational capability.

Table 11 Direct, total indirect and total effects

	Direct effects	Total indirect effects	Total effects
III → EII	0.833***	----	0.833***
III → PCOC	0.251*	0.400***	0.651***
EII → PCOC	0.481***	----	0.481***
III → PP	-0.199 NS	0.634***	0.435***
EII → PP	0.314**	0.275**	0.589***
PCOC→PP	0.572***	----	0.572***

Note: III Internal information integration, EII External information integration, PCOC Port community operational capability, PP Port performance. ***p<0.001, ** p<0.05, * p<0.1, NS: Non-significant.

Table 11 summarises the direct, total indirect and total effects of each path. Through Table 11, we can see the direct effect of III on PCOC (β=0.251, p<0.1) and total indirect effects (β=0.400, p<0.001). The total effect of III on PCOC is equal to the sum of direct effect and total indirect effect. Table 11 indicates that the direct, indirect and total effects of III on PP and EII on PP. Thus, in the port supply chains, we should also pay attention to the indirect path of port performance. In addition to focusing on internal information integration, we should pay more attention to external information integration and port community operational capability, to improve port performance, whether directly or indirectly.

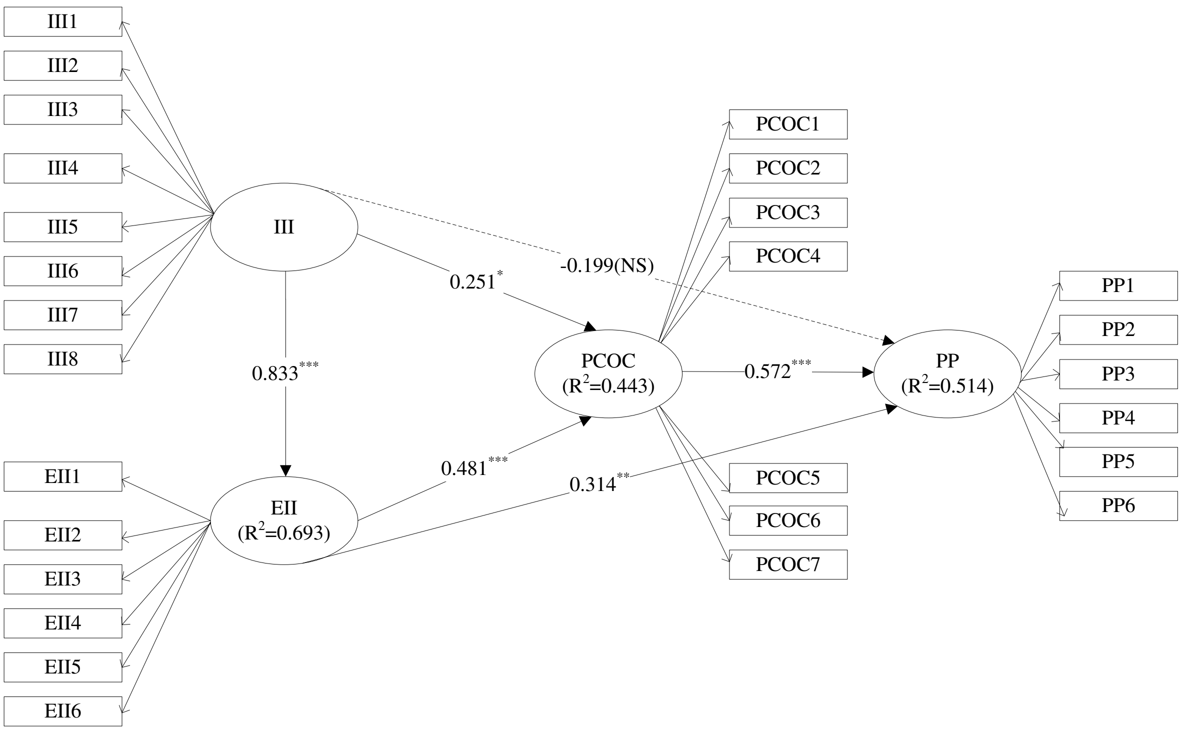

Figure 4. The result of path analysis

5. Discussion and Conclusions

5.1. Theoretical implications

Our research explores how information integration afforded by PCIS may impact port performance by means of empirical research. A survey was conducted in a major port in China with a total of 351 questionnaires issued to a range of port community members, with a response rate of 26.5%. A PLS-SEM analysis was conducted. Our model focuses on testing the mechanism of information integration on port performance among the port community members; that is, both internal and external information integration and their direct and indirect impact on port performance.

The impact of information integration on firm performance in the transport and supply chains has been examined in several previous studies (Flynn et al., 2010; Shou et al., 2017; Prajogo et al., 2012; Yu et al., 2017). Our research contributes to the literature by verifying this relationship in the specific context of the port-centric supply chain; an important but yet overlooked area.

Our research confirms that internal information integration plays a pivotal role in improving port performance. While it does not affect PP directly, it exerts its influence via supporting EII and affecting PCOC. It means that the port sector cannot merely focus on its own internal integration, because the improvement of its own information environment does not directly lead to port performance improvement. Therefore, the translation of the internal information integration into port operational capability becomes crucial. Therefore a PCIS is required to allow cross-functional data exchange and timely communication between a port and its community members. The data consistency and visibility achieved via internal integration can enhance the operational capacity of the port community and subsequently improve port performance.

We find that EII has both a direct impact on PP and an indirect impact on PP via PCOC. Flexible information linkages with existing and new community members help a port to be able to react and adapt to the changing environment whilst maintaining operational efficiency. Effective information sharing supports the smooth execution of various port activities. This enhances PCOC and subsequently positively influences PP. EII also directly affects PP, for instance, via its explorative capability of supporting innovative provisions of IT-enabled products and services, and thus enables a port to provide value-added services to its community members. This will then improve a port's competitiveness in the global market.

Our findings indicate that PCOC fully mediates the relationship between information integration and port performance; that is, PCOC enabled by internal and external information integration is positively associated with port performance. A port's capability in managing its financial, information and physical flows of cargo requires the flexible configuration of information linkages and effective information exchanges within and between a port and its community members. Improvements in PCOC will lead to improvements in a port's operational and business performance, and ultimately elevate the competitiveness of the whole sector. This will further strengthen the role of port in the global supply chain.

PCIS decreases the cost of coordinating with various stakeholders in port supply chain and increase the real-time data sharing among them, which improves the flexibility and responsiveness of the port supply chain and better satisfies external stakeholders' requirements. Therefore, regarding a single port performance, the port's revenue (i.e., sales, profits and market shares) will increase more than its competitors'. Regarding the whole industrial performance, the port industry will compete more effectively in the marketplace; that is, easily entering a new market and stimulating market demand.

5.2. Practical and policy implications

Our study offers a clear pathway for developing a port's digitalisation processes in order to achieve a competitive advantage. A port should commence its digitalisation journey with internal information integration, then move towards building effective information links with its existing and new community members. The impact of digitalisation on port performance can be achieved via two pathways:

- The mediated path, where improvement in port performance can be achieved if information integration is coupled with PCOC. This means that the PCOC plays a critical role in materialising the intended benefits. EII builds on III, emphasising the need for achieving port-wide visibility of its community members' activities. Thus, combined with a port's capability of managing its strategic flows of cash, information and cargo in a supply chain, this will lead to an improvement in service quality, cargo operation time, and profit. For instance, Portbase, a nation-wide initiative that facilitates bilateral connections between a port and its members, has delivered concrete savings in time and money (Berns et al., 2017). It is worth noting that if a port focuses solely on its internal information integration, it may not be able to fully capture and capitalise on the benefits of the potential of digitalisation. Likewise, the impact of effective external integration may be compromised by poor internal integration, leading to lower operation efficiency and productivity; and
- The direct path, where performance improvement does not tie a port in with PCOC. It implies that the innovative use of PCISs may lead to radical ideas, transformative changes, and emerging business models. For example, blockchain technology has

recently been explored in the shipping sector. The concept of the smart port is being investigated by the city of Antwerp in using blockchain technology with the Internet of Things to enable rights to be transferred from one party to another in container management (Port of Antwerp, 2017).

A phased approach would be most viable in order to build digitalisation capability. Namely, the investment of an ICT system and its digitalisation journey should first focus on internal information integration and then move to external integration. The fully-developed information integration, coupled with or without PCOC, will then deliver the desired performance gains. Although offering a full guide on how to implement and join a port centric ICT platform is not within the remit of this paper, we do want to point out that all port community members need to include adequate cyber security measures in place. Most PCIS systems in practice are centralised platforms. While centralisation brings the benefits of efficiency and speed, it does bear its own security risks. For instance, the information integrity or the platform itself could compromised. A recent cyberattack known as NotPetya in 2017 is a clear example that demonstrates how centralised systems once being attached could bring a devastating impact on firms.

5.3. Limitations and future research

As in any empirical study, our study has its limitations. First, the sample data were collected from psychometric analyses, which may introduce a potential self-selection bias in the survey method. Second, our research investigates the impact of PCIS on a major port in China. Given the significance of Qingdao Port in the global trade and economy, its impressive digitalisation capability, and the fact that it represents how the main ports operate in China, show that the insights gained via the survey within this port will be informative and of considerable value to other ports in China, Asia and worldwide. However, we need to be cautious about generalising our findings. Our study is the first that attempts to establish a link between PCIS and port performance, and is simply explorative in nature. Future research should aim to further validate our model using a larger sample with multiple ports. It is also worthwhile conducting a study of port performance comparing the pre- and post-adoption of PCIS, thus providing empirical evidence of the benefits that PCIS systems bring to port performance.

Despite the limitations, the results of this study suggest that our conceptual model provides a useful way in which to evaluate the impact of PCIS. These findings are of particular interest to managers in the port industry who wish to improve port performance. The results are also useful to practitioners and academics interested in the use of ICT in port operation and management. Finally, the conceptual model may offer guidance in the development of similar models and for future research with different sampling and industries.

Acknowledgements

This work was supported by the Social Science Foundation of Shandong Province of No. 17CCXJ19, the Fundamental Research Funds for the Central Universities in China of No. 201713011, and National Social Science Foundation of China of No. 14CGL053. This research was partially funded by the Hong Kong Polytechnic University (G-YBTM).

Appendix A. Cross loading analysis result

Indicators	III	EII	PCOC	PP
III1	**0.709**	0.544	0.481	0.296
III2	**0.721**	0.536	0.505	0.322
III3	**0.741**	0.684	0.382	0.284
III4	**0.790**	0.663	0.530	0.341
III5	**0.751**	0.595	0.447	0.198
III6	**0.680**	0.538	0.513	0.322
III7	**0.725**	0.646	0.456	0.312
III8	**0.740**	0.657	0.498	0.446
EII1	0.660	**0.746**	0.474	0.348
EII2	0.682	**0.774**	0.529	0.474
EII3	0.686	**0.830**	0.505	0.412
EII4	0.649	**0.831**	0.519	0.462
EII5	0.637	**0.716**	0.449	0.373
EII6	0.590	**0.768**	0.442	0.300
EII7	0.480	**0.605**	0.699	0.465
PCOC1	0.552	0.600	**0.822**	0.509
PCOC2	0.545	0.535	**0.824**	0.537
PCOC3	0.483	0.514	**0.812**	0.540
PCOC4	0.553	0.564	**0.808**	0.623
PCOC5	0.490	0.521	**0.791**	0.530
PCOC6	0.429	0.482	**0.781**	0.447
PCOC7	0.590	0.645	**0.787**	0.504
PP1	0.423	0.533	0.636	**0.806**
PP2	0.424	0.490	0.628	**0.842**
PP3	0.375	0.495	0.528	**0.838**
PP4	0.227	0.329	0.427	**0.828**
PP5	0. 239	0.249	0.333	**0.711**

PP6	0.317	0.398	0.495	**0.766**

Appendix B. Survey items (measurement constructs)

Section A: General Background Information

Please tick or fill in the answer that best describe you and your organisation.

1. What is your level of responsibility within your company?

□ Vice President or above

□ Director/Vice Director

□ Senior manager/Assistant Manager

□ Supervisor

□ Clerk/Operator

□ Others (please specify):

2. What is your area of responsibility within your company?

□ CEO/Managing Director

□ Logistics/Operations

□ Supply chain

□ Information Community Technology (ICT)

□ Marketing

□ Other (please specify):______________

3. What group does your company belong to in a port community?

□ Agents

□ Forwarders

□ Terminals

□ Customs

□ Port authorities

□ Product inspection authorities

□ Other, please specify_____________

□ Road hauliers

□ Berge operators

□ Rail operators/hauliers

□ Importers

□ Exporters

□ Shipbrokers/Shipping companies

4. How many employees in your company?

□1-9

□10-19

□20-49

□50-99

□100-199

□200-499

□>499

5. How long have you been working in the port industry?

□ 1-5 years □ 6-10 years □ 11-15 years □ 16-20 years □ over 20 years

Section B: Internal information integration (III)

How does a port centric ICT system (PCIS) support Internal Information Integration?

Please indicate the extent of internal information integration within port operator (1 = strongly disagree; 5 = strongly agree).

Internal Information Integration	**Indicators**
Data and enterprise application integration are in place among internal functions to enhance coordination.	III1
We have good information visibility across functions within our port.	III2
All relevant decision making information shared within our port is accurate and trustworthy.	III3
All relevant decision making information is shared within our port is frequent and timely.	III4
Our IT infrastructure is capable of meeting our current business needs.	III5
PCIS plays a pivotal role in facilitating information sharing within our port.	III6
PCIS plays a pivotal role in supporting cross functional cooperation.	III7
PCIS plays a pivotal role in supporting cross functional teamwork for process improvement or service innovation.	III8

Section C: External information integration (EII)

How does a port centric ICT system (PCIS) support External Information Integration?

Please indicate the extent of information integration with external stakeholders such as shipping companies, freight forwarders, transport operators, custom clearances and port authority (1 = strongly disagree; 5 =

strongly agree).

External Information Integration	Indicators
Electronic information shared between our community members and external stakeholders is standardized.	EII1
PCIS allows us to exchange information with our external private stakeholders outside our port community, such as shipping companies and freight forwarders, in a timely and accurate manner.	EII2
PCIS allows exchanging information with external public stakeholders outside our port community, such as custom clearance and the port authority, in a timely and accurate manner.	EII3
PCIS allows our community members to exchange information efficiently in a timely and accurate manner.	EII4
PCIS allows us to easily build and alter our information linkages to our existing supply chain partners, such as shipping companies and freight forwarders.	EII5
PCIS allows us to easily build and alter our information linkages to new supply chain partners.	EII6
PCIS enables us to actively explore innovative ways of using ICT in offering new products or services to our supply chain partners.	EII7

Section D: Port community operational capability (PCOC)

How does a port-centric ICT system (PCIS) support Port Community Operational Capability? Please indicate the degree of Port Community Operational Capability in the following areas (1 = strongly disagree; 5 = strongly agree).

Port community operational capability		Indicators
Financial Flow	Costs associated with billing, payment processing, and dispute handling are reduced.	PCOC1
	The invoicing and receivables cycle time is shortened while payments are accelerated.	PCOC2
	The availability of financial information for decision-making is improved.	PCOC3
Information Flow	Information concerning shipment and cargo tracking is visible at all steps across port and port users.	PCOC4
	Integrated information systems are used to share data/information with port users.	PCOC5
Physical Flow	Cargoes flow through our port more	PCOC6

	efficiently.	
	The transferring of cargo from one mode to another is improved.	PCOC7

Section E: Port performance (PP)

How does a port-centric ICT system (PCIS) contribute to port performance?

Please indicate the degree to which you agree to the following statements about port performance (1 = strongly disagree; 5 = strongly agree).

Port Performance		**Indicators**
Operational Performance	The effectiveness of port operations (i.e. service quality and price) is improved.	PP1
	The efficiency of port operations (i.e. cargo operation time) is improved.	PP2
Business Performance	After using port-centric ICT system, the port's increase in sales is more than its competitors.	PP3
	After using port-centric ICT system, the port's increase in profit is more than its competitors.	PP4
Industrial Performance	Demand for the products of the port industry is growing and will continue to grow.	PP5
	More firms in the port industry will use ICT systems.	PP6

References

Acciaro, M., and C. Sys. 2020. "Innovation in the maritime sector: aligning strategy with outcomes." Maritime Policy & Management: 47(8), 1045-1063. doi: 10.1080/03088839.2020.1737335.

Acciaro, Michele, Claudio Ferrari, Jasmine S. L. Lam, Rosario Macario, Athena Roumboutsos, Christa Sys, Alessio Tei, and Thierry Vanelslander. 2018. "Are the innovation processes in seaport terminal operations successful?" Maritime Policy & Management 45 (6):787-802. doi: 10.1080/03088839.2018.1466062.

Bensassi, S., Márquez-Ramos, L., Martínez-Zarzoso, I., and Suárez-Burguet, C., 2015. Relationship between logistics infrastructure and trade: Evidence from Spanish regional exports. Transportation Research Part A: Policy and Practice, 72, 47-61.

Berns, S., Vonck, I., Dickson, R., and Dragt, J. 2017. Smart ports: point of view, available from https://www2.deloitte.com/content/dam/.../deloitte-nl-er-port-services-smart-ports.pdf, date accessed November 10 2018

Berns, S., Vonck, I., Dickson, R., and Dragt, J., 2017. Smart Ports: point of view, available from https://www2.deloitte.com/content/dam/.../deloitte-nl-er-port-services-smart-ports.pdf, date accessed 15 Oct 2018.

Caridi, M., Moretto, A., Perego, A., and Tumino, A. 2014. The benefits of supply chain visibility: A value assessment model. International Journal of Production Economics, 151, 1-19.

Carlan, V., Sys, C., and Vanelslander, T. 2016. How port community systems can contribute to port competitiveness: Developing a cost-benefit framework. Research in Transportation Business & Management, 19, 51-64.

Cheng, T.C.E., K.-H. Lai, and C.W.Y. Wong 2011. Value of Information Integration to Supply Chain Management: Roles of Internal and External Contingencies. Journal of Management Information Systems, 28(3), 161-200.

Chopra, S., and Sodhi, M.S. 2004. Supply-chain breakdown. MIT Sloan Management Review, 46(1), 53-61.

Diamantopoulos, A., and Siguaw, J.A. 2006. Formative versus reflective indicators in organizational measure development: a comparison and empirical illustration. Br. J. Manag. 17 (4), 263-282.

Dong, S., Xu, S. X., and Zhu, K. X. 2009. Research Note: Information Technology in Supply Chains: The Value of IT-Enabled Resources Under Competition. INFORMS, 2009.

IPCISA 2015. How to develop a Port Community System. International Port Community Systems Association.

Fawcett, S. E., S. Croom, P. Osterhaus, G. M. Magnan, J. C. Brau, and M. W. McCarter 2007. Information sharing and supply chain performance: the role of connectivity and willingness, Supply Chain Management: An International Journal, 12(5), 358-368.

Flynn, B. B., B. Huo, and X. Zhao 2010. The impact of supply chain integration on performance: A contingency and configuration approach. Journal of Operations Management, 28(1), 58-71.

Fornell, C., and Larcker, D.F. 981. Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research 18 (1), 29–50.

Gefen, D., Straub, D., and Boudreau, M.C. 2000. Structural equation modeling and regression: Guidelines for research practice. Communications of the association for information systems, 4(1), 7.

Gordon, J.R., Lee, P.M., and Lucas Jr, H.C. 2005. A resource-based view of competitive advantage at the Port of Singapore. The Journal of Strategic Information Systems, 14(1), 69-86.

Gunasekaran, A., Subramanian, N., and Papadopoulos, T. 2017. Information technology for competitive advantage within logistics and supply chains: A review. Transportation Research Part E: Logistics and Transportation Review, 99, 14-33.

Gunasekaran, A., Patel, C., and Tirtiroglu, E. 2001. Performance measures and metrics in a supply chain environment. International Journal of Operations & Production Management, 21(1/2), 71-87.

Hair, J.F., Hult, G.T.M., Ringle, C.M., and Sarstedt, M. 2014. A Primer on Partial Least Squares Structural Equation Modelling (PLS-SEM). SAGE Publications, Thousand Oaks, CA.

Hair, J.F., Ringle, C.M., and Sarstedt, M. 2011. PLS-SEM: Indeed a silver bullet. *Journal of Marketing Theory and Practice*, *19*2, 139-152.

Hair Jr, J.F., Hult, G.T.M., Ringle, C.M. and Sarstedt, M., 2021. A primer on partial least squares structural equation modeling (PLS-SEM). Sage publications.

Hair, J.F., Risher, J.J., Sarstedt, M. and Ringle, C.M. (2019), "When to use and how to report the results of PLS-SEM", European Business Review, Vol. 31 No. 1, pp. 2-24. https://doi.org/10.1108/EBR-11-2018-0203.

Han, J.H., Wang, Y., and Naim, M. 2017. Reconceptualization of information technology flexibility for supply chain management: An empirical study. International Journal of Production Economics, 187, 196-215.

Harris, I., Wang, Y., and Wang, H. 2015. ICT in multimodal transport and technological trends: Unleashing potential for the future. International Journal of Production Economics, 159, pp.88-103.

Huo B, Han Z, and Prajogo D. 2016. Antecedents and consequences of supply chain information integration: A resource-based view. Supply Chain Management, 21(6), 661-677.

Iacobucci, D., Saldanha, N., and Deng, X. 2007. A meditation on mediation: evidence that structural equations models perform better than regressions. J. Consum. Psychol., 172, 139–153.

Kia, M., Shayan, E., and Ghotb, F. 2000. The importance of information technology in port terminal operations. International Journal of Physical Distribution & Logistics Management, 30(3/4), 331-344.

Kim H. J. 2017 Information technology and firm performance: the role of supply chain integration. Operations Management Research, 10(1-2), 1-9.

Lee-Partridge, J.E., Teo, T.S., and Lim, V.K. 2000. Information technology management: the case of the Port of Singapore Authority. The Journal of Strategic Information Systems, 9(1), 85-99.

Lee, S.-Y., J. L. Tongzon, and Y. Kim. 2016. Port e-Transformation, customer satisfaction and competitiveness. Maritime Policy & Management, 43(5): 630-643. doi: 10.1080/03088839.2015.1105394.

Litze Hu and Peter M. Bentler 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives, Structural Equation Modelling: A Multidisciplinary Journal, 6(1), 1-55.

Frohlich, M. 2002. Techniques for improving response rates in OM survey research, Journal of Operations Management, 20(1), 53–62.

Maiga, A.S., A. Nilsson, and C. Ax 2015, Relationships between internal and external information systems integration, cost and quality performance, and firm profitability. International Journal of Production Economics, 169: 422-434.

Mangan J., Lalwani C., and Fynes B. 2008. Port-centric logistics. International Journal of Logistics Management, 19(1), 29-41.

Mattei, Fondazione Eni Enrico (2020), Port of the future: Addressing efficiency and sustainability at the Port of Livorno with 5G, available from https://www.ericsson.com/en/blog/2020/7/the-5g-port-of-the-future, date accessed 11/3/2021.

Melville, N., Kraemer, K., and Gurbaxani, V. 2004. Information technology and organizational performance: An integrative model of IT business value. MIS Quarterly, 282, 283-322.

Mondragon, A.E.C., Mondragon, C.E.C., and Coronado, E.S., 2017. ICT adoption in multimodal transport sites: Investigating institutional-related influences in international seaports terminals. Transportation Research Part A: Policy and Practice, 97, 69-88.

Ngai, E.W., Chau, D.C., and Chan, T.L.A. 2011. Information technology, operational, and management competencies for supply chain agility: Findings from case studies. The Journal of Strategic Information Systems, 20(3), 232-249.

Nguyen, Son, Shu-Ling Chen Peggy, and Yuquan Du. 2020. Risk identification and modeling for blockchain-enabled container shipping. International Journal of Physical Distribution & Logistics Management, 51(2), 126-148. doi: 10.1108/ijpdlm-01-2020-0036.

Nicolás Gonzálvez-Gallego, Francisco-Jose Molina-Castillo, Pedro Soto- Acosta, Joao Varajao & Antonio Trigo 2015. Using integrated information systems in supply chain management, Enterprise Information Systems, 92, 210-232.

Nota, G., Bisogno, M., and Saccomanno, A. 2018. A service-oriented approach to modelling and performance analysis of Port Community Systems., International Journal of Engineering Business Management, 10, 1-17.

Nunnally, J.C., Bernstein, I.H. 1994. Psychometric Theory. McGraw-Hill, New York, NY.

Oesterreich, T.D., and Teuteberg, F. 2016. Understanding the implications of digitalisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. Computers in Industry, 83, 121-139.

Perego A., Perotti S., and Mangiaracina R. 2011. ICT for logistics and freight transportation: a literature review and research agenda. International Journal of Physical Distribution & Logistics Management, 41(5), 457-483.

Peng, D.X. and Lai, F., 2012. Using partial least squares in operations management research: A practical guideline and summary of past research. Journal of operations management, 30(6), pp.467-480.

Popp, A. 2000. Swamped in information but starved of data: information and intermediaries in clothing supply chains. Supply Chain Management: An International Journal, 5(3), 151-161.

Port of Antwerp 2017. Smart port with blockchain, available from https://www.portofantwerp.com/en/news/smart-port-blockchain, date accessed October 10 2018.

Prajogo, Daniel, and J. Olhager 2012. Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration. International Journal of Production Economics, 135(1), 514-522.

Qiannong Gu, T. Jitpaipoon, and J. Yang 2017. The impact of information integration on financial performance: A knowledge-based view. International Journal of Production Economics, 191, 221-232.

Rai, A., Patnayakuni, R., and Seth, N. 2006. Firm performance impacts of digitally enabled supply chain integration capabilities, MIS Quarterly, 302, 225-246.

Reinartz, W., Haenlein, M., and Henseler, J. 2009. An empirical comparison of the efficacy of covariance-based and variance-based SEM. International Journal of Research in Marketing, 26 (4), 332–344.

Riedl, J., Delenclos, F., and Rasmussen, A. 2018. To get Smart, ports go digital, available from https://www.bcg.com/en-gb/publications/2018/to-get-smart-ports-go-digital.aspx, date accessed November 20 2018.

Rönkkö, M., McIntosh, C.N., Antonakis, J., and Edwards, J.R. 2016. Partial least squares path modeling: Time for some serious second thoughts. Journal of Operations Management, 47, 9-27.

Sarstedt, M., Hair, J.F., Ringle, C.M., Thiele, K.O., and Gudergan, S.P. 2016. Estimation issues with PLS and CBSEM: Where the bias lies! Journal of Business Research, 69(10), 3998-4010.

Schoenherr, T., and M. Swink 2012. Revisiting the arcs of integration: Cross-validations and extensions, Journal of Operations Management, 30(1-2), 99-115.

Shou, Y., Li, Y., Park, Y., and Kang, M. 2018. Supply chain integration and operational performance: the contingency effects of production systems. Journal of Purchasing and Supply Management, 24(4), 352-360.

Titah, R., Shuraida, S., and Rekid, Y. 2016. Integration breach: Investigating the effect of internal and external information sharing and coordination on firm profit. International Journal Production Economics, 181 Part A, 34–47.

Tseng, P.H., and C. H. Liao 2015. Supply chain integration, information technology, market orientation and firm performance in container shipping firms. International Journal of Logistics Management, 26(1), 82-106.

Vernon, F. 2008. Supply chain visibility: lost in translation? Supply Chain Management: An International Journal, 13(3), 180-184.

Wong, C.W.Y., Lai, K.H., and Cheng, T.C.E. 2011. Value of Information Integration to Supply Chain Management: Roles of Internal and External Contingencies, Journal of Management Information Systems, 28(3), 161-200.

Woo, S.-H., S. J. Pettit, and A. K.C. Beresford 2013. An assessment of the integration of seaports into supply chains using a structural equation model. Supply Chain Management: An International Journal, 18(3), 235-252.

Yip, T. L., Wang Y.L., Haider, J., and Velde, M. van der 2016. Port-centric ICT system: Building value in supply chains. In: E-Logistics: Managing Your Digital Supply Chains for Competitive Advantage. Kogan Page Publishers, pp. 154-182.

Yip, T. L., Wang Y.L., Haider, J., and Velde, M. van der 2021. Port-centric ICT system: Building value in supply chains. In: E-Logistics (2nd ed): Managing Your Digital Supply Chains for Competitive Advantage. Kogan Page Publishers, pp. 234-266.

Yu, W., Chavez, R., Jacobs, M.A., and Feng, M.Y. 2018. Data-driven supply chain capabilities and performance: A resource-based view. Transportation Research Part E: Logistics & Transportation Review, 114, 371-385.

Zhao, X., B. Huo, W. Selen, and J. H. Y. Yeung 2011. The impact of internal integration and relationship commitment on external integration. Journal of Operations Management, 29(1-2): 17-32.

Zhao, X., J. Xie, and W. J. Zhang 2002. The impact of information sharing and order-coordination on supply chain performance. Supply Chain Management: An International Journal, 7 (1): 24–40.