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Perceptions of the Relationship between Port Security Level, Resilience, Cargo Operational Performance, and Sustainability Performance among Korean Port Operators and Shipping Companies*

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Abstract

Purpose – As globalization progresses, complexity also increases, and various factors that threaten port functions are emerging. Accordingly, the demand for port security to prevent the crisis and resilience that quickly recovers its original function after the crisis is also increasing in port operations. However, few studies have examined how to ensure the port security and how the resilience affects operation performance of port and sustainability performance as well. So the study aims to find out how port security affects port resilience and port operational performance, and consequently, this two factors affect socioeconomic and environmental sustainability performance respectively and synthetically.

Design/methodology – Confirmatory Factor Analysis (CFA) was first performed to determine the validity of the factors of model and hypothesis test was performed using Structural Equation Model (SEM) to analyze the Port Performance Model, which show the perception logic among port security level, port resilience, operation performance, and sustainability performance. In order to empirically analyze this model, total 264 respondents from port security operators, shipping companies in South Korea were surveyed.

Findings – As result of SEM, First, port security level positively affected the resilience (H1) and cargo operational performance (H2) but not in both of the sustainability performances (H3, H4). Second, resilience positively affected only cargo operational performance (H5) and socio-economic sustainability performance (H7). Last, cargo operation performance positively affects the both of sustainability performances (H8, H9).

Originality/value – It was confirmed that port security could improve cargo operational performance through ensuring port resilience and eventually increase the socio-economic sustainability. Therefore the study implies that careful integration and management of port security, port resilience, and sustainability are required, along with compromise on sustainable development goals in the social, economic, and environmental area among all stakeholders.

Keywords: Cargo Operational Performance, Port Security, Resilience, Structural Equation Modeling, Sustainability Performance
JEL Classifications: F14, O53, R49

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1. Introduction

As ports are responsible for 80~90% of the world's trade volume and 60~70% of its trade value over the last 50 years, they are critical elements of a nations' infrastructure (UNCTAD, 2018). As such, suspension of port functions due to unexpected events can result not only in financial difficulties for the port operator but also in significant economic damage to the region and country to which the port belongs. Thus, activities that ensure port security through identification of, preparation for, and response to events that may threaten port functions are important to the national economy (Harrell and Sales, 2019). Additionally, diverse events threaten port functions, for example physical attacks such as the terrorist attacks of September 11, 2001, natural disasters such as the Great East Japan Earthquake of 2011, infectious diseases such as COVID-19, and cyber terrorism attacks. Predicting and preventing all events in such a situation is near impossible. Thus, in recent years, demand has increased not only for port security but also for the reinforcement of port resilience, which refers to the ability to quickly restore a port's original functions in response to the consequences of unpreventable events (Kim, 2021; Kim et al., 2021).

Although the importance of ensuring port security and resilience continues to increase, scholars have presented conflicting views on the effects of the resiliency trend on cargo operational performance, which reflects the original function of ports. In previous studies on the effects of the reinforcement of port security on operational performance, researchers have found that positive aspects such as faster document processing (Mazaheri and Ekwall, 2009) and improved customer satisfaction and reputation (Chang and Thai, 2016) coexist with negative aspects such as delays and cost increases in the operation process (Mazaheri and Ekwall, 2009) and increased port rotation time and ship sailing time (Sadovaya and Thai, 2015). In addition, while some have argued that securing port resilience will lead to improvements in operational performance, little empirical analysis has yet been performed.

Recently, with the emergence of environmental pollution and resource depletion issues, the importance of ensuring ports' sustainability performance in addition to their operational performance has emerged. Securing resilience and sustainability in ports, which see 80% of the global trade, with the aim of improving the socio-economic quality of users by continuously providing services including essential social services as well as maintenance and guarantees thereof is crucial for the stability of the global economy (Fiksel, 2003). However, securing resilience and sustainability is an investment that takes into consideration long-term effects, and studies have demonstrated that companies cannot but be skeptical about investments in costs to ensure security or resilience in order to achieve future-oriented goals or to secure sustainability because they concentrate on producing short-term effects by securing efficiency in resource utilization (Gao and Bansal, 2013; Ortiz-de-Mandojana and Bansal, 2016).

Ensuring port security can be considered a means of ensuring macroscopic resilience, and improving resilience can be an important factor in improving port operational performance and securing sustainability; however, relevant empirical research remains insufficient. Previous studies have focused on the partial correlation between port security and operational performance, between port security and resilience, and between resilience and sustainability performance. In particular, few studies have empirically analyzed the effects of port security, as a means of securing resilience, on sustainable national development, which is one of the main purposes of port security.

Toward filling this gap in the literature, the study aimed to understand the effects of port security level and resilience on operational performance and sustainability performance by empirically analyzing the relationships among them. To that end, data were collected through a survey targeting port operators responsible for port security and shipping companies in South Korea, and relationships between each factor were identified by confirmatory factor analysis and structural equation modelling.

Accordingly, the present study found that port security level positively affected resilience and cargo operational performance levels. In addition, it was verified that resilience positively affected the operational performance and socio-economic sustainability performance of ports and that operational performance positively affected sustainability performance. These results indicate that implementation of port security and management of resilience can comprehensively positively affect port performance, and verification of this through empirical analysis is a major contribution of this study.

2. Literature Review

2.1. Port security level

Port security basically refers to activities to control access to ports for the purpose of preventing threats that could suspend port functions (Harrell and Sales, 2019). Port security began in earnest after the terrorist attacks on the World Trade Center in New York City on September 11, 2001. After the terrorist attacks, the United States began to reinforce security at airports and ports, etc., for all modes of transportation entering the country. Subsequently, the International Maritime Organization (IMO) enacted the ISPS Code, a security regulation for international ships and port of call facilities; in 2004 the ISPS code stipulated that shipping companies operating international ships and the associated ports of call implement various security activities.

The literature on the measurement of port security level was examined as follows. To ensure supply chain security, (Hintsa et al., 2009) suggested the need for the following management areas, facility management, cargo management, human resource management, information management, business network and corporate systems management, and crisis and disaster recovery management. (Yang and Hsu, 2018) presented similar security management factors, including cargo management, facility management, stock management, information management, human resource management, partnership management, and prevention and handling of security accidents.

In the context of security quality at the Port of Kaohsiung in Taiwan, Chang and Thai (2016) considered technical security facilities (e.g., RFID), information security facilities (e.g., EDI), physical security facilities (e.g., CCTV, access management systems), professional knowledge of security personnel in security services, security operations expertise of security personnel, security personnel enthusiasm regarding security issues, strict and swift baggage screening procedures, strict and swift security document management procedures, and swift response to security procedures-related issues. Along with the effects on ensuring port security quality and port service quality, Chang and Thai (2016) investigated the effects of port security and service quality on customer satisfaction among Taiwanese shipping companies, agencies, forwarders, and terminal operators. They found that ensuring port security quality can positively affect port service quality and that port security and port service quality can positively affect customer satisfaction.

As per the discussion above, port security management and port security quality factors stipulated among the ISPS code's measures for ensuring port security and previous studies such as Yang and Hsu (2018) and Chang and Thai (2016) commonly include level of baggage screening procedures, level of physical security facilities, speed of response to security incidents, and expertise of security personnel. Accordingly, the present study explored those four factors.

2.2. Port resilience

Various definitions of resilience appear in the literature. For example, Pettit et al. (2010) defined it as "the ability of the supply chain to withstand serious changes, and to adapt and grow." Apparently, many previous studies have regarded resilience as the ability to maintain normal function in preparation for a disruption or interruption of supply chain functions or to recover normal functions after such an interruption or disruption.

Among research on the components of resilience, Pettit et al. (2010) presented 14 items, purchasing flexibility, order fulfillment flexibility, capacity, efficiency, visibility, adaptability, predictability, recovery, diffusibility, collaboration, organization, market position, security, and financial soundness. Jüttner and Maklan (2011) conducted research on the relationship between supply chain resilience, supply chain management, and vulnerability, and they identified flexibility, velocity, visibility, and collaboration as components of resilience. Vugrin et al. (2010), Francis and Bekera (2014), and Yu et al. (2015) define resilience as the sum of absorptive capability, adaptive capability, and restorative capability. In particular, Vugrin et al. (2010) proposed robustness redundancy as indicators for measurement of absorptive capability, emergency measures and substitutability as indicators of adaptive capability and the quantity of recovered resources and swift procurement capability as indicators of measurement of restorative capability. Shashi et al. (2020) reviewed studies on the resilience of the supply chain from 2003 to 2018 in order to form a framework for measuring resilience. The framework defines resilience in the supply chain field along three dimensions, predictability, resistance, and recovery and response and includes indicators for the measurement of each dimension. Robustness, redundancy, and design were presented as indicators for the measurement of predictability; collaboration and agility were presented as indicators for the measurement of resistance; and various response capabilities were presented as indicators for the measurement of recovery and response.

Along these lines, Kim et al. (2021) framework for measuring port resilience comprises nine factors: robustness, redundancy, visibility, flexibility, collaboration, agility, information sharing, response, and recovery. The research model in the present study was based on Kim et al. (2021)'s framework, but only eight factors for the measurement of resilience were selected, as agility was excluded. Flexibility and agility hold similar conceptual attributes and have been used interchangeably across numerous studies (Bernardes and Hanna, 2009; Eckstein et al., 2015). Moreover, according to Abdelilah et al. (2018), agility is a combination of flexibility and responsiveness. Since response and flexibility are separate factors in the Kim et al. (2021) model, research in this study was conducted excluding agility.

2.3. Cargo operational performance in port

Previous studies have shown that implementation of the ISPS Code, a representative security system in the field of shipping and ports, can positively affect cargo operational performance including through improved cargo handling, improved inventory management, improved document processing, reduced transportation time and increased efficiency, and increased visibility (Bichou, 2008; Crutch, 2006; Thai, 2009). Conversely, negative effects of ISPS code implementation include delayed customs clearance, increased congestion at ports, reduced reliability and flexibility in processing time forecasting, additional staffing and staff training, increased cargo handling time, increased port rotation time, and increased ship sailing time (Bichou, 2008; Sadovaya and Thai, 2015; Thai, 2009; Urciuoli et al., 2010; Yang, 2010). Operators, who provide port services have concluded that implementation of ISPS Code offers few positive effects on operational performance and that negative effects include delayed operational processes and increased documentation and administrative work (Mazaheri and Ekwall, 2009). That is, the effects of reinforcing the security level on the operational performance of ports in general and the operational performance of cargo in particular involve a mix of positive aspects such as improved cargo handling and negative aspects such as increased cargo processing time and delayed operation processes.

An article by Peleg-Gillai et al. (2006) is a representative example of studies on the relationship between security and operational performance. They investigated the effects of the implementation of security-related systems, such as the ISPS Code, on supply chain operational performance with 11 manufacturers and three logistics service suppliers. They found positive effects such as improved product safety, improved inventory management, enhanced supply chain visibility, improved product processing, improved processes, efficient customs clearance procedures, improved speed, improved restorative capability, and improved customer satisfaction. Yang and Wei (2013) studied the effects of the level of security management on security performance in the container transportation industry in Taiwan, and presented decreased casualties, increased cargo flow, decreased cargo loss and damage, decreased equipment failure, decreased ship waiting time, and decreased customs inspection time as indicators of security performance. Yang and Hsu (2018) analyzed the effects of the security management levels of maritime firms on cargo operational performance. Among the performance indicators presented by Yang and Wei (2013), the frequency of cargo loss and damage, the frequency of accidents in cargo handling, and the flow of cargo (increase in cargo flow through operational efficiency) were presented as indicators for the measurement of cargo operational performance. In this study, cargo operational performance was measured based on the model by Yang and Hsu (2018).

2.4. Port sustainability performance

The Keeble (1988) defined sustainability, which came to the fore due to environmental problems in the 1960s and resource depletion issues such as the oil shock of the 1970s as the ability to satisfy current needs without compromising the ability of future generations to meet their needs. This definition of sustainability has developed over time into the pursuit of meaningful coexistence within and among social, economic, and ecological systems (Levin, 2006). This change in definition is due to the complex development of social, economic, and ecological systems and the increased uncertainty such complexity embodies (Érdi, 2008). Environmental Commission (2014) defines port sustainability as the promotion of the profits of the port and the development of the region for coexistence with future generations, with cooperation between the port and port users in green economic growth strategies, active development and operation of the port through stakeholder participation, and in consideration of the roles of the port in the region and within the supply chain. It also summarized environmental and social issues that must be addressed to realize port sustainability.

Numerous studies have largely classified sustainability performance into economic, social, and environmental aspects. Stein and Acciaro (2020) summarized the economic, social, and environmental factors of sustainability explored in relevant studies published from 2012 to 2019. First, they found that income and revenue and service quality were the main economic performance indicators used. Social performance indicators found include effects on the local community, employment quality, and effects of policy. Lastly, they found that water pollution management, air pollution management, noise control, environmental efficiency, and marine environment and ecosystem conservation were used as indicators of environmental performance. In a study on the relationship between sustainable supply chain management and port sustainability performance from the perspective of port operators, Lu et al. (2016a) proposed gauging ports' socio-economic sustainability performance in terms of service quality improvement, improvement in relations between port authorities and local residents, port authorities' cooperation in industrial and economic development, and the effects of ports' economic development enhancement on areas surrounding the port. They proposed that the effects of positive environmental performance include decrease in traffic accidents in port areas, decrease in industrial accidents, decrease in pollution caused by oil spills, improvement of air quality in port areas, and noise reduction in port areas.

In the present study, as per Lu et al. (2016a), ports' sustainability performance was classified into social and economic performance and environmental performance. Furthermore, as per the classifications in Stein and Acciaro (2020), the indicators of port socio-economic sustainability comprised four factors: a port's relationship with local communities, cooperation with the industrial and economic development of the country, contribution to the economic development of surrounding areas, and contributions to related companies' economic performance. Environmental sustainability performance was measured along three indicators: contribution to air quality improvement in the surrounding area, contribution to noise reduction in the surrounding areas, and contribution to improved water quality in the surrounding areas.

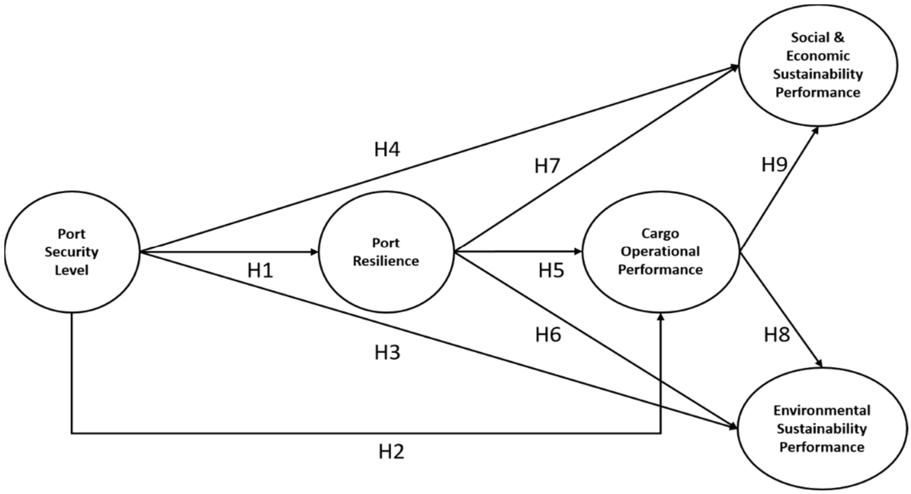
3. Methods

3.1. Research framework and hypotheses development

On the basis of the literature review above, this study sought to empirically identify the relationship between port security level, resilience, cargo operational performance, and port sustainability performance. The comprehensive research model is presented in Figure 1.

Through this research model, this study analyzes whether port security level affects resilience and whether security level and resilience significantly affect cargo operational performance and socio-economic and environmental sustainability performance. As such, it confirms that ensuring security and resilience in ports, which are social overhead capital facilities, can be closely related to social security for the promotion of a country's economic stability as well to the operation of cargo. That is, this study seeks to determine the implications of strategies to ensure port security and resilience at the national level by analyzing whether port security and resilience can ultimately positively affect sustainability in that it fosters coexistence between present and future societies.

Fig. 1. Research Framework



3.1.1. Impacts of port security level

As seen in the literature review, the purpose of port security is to ensure safety by controlling access to ports and can be a means to reinforce resilience (Harrell and Sales, 2019). Although views on the effects of port security on cargo operational performance can conflict, many are positive. For example, Yang and Hsu (2018) found that security management positively affects cargo operational performance, and Chang and Thai (2016) found that the quality of port security can positively affect service quality and customer satisfaction. Lastly, in examining the impact of port security on sustainability performance, Lu et al. (2016a) opined that identifying risks through security management would bolster sustainability management. According, the following hypotheses were tested in the present study:

H1: Port security level will positively affect port resilience.
H2: Port security level will positively affect port operational performance.
H3: Port security level will positively affect environmental sustainability performance.
H4: Port security level will positively affect social and economic sustainability performance.

3.1.2. Impacts of port resilience

Although port resilience basically refers to a port's ability to ensure that its functions are not interrupted and to quickly recover to its original state if such functions are interrupted, activities to further ensure this can help improve the port's operational capability (Kim et al., 2021). Pettit et al. (2013) argued that manufacturers can improve corporate competitiveness by establishing resilience management systems, and Harrell and Sales (2019) found that supply chain resilience plays a pivotal role in supply chain performance. Yang and Hsu (2018) found that increased levels of supply chain resilience management can improve maritime firms' cargo operational performance. Lastly, according to numerous studies, securing resilience is among the factors essential for improving sustainability (Asprone and Manfredi, 2015; Kim et al., 2021). Thus, the following additional hypotheses are tested in this study:

H5: Port resilience will positively affect port operational performance.
H6: Port resilience will positively affect environmental sustainability performance.
H7: Port resilience will positively affect socio-economic sustainability performance.

3.1.3. Impacts of cargo operational performance

Studies on the relationship between operational performance and resilience performance are relatively rare. Hakam and Solvang (2009) argued that improving operational efficiency (such as through tracking cargo movement and reducing processing time) by securing flexibility in port operations can augment sustainable development. Further, Kim and Chiang (2017) reviewed annual sustainability reports issued by international organizations such as ESPO, OECD, and IAPH and found that improved cargo handling efficiency in ports is among factors essential for building sustainable ports. Through a survey of port officials in Shanghai, Hong Kong, and Busan, Kang and Kim (2017) found that improving cargo handling processes and service quality constitute important factors in port sustainability practices According, this study tests the following additional hypotheses:

H8: Port resilience will positively affect environmental sustainability performance.
H9: Port resilience will positively affect socio-economic sustainability performance.

3.2. Research design

Data for this study was collected through administration of a survey. To secure the validity of the survey, the following methods were employed. First, the researchers composed questions in English with reference to relevant literature from other countries. The survey was then translated into the Korean language because it targeted Korean companies. After the translation, an expert in the port and supply chain fields who was bilingual in Korean and English was consulted to check that no changes to the meanings of questions had occurred in the translation process. In addition, content validity of the survey was assured, for example, revising questions with ambiguous meanings according to interviews with relevant experts, including domestic port experts, port operator workers, and experts from the Korea Maritime Institute, a government-run research institute in the shipping and port sectors. The survey comprised 37 items, including items on basic information such as respondents' affiliation, work experience, and major ports of use and questions for each factor. Participants responded to the survey on a five-point Likert scale (1=strongly disagree, 5=strongly agree). The survey was conducted by e-mail and telephone and targeted port facility security officers (PFSO), internal security auditors, operational strategy and emergency response officers, ship security officers (SSO), safety quality officers, deck officers, and security officers at port authorities (including the Korean Port Logistics Association). The survey was conducted over a two-month period from August to September 2020. A total of 264 responses were collected, and after excluding 11 partially unanswered responses, 253 responses were used for analysis.

Items for measuring "port security level," "port resilience," "cargo operational performance," and "port sustainability performance" (socio-economic, and environmental performance), key concepts in this study, were organized as presented in Table 1 based on the relevant literature.

Table 1. Questionnaire items

Constructs and measurement items				Literature
Port security level (PSL)			PSL1: Level of strictness in cargo screening procedures	(Chang and Thai, 2016) (Yang and Hsu, 2018)
			PSL2: Level of equipment in physical security facilities (CCTV, access-controlled facilities, etc.)	
			PSL3: Level of swiftness of response to security incidents and accidents	
			PSL4: Level of professional knowledge of security personnel in security services	
Port resilience (PR)	Absorptive capability	Robustness (ROB)	ROB1: Original level of work performance under any situation	(Kim et al., 2021)
			ROB2: Level of ability to maintain stability under any external change	
			ROB3: Level of operation in various situations without the need for special coordination	
		Redundancy (RED)	RED1: Level of maintenance of reserve resources for supporting physical work, such as equipment and personnel	
			RED2: Level of retention of backup energy systems and multipurpose resources for emergencies	
			RED3: Level of retention of spare capacity in order to manage unexpected fluctuations in demand	
		Visibility (VIS)	VIS1: Level of establishment of an information system that accurately tracks all tasks	
			VIS2: Level of real-time management of data on equipment, personnel, etc.	
			VIS3: Level of establishment of effective business intelligence program for data analysis	
	Adaptive capability	Flexibility (FLE)	FLE1: Ability to reschedule tasks to respond to suspension in functions	
			FLE2: Ability to adjust task processing capabilities in response to suspension in functions	
		Collaboration (COL)	COL1: Level of collaboration with various companies to achieve main management objectives	
			COL2: Level of sharing strategic objectives with partners	
			COL3: Level of efforts for mutual benefits jointly with main partners	
		Information sharing (IMS)	IMS1: Level of appropriate exchange of information with partners	
			IMS2: Level of periodic exchange of information with partners	
			IMS3: Level of accurate exchange of information with partners	

Constructs and measurement items			Literature
Restorative capability	Response (RES)	RES1: Ability to respond quickly to suspension of operation	
		RES2: Ability to appropriately respond to crises	
		RES3: Formation of emergency response organization in preparation for crises	
	Recovery (REC)	REC1: Level of ability to absorb large losses	
		REC2: Ability to recover from crises at low cost	
		REC3: Level of potential reduction due to the effects of crisis response capabilities	
Cargo operational performance (COP)		COP1: Level of cargo loss and damage reduction	(Yang and Hsu, 2018)
		COP2: Level of reduction in frequency of security incidents and injury accidents	
		COP3: Level of increase in port operational efficiency	
Sustainability performance	Socio-economic performance (SESP)	SESP1: Level of community relations	(Lu et al., 2016a) (Lu et al., 2016b)
		SESP2: Level of collaboration in the industrial and economic development of the country	
		SESP3: Level of contribution to economic development in the surrounding areas	
		SESP4: Level of contribution to economic performance of relevant companies	
	Environmental performance (ESP)	ESP1: Level of contribution to improvement of air quality in the surrounding areas	
		ESP2: Level of contribution to noise reduction in the surrounding areas	
		ESP3: Level of contribution to the improvement of water quality in the vicinity	

3.3. Demographic details

Table 2 presents the results of participants' responses to items about their characteristics in three categories: affiliation, work experience, and major ports of use. One hundred twenty-six respondents (49.8%) were from shipping companies, 103 (40.7%) were from operating companies, and (24, 9.5%) were from port authorities. For purposes of this study, responses from port authority affiliates and port operator affiliates were not analyzed separately because port authorities and port operators both manage port facilities and port security, and some public docks are even directly managed by port authorities. Forty-three respondents (17%) had worked five years less, 49 (19.4%) had worked five to 10 years, 48 (19.0%) worked 10 to 15 years, 42 (16.6%) worked 15 to 20 years, and 71 (28%) had worked more than 20 years. The reliability of the overall response to the survey is considered high as the highest proportion (63.7%) of participants reported having worked over 10 years in the field and can thus be considered experts.

Table 2. Demographic details

Classification		Number of responses	Proportion
Affiliation	Shipping company	126	49.8%
	Operator	103	40.7%
	Port authority	24	9.5%
	Sum	253	100%
Service experience	5 years or less	43	17.0%
	5-10 years	49	19.4%
	10-15 years	48	19.0%
	15-20 years	42	16.6%
	More than 20 years	71	28.1%
	Sum	253	100%

4. Results of empirical analysis

4.1. Results of CFA

Confirmatory factor analysis (CFA) was first performed to determine the validity and reliability of the measurement model. All analyses were conducted using the lavaan package of R 4.0.0. Table 3 presents the results that confirm convergent validity through CFA. Convergent validity indicates high correlation among multiple variables measuring a single factor and is usually determined using the standardized estimate of each variable and the values of composite reliability (CR) and average variance extracted (AVE). In Table 3, SE refers to standardized error, representing the value corresponding to the standard deviation, and the p-value represents the probability of significance. Convergent validity is generally satisfied when the standardized estimate is 0.5 or higher, the CR is 0.7 or higher, and the AVE is 0.5 or higher (Fornell and Larcker, 1981). According to the analysis, the lowest standardized estimate among all items was 0.605, and all items were significant at the 1% level. In addition, a value between 0.750 and 0.928 and and AVE value between 0.541 and 0.818 were demonstrated. As such, convergent validity is satisfied for the present study's model.

Table 3. Convergent validity

Factor	Measured variable	Estimate	Standardized estimate	S.E.	p-value	CR	AVE
PSL	PSL1	1	0.787			0.885	0.660
	PSL2	1,071	0.873	0.071	0.000**		
	PSL3	1.085	0.868	0.073	0.000**		
	PSL4	0.826	0.711	0.069	0.000**		
ROB	ROB1	1	0.702			0.827	0.617
	ROB2	1.389	0.902	0.121	0.000**		
	ROB3	1.081	0.737	0.102	0.000**		
RDE	RED1	1	0.714			0.782	0.548
	REd2	1.152	0.837	0.102	0.000**		
	RED3	0.976	0.658	0.102	0.000**		

Factor	Measured variable	Estimate	Standardized estimate	S.E.	p-value		CR	AVE
VIS	VIS1	1	0.789				0.823	0.609
	VIS2	1.004	0.831	0.081	0.000	**		
	VIS3	0.817	0.716	0.074	0.000	**		
FLE	FLE1	1	0.846				0.865	0.762
	FLE2	1.044	0.899	0.083	0.000	**		
COL	COL1	1	0.743				0.864	0.680
	COL2	1.208	0.873	0.089	0.000	**		
	COL3	1.146	0.852	0.087	0.000	**		
IMS	IMS1	1	0.900				0.750	0.818
	IMS2	1.039	0.899	0.048	0.000	**		
	IMS3	1.075	0.915	0.048	0.000	**		
RES	RES1	1	0.842				0.874	0.699
	RES2	1.021	0.916	0.056	0.000	**		
	RES3	0.815	0.741	0.060	0.000	**		
REC	REC1	1	0.835				0.777	0.541
	REC2	0.920	0.748	0.082	0.000	**		
	REC3	0.740	0.605	0.080	0.000	**		
ASC	ROB	1	0.652				0.810	0.592
	RED	1.367	0.924	0.198	0.000	**		
	VIS	1.311	0.705	0.197	0.000	**		
AAC	FLE	1	0.653				0.786	0.551
	COL	1.150	0.788	0.148	0.000	**		
	IMS	1.150	0.779	0.138	0.000	**		
RSC	RES	1	0.984				0.856	0.752
	REC	0.760	0.732	0.080	0.000	**		
PR	ASC	1	0.791				0.909	0.771
	AAC	1.316	0.990	0.214	0.000	**		
	RTC	1.860	0.841	0.264	0.000	**		
COP	COP1	1	0.842				0.835	0.630
	COP2	0.982	0.855	0.086	0.000	**		
	COP3	1.163	0.670	0.091	0.000	**		
SESP	SESP1	1	0.853				0.877	0.641
	SESP2	0.945	0.854	0.058	0.000	**		
	SESP3	0.838	0.778	0.058	0.000	**		
	SESP4	0.839	0.709	0.067	0.000	**		
ESP	ESP1	1	0.874				0.928	0.810
	ESP2	1.054	0.921	0.051	0.000	**		
	ESP3	1.005	0.905	0.050	0.000	**		

Notes: PSL: Port security level; ROB: Robustness; Red: Redundancy; VIS: visibility; FLE: Flexibility; COL: Collaboration; IMS: Information sharing; RES: Response; REC: Recovery; ASC: Absorptive capacity; AAC: Adaptive capacity; RSC: Restorative capacity, PR: Port resilience; COP: Cargo operational performance; SESP: Social and economic sustainability performance; ESP: Environmental sustainability performance; SE: Standardized error; ** : significant at $p<0.01$, *: significant at $p<0.05$

Table 4 presents the results of discriminant validity analysis. Discriminant validity indicates a difference between factors that represent different concepts, and verification of discriminant validity is achieved by comparing the AVE and the square values of the correlation coefficient between the factors. Discriminant validity is considered present if AVE is greater than the square value of the correlation coefficient (Lu et al., 2016a). Table 4 presents the square value of the correlation coefficient between each factor and AVE, with the diagonal matrix representing AVE and the rest representing the square values of the correlation coefficients. AVE was larger than the square value of the correlation coefficient for all items, indicating discriminant validity between factors.

Table 4. Discriminant validity

Classification	PSL	PR	COP	ESP	SESP
PSL	0.660				
PR	0.397	0.771			
COP	0.623	0.433	0.630		
ESP	0.118	0.166	0.265	0.810	
SESP	0.377	0.524	0.442	0.132	0.641

The goodness-of-fit of the model was analyzed prior to hypothesis verification; the relevant figures are presented in Table 5. To evaluate the measurement model, χ^2 value, Tucker Lewis index (TLI), comparative fit index (CFI), and root mean square error of approximation (RMSEA) are commonly used (Kim et al., 2023). Goodness-of-fit is generally considered demonstrated if the χ^2 value divided by the degree of freedom (df) is less than 3, if the CFI value is greater than 0.9, if the TLI value is greater than 0.9, and the RMSEA value is less than 0.1 (Hair, 2009). For the model in this study, the TLI value was 0.893, which is near 0.9. In addition, χ^2/df was 3 or less, the CFI value was 0.9 or more, and the RMSEA value was 0.1 or less, satisfying the criteria for almost all indicators, and thus demonstrating acceptable goodness-of-fit.

Table 5. Fit Indexes

Classification	χ^2	df	P-value	CFI	TLI	RMSEA
Figures	1233.249	608	0.000	0.902	0.893	0.064

4.2. Results of hypothesis testing

A hypothesis test was performed using Structural Equation Modelling (SEM) using R 4.0.0. SEM is a statistical technique used for estimating models of linear relationships among variables including both measured variables and latent variables (MacCallum and Austin, 2000). The results are presented in Table 6. The standardized estimate is 0.630 for the relationship between the port security level and port resilience (H1) and 0.622 for the relationship between port security level and cargo operational performance (H2), with both being significant under the 1% level. The standardized estimate for the relationship between port security level and environmental sustainability (H3) was negative at-0.216, and the standardized estimate for the relationship between port security level and socio-economic sustainability (H4) was 0.093, but neither hypothesis was supported. The standardized estimate for the relationship between port resilience and cargo operational performance (H5) was 0.266, and it was significant at the 1% level; the standardized estimate for the relationship between port resilience and environmental sustainability (H6) was 0.164 but was not supported.

Next, the standardized estimate for the effect of port resilience on social and economic sustainability performance (H7) was 0.487, and the relationship between port security operational performance and environmental sustainability performance (H8) was 0.578; both were significant at the 1% level. Lastly, standardized estimate for the relationship between port security operational performance and socio-economic sustainability performance (H9) was 0.271, and was significant at the 5% level. In summary, port security level appears to significantly affect port resilience and cargo operational performance in the positive (+) direction and that port resilience appears to significantly affect cargo operational performance and socio-economic sustainability in the positive (+) direction. In addition, cargo operational performance appears to significantly affect environmental sustainability performance and socio-economic sustainability performance in the positive (+) direction. Ultimately, six of the research hypotheses, H1, H2, H5, H7, H8, and H9, were supported.

Table 6. Results of hypothesis test

Classification	Estimate	Standardized estimate	S.E.	p-value
PSL→PR(H1)	0.309	0.630	0.052	0.000**
PSL→COP(H2)	0.654	0.622	0.083	0.002**
PSL→ESP(H3)	-0.253	-0.216	0.144	0.079
PSL→SESP(H4)	0.113	0.093	0.124	0.359
PR→COP(H5)	0.571	0.266	0.171	0.001**
PR→ESP(H6)	0.392	0.164	0.232	0.091
PR→SESP(H7)	1.212	0.487	0.257	0.000**
COP→ESP(H8)	0.643	0.578	0.151	0.000**
COP→SESP(H9)	0.314	0.271	0.127	0.013*

Notes: **: significant at $p<0.01$; *: significant at $p<0.05$

4.2.1. Analysis of mediating effect

Next, the mediating effect was verified to identify whether the indirect effect path was statistically significant. Standard error was calculated using bootstrapping. The bootstrapping method has the advantage of not being required to assume the normal distribution of estimates and is thus widely used for mediating effect analysis (Hayes, 2013). Table 7 presents the results of verification through application of the bootstrapping method. Bootstrapping was performed 5,000 times. According to the analysis, the indirect effect was significant along three paths: PSL → PR → COP, PSL → PR → SEEP, and PSL → PR → COP → SESP, whereby a mediating effect was found. That is, both the direct and indirect effects of port resilience on cargo operational performance were mediated by port resilience, and while port security level does not directly affect socio-economic sustainability performance, indirect effects mediated by port resilience and indirect effects mediated by port resilience and cargo operational performance have been observed.

Table 7. Result of mediating effect analysis

Explanatory variable	Parameter		Endogenous variable	Direct effect	Indirect effect
PSL	PR		COP	0.622(0.000**)	0.168(0.009**)
PSL	PR		ESP	-0.216(0.079)	0.103(0.167)
PSL	PR		SESP	0.093(0.359)	0.307(0.001**)
PR	COP		ESP	0.164(0.091)	0.154(0.104)
PR	COP		SESP	0.487(0.000**)	0.072(0.158)
PSL	PR	COP	ESP	-0.216(0.079)	0.097(0.062)
PSL	PR	COP	SESP	0.093(0.359)	0.045(0.047*)

Notes: Values in parentheses are the p-values; **: significant at $p<0.01$; *: significant at $p<0.05$

4.2.2. Analysis of moderating effect

Survey respondents can be largely divided into two groups: operators and shipping companies. Thus, in order to verify the presence of the moderating effect for each group, any differences between the unconstrained model, the measured factor constrained model, and the structure factor constrained model were identified through verification of differences in χ^2 in the goodness-of-fit model. The measured factor constrained model assumes that all estimates of the relationship between the measured variable and latent variable are all identical. The structure factor constrained model assumes that all causal coefficients between the latent variables are identical. A moderating effect is found when no difference in goodness-of-fit between the unconstrained model and the measured factor constrained model is observed and where difference in goodness-of-fit between the measured factor constrained model and the structure factor constrained model is observed. Table 8 presents the results of the verification of the presence of a moderating effect. In this research model, analysis was conducted after setting the variance for adaptive capability and restorative capability to a very small value (0.005) due to the Heywood problem, where error variance is calculated as a negative value in analysis of the unconstrained model. Setting the variance to a small value as such is a common method for solving the Heywood problem (Chen et al., 2001; Kim et al., 2021). The difference in goodness-of-fit between the unconstrained model and the measured factor constrained model was a p-value of 0.098, and it was not significant at the 5% level, indicating no difference between the two models. Conversely, the p-value of the measured factor constrained model and the structure factor constrained model was 0.003, significant at the 1% level. Thus, a moderating effect is present for the response group.

As a moderating effect was found, the results of between-groups hypothesis verification were compared. The results are presented in Table 9. Both operators and shipping companies accepted Hypotheses H1, H2, H7, and H8 while neither group accepted H3, H4, and H6. Only the shipping company group accepted H5, and only the operator group accepted H9. The between-group results differed from the overall results in that port resilience had no significant effect on cargo operational performance for the operator group and the effect of cargo operational performance had no significant effect on socio-economic sustainability for the shipping company group.

Table 8. Results of moderating effect test

Classification	Estimate	df	χ^2	χ^2 diff.	df diff.	p-value	
Test 1	Unconstrained model	1220	2141.1				
	Measured factor constrained model	1252	2183.8	42.698	32	0.098	
Test 2	Measured factor constrained model	1252	2183.8				
	Structured factor constrained model	1261	2208.8	24.97	9	0.003	**

Note: **: significant at p<0.01

Table 9. Results of moderating effect-based hypothesis test

Classification		Estimate	Standardized estimate	S.E.	p-value
PSL→PR(H1)	Operator	0.389	0.669	0.078	0.000**
	Shipping company	0.113	0.279	0.049	0.021*
PSL→COP(H2)	Operator	0.676	0.703	0.108	0.000**
	Shipping company	0.552	0.554	0.100	0.000**
PSL→ESP(H3)	Operator	-0.241	-0.216	0.219	0.271
	Shipping company	-0.178	-0.159	0.143	0.215
PSL→SESP(H4)	Operator	0.193	0.171	0.179	0.282
	Shipping company	0.148	0.137	0.128	0.245
PR→COP(H5)	Operator	0.304	0.183	0.166	0.067
	Shipping company	0.702	0.286	0.282	0.013**
PR→ESP(H6)	Operator	0.449	0.234	0.256	0.080
	Shipping company	0.236	0.086	0.305	0.440
PR→SESP(H7)	Operator	0.425	0.219	0.213	0.047*
	Shipping company	1.529	0.571	0.450	0.001**
COP→ESP(H8)	Operator	0.576	0.497	0.233	0.013*
	Shipping company	0.621	0.555	0.172	0.000**
COP→SESP(H9)	Operator	0.522	0.446	0.192	0.007**
	Shipping company	0.136	0.125	0.146	0.351

Notes: **: significant at p<0.01, *: significant at p<0.05

5. Discussion and Conclusion

5.1. Discussion

According to hypothesis verification, port security level has a positive (+) impact on port resilience. Also, Port resilience has a positive (+) impact cargo operational performance. Cargo operational performance has positive (+) impact socio-economic sustainability performance, and environmental sustainability performance. Port security level appears to significantly affect both port resilience and port security operational performance in the positive (+) direction. This further confirms the results found by Yang and Hsu (2018), who argued that security management positively affected resilience, and in turn, that resilience positive affected operational performance. Furthermore, this study found that, along with a direct effect of port security level on the cargo operational performance, the indirect effect of port security level on cargo operational performance through port resilience is also in the positive (+) direction. Mutual cooperation involving securing resilience along with port security, which focuses on identifying unexpected risks, can significantly affect increases in cargo operational performance, such as by reducing cargo loss and damage, reducing the frequency of security incidents and injury accidents, and operating efficiently.

In terms of sustainability, this study also found that port security level and port resilience, which comprise the capability to identify, prepare, respond to, and recover from uncertain and contingent threats, are social security-related management tools that can promote social, economic, and environmental sustainability. Port security refers not only to control of access to port facilities but also to the seeking of improvements in cargo operational performance by identifying threats through access control and reducing port facilities' vulnerability through port resilience with preparation, response, and restoration functions for managing threats.

The findings suggest that improved port security levels can foster social, economic, and environmental sustainability, which enables the present and future of ports, companies, regions, and countries to coexist. That is, ensuring port security and port resilience against threats is a social security tool used to promote the coexistence of present and future generations through ports, and in order to achieve this, stakeholders in the social, economic, and environmental fields must compromise on sustainable development goals (Smiljanic, 2016). In addition, as Matutinović (2015) contended, careful integrated management of port security, resilience, and sustainability is needed. The mediating effect analysis results also suggest the need for such integrated management. Port security and port resilience alone do not directly significantly affect sustainability performance, but improvements in security level, as mediated through resilience and cargo operational performance, can positively affect social and economic sustainability, indicating that integrated management of security and resilience is necessary.

Further, according to the results of the moderating effect analysis, the operator group did not accept the hypothesis that port resilience positively positive affects cargo operational performance, presenting a difference from the overall analysis results. This is perhaps because operators are directly responsible for investing the substantial amounts of money required to ensure port security and port resilience. Of course, at the corporate level, tangible results in line with input costs are required. However, since port security seeks to secure an ideal future (in social, economic, and environmental aspects) amid increasing contingencies and uncertainties, maintenance of services for the future should be considered in determining investment performance; accordingly, operators will need to recognize the importance of ensuring port security and resilience in terms of long-term sustainability performance.

Lastly, the shipping company group did not accept the hypothesis that cargo operational performance positively affects socio-economic sustainability performance. This is presumably because shipping companies are port users, and thus it is highly likely that they recognize cargo operational performance as simply a means to secure profit, making it difficult for them to see that cargo operational performance leads directly to improvements in sustainability performance. However, as Kim and Chiang (2017) and Kang and Kim (2017) found, improvement in cargo operational performance leads to improvement in logistics efficiency at the national level and may further drive socio-economic sustainability improvements. Accordingly, shipping companies should recognize this connection and pursue improvements in port operational efficiency.

5.2. Conclusion

This study aimed to confirm the legitimacy of the integrated management of port security, resilience, and sustainability and the implementation of enhanced levels of port security by empirically analyzing the relationship between port security level, port resilience, cargo operational performance, socio-economic sustainability performance, and environmental sustainability performance by surveying port operators and shipping companies in South Korea. This study sought to identify the perceived effects of the implementation of port security on port operational efficiency and to suggest relevant directions for the integrated management of port security and resilience. According to the findings, the relationship between port security level and port resilience is positive (+), the relationship between port resilience and port security operation performance is positive (+), and a positive (+) effect was observed between cargo operational performance, socio-economic sustainability performance, and environmental sustainability performance. This suggests that increased port security level and port resilience, along with the capability to identify, prepare for, and respond to uncertain threats and contingencies and to restore port functions disrupted by such threats, can not only help improve cargo operational performance but also be used as social security management tools that promote social, economic, and environmental sustainability. The direct effects of the relationship between port security level and socio-economic sustainability performance, port security level and environmental sustainability performance, and resilience and environmental sustainability performance have not been verified. However, a mediating effect was found, indicating that port security and resilience need to be managed through organic linkages in order to promote port sustainability.

The study makes the following contributions and implications. First, this study highlights the importance of each factor in responding to various threats and proposed reinforcement of the linkages between each factor in order to maintain port functions for responding to threats. Next, the role of resilience in the field of ports is investigated and by analyzing the effects of linkages between resilience with port security level, cargo operation performance, and port sustainability (socio-economic and environmental). In particular, the study of the resilience of infrastructure facilities, including ports, has focused on maintaining facility functions by preparing for, responding to, and recovering from disruptions or modifications to facility structures due to earthquakes and typhoons. This study is distinguishable from such previous studies in that it investigates port resilience in combination with port security for security incidents accompanying disruption. In addition, the present study is distinct from previous studies in that the research model was separately analyzed according to each survey group, and the moderating effects were compared. As seen in studies on port security, operators and shipping company affiliates present various differences in position on reinforcing port security. This study is further distinct from previous studies in that it separately analyzed and compared the positions of the two groups of stakeholder regarding the influence of port security on cargo operational performance and compared those results with the overall study results that include both the user and supplier groups. Lastly, this study's main contribution is in its confirmation of the need for integrated management of port security, resilience, and sustainability and in demonstrating that port security not only involves control of access to port facilities but can also form the basis for improvements in cargo operational performance and sustainability performance. Ports are key infrastructure connecting global trade, and improving their operational performance and sustainability plays an important role in the development of international trade. Comprehensive management of security and resilience to maintain the functioning of ports can be a means to develop national economies through trade facilitation.

The study's limitations are as follows. First, security cost variables were not included during verification of the relationship between the port security level and cargo operational performance. Lastly, the survey in this study was administered amidst the proliferation of COVID-19, which may have impacted the subjectivity of the survey respondents regarding port security, port resilience, and port sustainability. In particular, survey respondents may have exaggerated their consideration of externally-oriented publicity effects; as such, long-term follow-up surveys (longitudinal surveys) with a time gap between the study and the closure of specific situations are needed.

On the basis of those limitations, we propose that the following areas be studied in the future. First, in order to understand the practical implications of ensuring port security levels, analysis of the effects of security input costs on the port security level and the port security operation performance must be conducted by including security costs as a control variable between port security level and port security operational performance. Lastly, the influence of specific situations on the research results should be examined through follow-up studies on the long term the relationship between "port security level," "port resilience," "port security operational performance," "socio-economic sustainability performance," and "environmental sustainability performance."

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