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Smart and Sustainable Port Performance in Thailand: A Conceptual Model

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Abstract

Global seaports are interested in the concept of smart and sustainable ports that many have an impact on global trade and economics. This research aims to find the main factors and indicators of smart and sustainable port management, and confirm the factors of smart and sustainable port management using a case study of the Eastern Economic Corridor (EEC) in Thailand. Mix method approach, qualitative research is used in the data collection with a total of three databases in 2015-2021. Content analysis with triangulation data is utilized to analyze these data finding the factors and indicators of smart and sustainable port management. Quantitative research is used confirmatory factor analysis (CFA) for confirming the factors and indicators and developing a conceptual model of smart and sustainable port performance. As the result, a conceptual model with three main factors is shown including the smart port environment, the smart port society, and the smart port economy. These main factors and indicators are represented as three factors and seventeen indicators of confirming explanation. This conceptual model for the introduction of port development explains smart and sustainable port performance and the key indicators to achieve port practice for improving international standards of smart and sustainable ports.

Keywords: smart port, sustainable port, conceptual model, Eastern Economic Corridor (EEC), sustainable development goals (SDGs).

1. Introduction

Technological development and intense business competition have continually affected natural resources and the environment in which we live. As the environment has progressively deteriorated in recent years, organizations have become aware of these problems and started implementing policies regulating the effects of human activities on the environment. The United Nations (UN) certainly recognized these problems and has introduced the 17 Sustainable Development Goals (SDGs) to support the environment, society, and quality of life. Therefore, the International Maritime Organization (IMO) which belongs to the UN has adopted these goals for port activities and maritime transport which are essential components driving the global economy. Maritime transport and port management are operated to facilitate the movement of products to customers as these activities and processes are necessary to achieve effective operations and movement in ports. However, these activities which are managed to develop efficiency, effectiveness, and competitiveness have adversely affected the environment and created social problems around the port area. Sustainable ports are essential and port performance operations measurement includes three main factors. These can be explained in terms of reducing the environmental effects and developing a socially friendly port area while balancing this with the economic performance of the ports.

The main focus of the smart port is the implementation of 4IR technology to increase port efficiency/productivity, lower the impact on the environment, and improve the safety and security of ports and port employees. The main focus of sustainable ports is to reduce environmental and social impacts, and support maritime transport operations and the overall economic system (Muangpan & Suthiwartnarueput, 2019). The merging of smart ports and sustainable ports is the preferable solution for long-term port development and management. Smart ports and sustainable ports are focusing on all the main important dimensions including the environment, society, and economy. It seems there will be huge investments in port infrastructure and technology for developing a port to be a smart and sustainable port, but it is a worthwhile long-term investment.

In Thailand, the government has emphasized the Eastern Economic Corridor (EEC) focusing on physical and social development, and the infrastructure development of seaports in the eastern provinces of Rayong, Chonburi, and

Chachoengsao (EEC, 2021). Several ports under the EEC project are under development to be smart ports; however, sustainable ports also have to be considered along with smart port development. The goals of the research were to find the main factors and indicators of smart and sustainable port management and to confirm the factors and indicators of smart and sustainable port management using a case study of the Eastern Economic Corridor (EEC) in Thailand for developing a conceptual model of smart and sustainable port management.

2. Literature Reviews

2.1 Sustainable Port Management

A sustainable port is a port that undertakes the development strategies and activities to meet the needs of those who use it for the higher competitive potential while protecting and sustaining the three dimensions which are the environmental, economic, and social aspects. Glavic and Lukman (2017) addressed these three dimensions as important components of sustainability in container port operations. The IMO has implemented this plan by adopting the 17 Sustainable Development Goals (SDGs) introduced by the UN, which consist of: no poverty, zero hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry innovation and infrastructure, reduced inequalities, sustainable cities, and communities, responsible consumption and production, climate action, life below water, life on land, peace justice, and strong institutions, and partnerships for the goals. To achieve these goals, one of the key factors is technology, which is considered a part of the Fourth Industrial Revolution (4IR) (Hofmann & Rüsch, 2017). The technologies already have a huge impact on the economy and society. According to Bond, the top 10 technologies considered to play important roles in assisting the plan to reach its goals include big data, circular economy, financial technology, blockchain, machine learning, artificial intelligence, satellite technology, apps for refugees/asylum seekers, household/community scale batteries, and 3D printing (ABD, 2020). By applying these technologies, especially the big data information and communication advancements that have transformed document management and decision-making processes to a completely electronic format (Molavi, Lim & Race,2020; Douaioui, Fri, Mabrouki & Semma, 2018), the maritime industry has been improved drastically in terms of efficiency and reliability of trade and transport.

According to the World Bank's Port Reform Toolkit Public-Private Infrastructure Advisory Facility, future ports are expected to intensify global competition, while the technology and distribution patterns will be changed to enhance intermodal efficiencies while the importance of the environment, safety, and security are increasing. These port changes lead to changes in the bargaining power of the stakeholders and the emergence of global logistics service providers (ABD, 2020).

2.2 Smart Port Management

UNCTAD (2020) has introduced the six policy actions to prepare for a post-pandemic world and one of the policies is to promote greater technology uptake and digitalization in world maritime transport to link global economies and supply chains. The technology and digitalization will enable enhanced efficiencies, energy efficiency, and productivity in maritime transport, therefore the smart port has been included in the solution that will encourage the maritime transport to achieve the said policy. ADB (2020) has defined a smart port as a port that ensures no waste of space, time, money, or natural resources. Smart ports are the implementation of fourth industrial revolution technologies such as IoT, AI, big data, and blockchain including automation and innovation technologies for improving port performance (UNESCAP, 2021). In the research by Molavi, Shib, Wua, & Lim, (2019), the smart port consists of four activity domains: operations, environment, energy, and safety and security. According to the smart port system that was designed by Douaioui et al (2018), the smart port consists of two pillars: interconnection and port automation. Firstly, the interconnection pillar requires three technologies including a smart information system, a data center, and cybersecurity. And secondly, the port automation pillar requires the port to use automation equipment and operations. The purpose of smart ports is to fulfill the needs of the stakeholders by providing higher work efficiency, transparency, safety, and security UNESCAP (2021). The benefits of implementation of smart ports for ports and stakeholders are improved customer services, encouragement of health and safety for port workers and users, reduced environmental impacts from port activities, becoming a better neighbor, increased port operation efficiency, and increased profit ADB (2020).

2.3 Academic Peer-Reviewed Journals

This reviewed research focused on academic peer-reviewed journals published in 2015-2021. The keywords were "Sustainable port management", "Smart port management" and "Smart and Sustainable port management" in three databases including Emerald, SpringerLink, and ProQuest. Reviewed literature is concerned with collecting articles from a total of 105 articles within back 7 years period. The number of articles on the A.D. year basis can be summarized as shown in Figure 1.

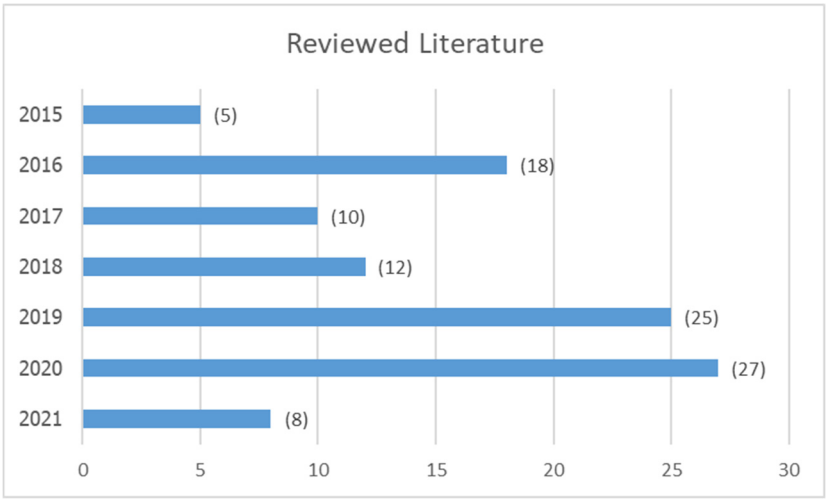

Figure 1. The number of reviewed papers per year, (-) is the number of articles

During the year 2015-2017, the articles were the concept and structure of environment port and smart introduction for stimulating factors, and operations. In 2015, were the sustainability and smart concept approach that there were fewer numbers of the relevant research (Buiza et al., 2015). In 2016, the port sustainability and smart introduced the three sustainable dimensions; however, this research was analyzed with reviewed literature. Most of the articles presented the port concept of activities and business organization (Laxe, Bermúdez, Palmero, & Novo-Corti, 2016; Roh, Thai & Wong, 2016; Antao et al. 2016; Chengpeng, Di, Xinping & Zaili, 2016). In 2017, Most articles were similar area to the research in the year 2016, but there was an increase in articles in the smart operation field (Xiao & Lam, 2017). During the period 2018-2021, the number of articles significantly grew smart and port sustainability articles that were focused on the factors and indicators finding. From 2018 to 2019, most articles of these researches were developed the main factors and indicators finding of port sustainability using reviewed literature (Molavi et al. 2019; Jović, K, Aksentijević, & Tijan, 2019). From 2020 to 2021, the smart and sustainability research field was developed with port sustainability and smart introduction measuring (González, González-Cancelas, Serrano, B, & Orive. 2020; Lim & Race, 2020; Wang & Han, 2020; Philipp, 2020)

3. Method

Mix method approach (as shown in figure 2), the first phase of qualitative research using was applied to content analysis using the triangulation data. This content analysis was a qualitative method that was used document synthetic to analyze the dimensions, indicators, and their relationships (Klaus, 2004; Bernard & Ryan, 2010). Triangulation data was utilized in the data more than two data sources for increasing the credibility and validity of the research results (Denzin, 2006; Bogdan, 2006; Altrichter, Feldman, Posch, & Somekh, 2008). Therefore, these techniques were applied to find a conceptual framework (Shields, 2013)

In this study, triangulation data were used in three data sources in developing the conceptual framework. Firstly, the literature reviews of 105 articles were focused on academic peer-reviewed journals published in 2015-2021. The searches of keywords were “Sustainable port management”, “Smart port management” and “Smart and Sustainable port management” in three databases including Emerald, SpringerLink, and ProQuest. This review of literature discusses journal published information in a subject field within back 7 years period, which is a survey of academic sources on focused topics. The goal of the study is to understand the current knowledge**.** Secondary, reports data were used with participant observation that integrated into the participants' environment for taking are interested in studying. This second source of the process with a shared identity to increase an understanding of the smart and sustainable port practices. The participant-observer is a practice manner that which the researchers aim to collect more detailed information and practical knowledge. Finally, in-depth interviews were conducted with smart and sustainable port management experts of the top three terminals in EEC. The third source aims to collect complete information on smart and sustainable port practices using directly responsively stakeholders.

Secondary phase, a quantitative research approach using Factor analysis (FA) was applied with Confirmatory factor analysis (CFA) to analyze these indicators for confirming the factors structure of a set of indicators and the relationship of these indicators to the factors; moreover, to examine the existing model and the reliability measures (Mishra, 2016; Sharif, Ghazi-Tabatabaei, Hejazi, Askarabad, & Dehshiri, 2011). Data analysis was studied the fitting analysis according to Pearson correlation coefficient and Kaiser-Meyer-Olkin test. Factor loadings would

surpass the common threshold of 0.4 that get a measure of fit of the data to this model (Ertz, Karakas, & Sarigollu, 2016).

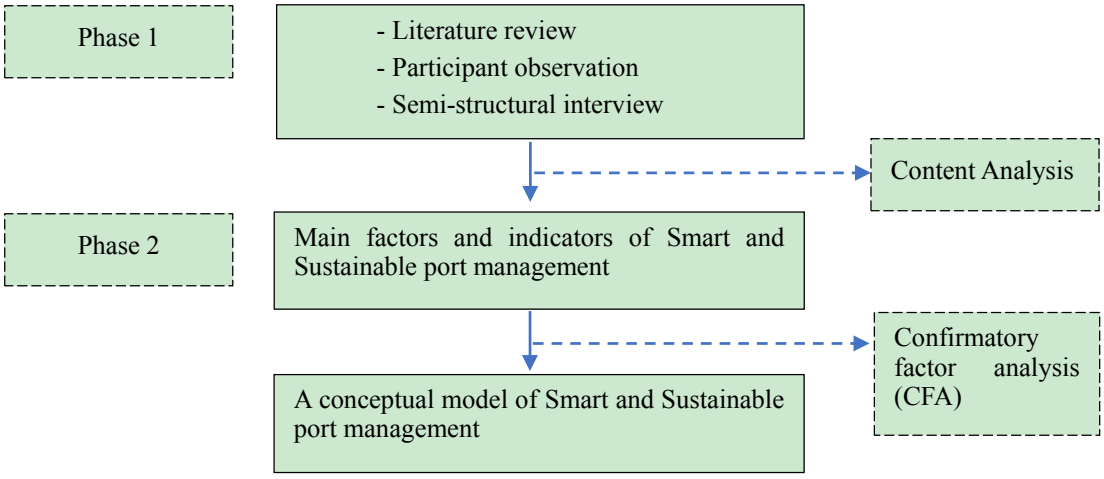

Figure 2. Research operation approach

4. Results

4.1 Main Factor and Indicators of Smart and Sustainable Port Management

This research applied triangulation data for analyzing all information including academic peer-reviewed journals, data reports, and participant observations, with a summary of the results provided in Table 1, which shows smart and sustainable management indicators. There are three dimensions of smart and sustainable port management indicators. The first dimension, the environmental smart port, has 8 indicators. The second dimension, the social smart port, has 6 indicators. Finally, the third dimension, the economic smart port, has 7 indicators. References for each indicator are also shown in the table column.

Table 1. Smart and sustainable port management indicators

Smart and sustainable management port indicators	González et al. (2020)	Molavi et al. (2019)	Molavi, Lim & Race (2020)	Buiza et al. (2015)	Tan et al. (2018)	Douaioui et al. (2018)	Rajabi et al. (2018)	Jović et al. (2019)	Alvin Yau et al. (2020)	Philipp (2020)	Zhao, Wang & Han (2020)	Durána, Córdovab & Palominosc (2019)	Lu, Shang, & Lin (2016)	Sgari et al (2015)	Laxe et al. (2016a)	Laxe et al. (2016b)	Roh, Thai & Wong (2016)	Xiao & Lam (2017)	Antao et al. (2016)	Chengpeng et al. (2016)
1. ENVIRONMENTAL ASPECTS OF SMART PORTS																				
1.1 International port environmental management standards certification. (En-Sp 1)	●	●	●	●										●	●		●		●	
1.2 Application of the port's wastewater treatment and management technology *. (En-Sp 2)	●	●	●								●	●	●	●		●		●	●	●

1.3 Implementation of the port's air quality analysis/carbon emissions assessment and monitoring technology *. (En-Sp 3)	●	●	●	●	●				●			●		●	●	●	●			●		●	●	●
1.4 Implementation of the port's noise pollution control technology *. (En-Sp 4)		●	●	●										●	●								●	●
1.5 Implementation of the port's waste management technology *. (En-Sp 5)	●	●	●	●											●			●				●	●	●
1.6 Implementation of clean energy/alternative energy operational procedures and measures with the most efficient transport utilization in the port. (En-Sp 6)	●		●	●			●										●	●					●	
1.7 Implementation of the operations plan, measures for the most effective port electricity consumption. (En-Sp 7)	●	●	●	●		●	●								●	●								
1.8 Implementation of operation plans and measures for the most effective port water consumption. (En-Sp 8)	●	●	●	●								●			●			●		●				●
2. SOCIAL ASPECTS OF SMART PORTS																								
2.1 International standards or awards of the port's social and safety certifications. (So-Sp 1)	●	●	●	●		●						●										●		
2.2 Implementation of technology* of security management systems and the safety of the port. (So-Sp 2)	●	●						●																●
2.3 Implementation of port technology* to detect and access the rights and safety of port operators. (So-Sp 3)																						●		
2.4 Implementation of technology* systems for handling and preventing accidents in the port. (So-Sp 4)	●	●	●			●						●		●			●				●			
2.5 Implementation of social development plans and training programs for port employees and the port security technology*. (So-Sp 5)	●		●										●	●			●			●		●		

2.6 Having plans and projects to work with the surrounding community through the port information technology* system. (So-Sp 6)													●				●			
3. ECONOMICS ASPECT OF SMART PORTS																				
3.1 Implementation of technology* management systems for measuring the efficiency of port productivity. (Ec-Sp 1)	●	●	●	●	●								●	●	●	●	●	●		●
3.2 Implementation of a technology* management system for measuring the efficiency of port freight handling management. (Ec-Sp 2)													●		●		●	●		
3.3 Implementation of a technology* management system for financial management and the port's operation cost control. (Ec-Sp 3)														●	●	●	●			
3.4 Implementation of technology* for the most efficient port area utilization. (Ec-Sp 4)	●	●										●			●		●			
3.5 Implementation of shared working platform technology* for port operators. (Ec-Sp 5)	●	●	●				●		●			●					●			
3.6 Implementation of supported technology* for navigation aids with digital systems. (Ec-Sp 6)	●																			
3.7 Implementation of port tools and equipment management technology *. (Ec-Sp 7)	●	●	●	●	●	●			●	●	●						●			

Note * Technology refers to the 4th Industrial Revolution (4IR) technologies and Bond's top 10 sustainability technologies, including artificial intelligence (AI), blockchain, Internet of Things (IoT), Big Data, circular economy, financial technology, machine learning, satellite technology, the app for refugees/asylum seekers, household/community scale batteries and 5G (ABD, 2020).

4.2 Conceptual Model of Smart and Sustainable Port Management

This conceptual framework shows the three main factors, indicators, and relationships among smart ports. Smart and sustainable port management is set up in the operational aspect which has three factors including the environmental aspects of smart ports (En-Sp), the social aspects of smart ports (So-Sp), and the economics of smart ports as shown in Figure 3.

Environmental aspects of smart ports (En-Sp)

The environmental aspect of smart ports (En-Sp) refers to reducing the environmental impact of all port activities including air and carbon emissions pollution, noise pollution, water pollution, waste pollution, water consumption,

and electricity consumption by the implementation of 4IR/sustainable technologies for detecting pollution, waste control, and efficient water and electricity consumption. The environmental aspect of smart port indicators is developed from the main indicators of the international port environmental management standards certification (En-Sp 1), application of the port's wastewater treatment and management technology (En-Sp 2), implementation of the port's air quality analysis/carbon emissions assessment and monitoring technology (En-Sp 3), implementation of the port's noise pollution control technology (En-Sp 4), implementation of the port's waste management technology (En-Sp 5), implementation of clean energy/alternative energy operational procedures and measures with the most efficient transport utilization in the port (En-Sp 6), implementation of the operational plan, measures for the most effective port electricity consumption. (En-Sp 7), and implementation of the operational plans and measures for the most effective port water consumption (En-Sp 8).

Social aspects of smart ports (So-Sp)

The social aspect of the smart port (So-Sp) dimension refers to the port's employee safety, port security, and surrounding community so that will encourage all port activities to meet the best practice and will affect the good image of the port through the implementation of 4IR/sustainable technologies. The social aspect of smart ports is developed from indicators of international standards or awards of the port's social and safety certifications (So-Sp 1), implementation of technology of security management systems and the safety of the port (So-Sp 2), implementation of port technology to detect and access the rights and safety of port operators (So-Sp 3), implementation of technology systems for handling and preventing accidents in the port (So-Sp 4), implementation of social development plans and training programs for port employees and the port security technology (So-Sp 5), and have plans and projects to work with the surrounding community through the port information technology system (So-Sp 6).

Economics aspect of smart ports (Ec-Sp)

The economics of smart ports (Ec-Sp) dimension refers to port productivity, cost, and financial efficiency/performance. The goal of this dimension is to implement 4IR/sustainable technologies to encourage port performance for efficiency in productivity with better value in terms of investments and cost. The economics of smart ports are developed from indicators of the implementation of technology management systems for measuring the efficiency of port productivity (Ec-Sp 1), implementation of a technology management system for measuring the efficiency of port freight handling management (Ec-Sp 2), implementation of a technology management system for financial management and the port's operation cost control (Ec-Sp 3), implementation of technology for the most efficient port area utilization (Ec-Sp 4), implementation of shared working platform technology for port operators (Ec-Sp 5), implementation of supported technology for navigation aids with digital systems (Ec-Sp 6), and implementation of port tools and equipment management technology (Ec-Sp 7).

Smart and sustainable port management

The introduced operation of integrating the smart and sustainable port management is explained the main factors and indicators practiced by the environment of smart port (En-Sp 1-8), the social of smart port (So-Sp 1-6), and the economics of smart port (Ec-Sp 1-7) in operational port planning. These 21 key performance indicators need to improve the performance measurement in port operation that is achieved the first practice to consider the port operation planning. The benefits of this management have improved the corporate and sustainability in port, utilization of electrification and sources of renewable energy, the efficiency of health, safety, social and environmental management in port, reduction the emissions management, and improved air quality around the port area including greenhouse gas, carbon measurement, footprinting, monitoring, and management. This operational base port will realize the upgrading smart port and sustainable port management toward international standards port.

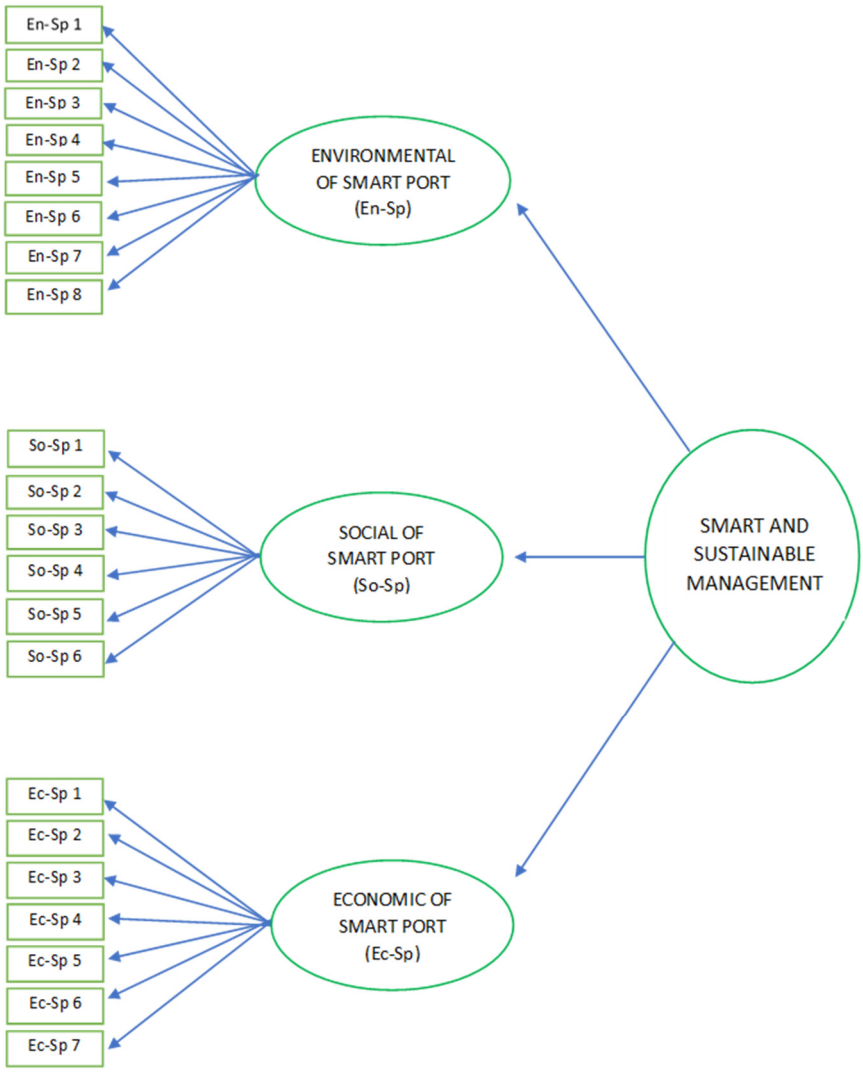

Figure 3. Conceptual model of smart and sustainable port management

4.3 Confirmatory Factor Analysis

4.3.1 Descriptive Statistics of Research Sample

This part presents the information of the research sample. There were 96 respondents from 11 container terminals in the Eastern Economic Corridor (EEC) that are 65.6 % members of PSHEMS (Port Safety, Health and Environmental Management System), and 84.4% received the certificate of ISO (International Organization for Standardization) The research samples are the most people who working as operation manager 93.8%, middle manager 6.3% which directly responsible for sustainable development 71.9% and smart port management 28.1% in the operation department.

4.3.2 Correlation Analysis

In performing factor analysis for this research, all pair-wise indicators of each smart and sustainable port domain were tested to investigate the relationship among them. The Pearson correlation coefficients of all pair-wise indicators in each smart port domain are significant)p<0.05(. The Kaiser-Meyer-Olkin measure statistic is 0.697 with a p-value is 0.000)Table 2(. The results found that all indicators are significantly related to each other. Therefore, a factor analysis should be performed using the Principal Component Method to group the relevant indicators into domains. (Krzanowski, 1984; Camacho, Rodríguez-Gómez, & Saccenti, 2017)

Table 2. Kaiser-Meyer-Olkin statistic and p-value

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.697
p-value	0.000

4.3.3 Measurement Model for Smart and Sustainable Port

The research was tested the measurement model of smart and sustainable port indicators as shown in figure 4 by using reliability and correlation analysis and followed by confirmatory factor analysis with principal component method extraction, and the varimax rotation was applied as a step for evaluating the error of indicators that compose the factors. The number of factors was fixed to three factors to confirm the framework of the three factors. Table 3 presents those indicator loadings representing the correlation of indicators to factors. The test indicates the strength of a relationship between factor and indicator by a value of the loading factor, and the confirmatory factor analysis classified that the three- factors model supported and has a relationship to the sample data. The high-value loading factor is representative of the factors that indicators belong to (Hurley et al., 1997).

According to Bartz (1999), the loading factor value can be used as the below guideline to consider the relationship between factor and indicator. Loading factor value of 0.41 indicates a medium correlation, 0.61indicates a large correlation, and 0.81 indicates a very large correlation.

Environmental aspects of the smart port factor, there are 8 indicators; En-Sp1, En-Sp2, En-Sp3, En-Sp4, En-Sp5, En-Sp6, En-Sp7, and En-Sp8 are significant correlative and have medium, large, and very large the relationship to this factor (loading factor values greater than 0.4).

Social aspects of the smart port factor, there are 5 indicators; So-Sp 2, So-Sp 3, So-Sp 4, So-Sp 5, and So-Sp 6 are significant correlative and have medium and large relationships to this factor (loading factor values greater than 0.4). For indicator So-Sp 1, has a small relationship to this factor (loading factor value less than 0.4). Therefore, indicator So-Sp 1 is removed from the social aspects of the smart port factor.

Economics aspect of the smart port factor, there are 4 indicators; Ec-Sp 1, Ec-Sp 3, Ec-Sp 5 and Ec-Sp 6 are significant correlative and have medium and large relationships to this factor (loading factor values greater than 0.4). Indicators Ec-Sp 2, Ec-Sp 4, and Ec-Sp 7 have a small relationship to this factor (loading factor value less than 0.4) Therefore, indicators Ec-Sp 2, Ec-Sp 4, and Ec-Sp 7 are removed economics aspect of the smart ports factor.

Table 3. Loading indicator of three factors

Indicator	Loading factor		
	Factor 1	Factor 2	Factor 3
1. Environmental aspects of smart ports (En-Sp)			
En-Sp 1	0.445		
En-Sp 2	0.761		
En-Sp 3	0.702		
En-Sp 4	0.771		
En-Sp 5	0.597		
En-Sp 6	0.861		
En-Sp 7	0.816		
En-Sp 8	0.761		
2. Social aspects of smart ports (So-Sp)			
So-Sp 2		0.714	
So-Sp 3		0.413	
So-Sp 4		0.696	
So-Sp 5		0.622	
So-Sp 6		0.404	
3. Economics aspect of smart ports (Ec-Sp)			
Ec-Sp 1			0.418
Ec-Sp 3			0.657
Ec-Sp 5			0.583
Ec-Sp 6			0.666

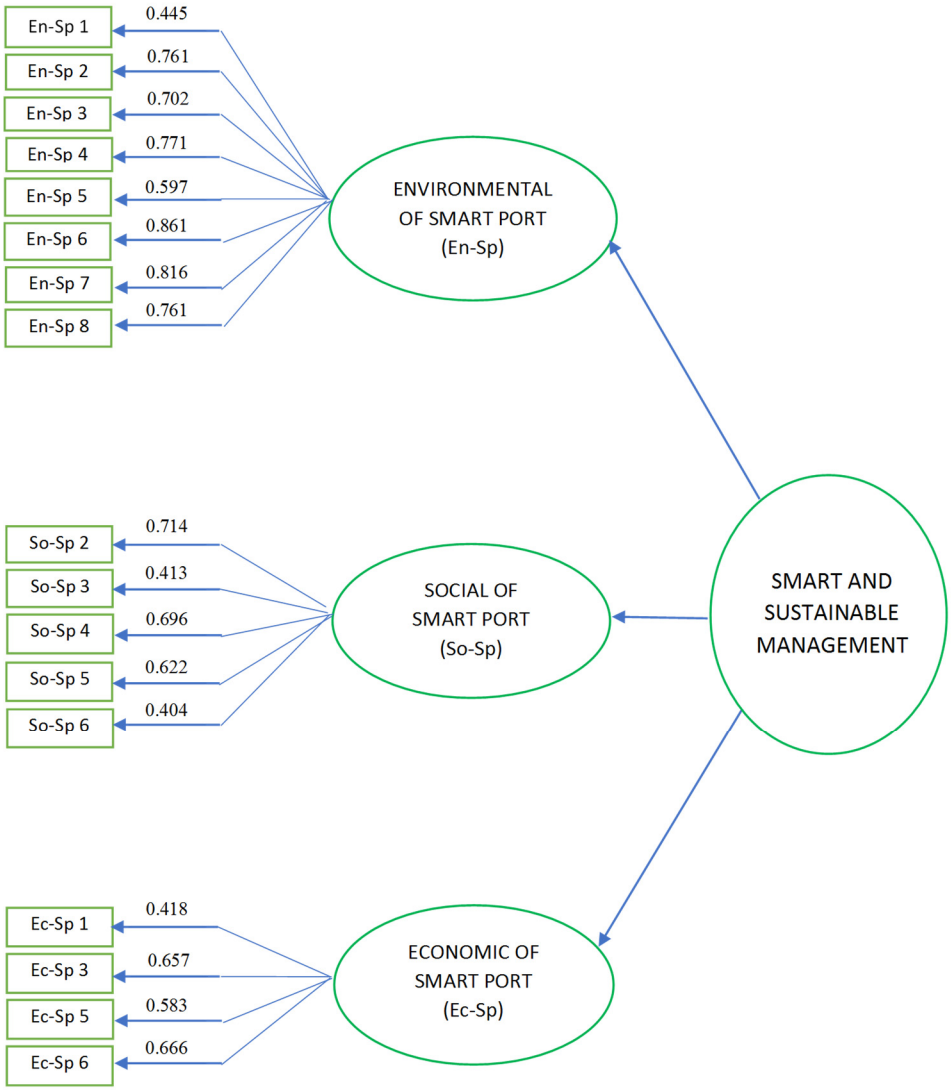

Figure 4. Smart port indicators measurement model

5. Conclusion

Since 2015 when the 195 nations comprising the United Nations agreed on the 17 Sustainable Development Goals (SDGs) and the International Association of Ports and Harbors (IAPH) launched the World Ports Sustainability Program in February 2019, plans have been implemented to integrate the SDGs into the business strategies and governance by port authorities and to help align them with global sustainability standards (UNESCAP, 2021). The 4IR/sustainable technologies are the solution that will support increased port performance and productivity, work safety and security, and reduce the environmental impact.

The government of Thailand has invested in ports under the Eastern Economic Corridor (EEC) project to develop smart ports. However, not only smart port development has been considered, but also sustainable perspectives have to be developed together to achieve smart and sustainable ports. This study is developed by the triangulation of data and the methodology required analytic induction, content analysis, and factor analysis using document synthesis to analyze the factors, indicators, and their relationships, resulting in the determination of three factors of smart and sustainable port management and 21 indicators. Then factor analysis was applied with confirmatory factor analysis (CFA) to analyze all 21 indicators, finally the result found 17 indicators as key indicator for smart and sustainable ports which can be classified in three main factor s; Environmental aspects of smart port factor

(En-Sp) (8 indicators ; (En-Sp 1) the international port environmental management standards certification, (En-Sp 2) application of the port's wastewater treatment and management technology, (En-Sp 3) implementation of the port's air quality analysis/carbon emissions assessment and monitoring technology, (En-Sp 4) implementation of the port's noise pollution control technology, (En-Sp 5)implementation of the port's waste management technology, (En-Sp 6) implementation of clean energy/alternative energy operational procedures and measures with the most efficient transport utilization in the port, (En-Sp 7) implementation of the operations plan, measures for the most effective port electricity consumption, and (En-Sp 8) implementation of operation plans and measures for the most effective port water consumption), Social aspects of smart port factor (So-Sp) (5 indicators; (So-Sp 2)implementation of technology of security management systems and the safety of the port, (So-Sp 3) implementation of port technology to detect and access the rights and safety of port operators, (So-Sp 4) implementation of technology systems for handling and preventing accidents in the port, (So-Sp 5) implementation of a social development plans and training programs for port employees and the port security technology, and (So-Sp 6) having plans and projects to work with the surrounding community through the port information technology system), and economics of smart port factor (Ec-Sp) (4 indicators; (Ec-Sp 1) the implementation of technology management systems for measuring the efficiency of port productivity, (Ec-Sp 3) implementation of a technology management system for financial management and the port's operation cost control, (Ec-Sp 5) implementation of shared working platform technology for port, and (Ec-Sp 6) implementation of supported technology for navigation aids with digital systems). The indicators and model of smart port management presented in this research will be a tool for managing and developing international standards in Thai smart and sustainable ports.

Therefore, smart and sustainable port management should be considered with these indicators in determining the port policies and practices to reduce the environmental impact, supporting economic and social development, and improving the quality of life of port employees and surrounding communities. Future research can consider methods to confirm these findings concerning indicators by involving experts using factor analysis.

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