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Factors Affecting the Smart Port Implementation at Laem Chabang Deep Sea Port, Thailand

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Abstract. This study aims at developing and validating a model of causal factors potentially affecting long-term development of Laem Chabang Deep-Sea Port in Thailand. The data collected by a questionnaire survey has been analyzed by a measurement model of latent variables. Several key hypotheses have also been tested by the proposed model. According to the model analysis, it is found that the empirical data analysis is consistent with the theoretical measurement model. The prosperous development is positively influenced with statistical significance by four latent variables – as represented by the following statistics: CMIN/P=0.068, CMIN/df=1.282, GFI=0.976, and RMSEA=0.027. Additionally, results from the Second Confirmatory Factor Analysis (SCFA) shows that there are two factors considered as key success factors for smart port implementation at the port. It is found that all four factors are rated at high-level of importance with operation, environment, safety and security, and energy, respectively.

Keywords. Smart Port, Sustainable Port Management, Laem Chabang Deep Sea Port

1. Introduction

Since ports are crucial part of supply chain, optimizing cost, efficiency, security, and environmental requirements are therefore key concerns in any port development. In recent years, digital innovation connected to cargo flows has been the primary factor in sustaining their competitiveness [1]. However, majority of ports yet continue to depend on manual and antiquated technologies to handle even the most fundamental tasks. In contrast, more sophisticated sectors are beginning to employ Industry 4.0 digital solutions – the solutions that blur the barriers between the physical, digital, and biological domains. Also, important issues, such as climate change, resource depletion, and insecurity, require more immediate actions [2]. While the new digital 4.0 solutions are already appearing at global major ports, such as Rotterdam and Antwerp, it is unclear what ports in general see as the most important areas of innovation and how this trend affects the future roles and power balance in the marine sector [1][3][4].
Thailand's Sustainable Development Goals (SDG) rating improved by 19 positions in 2019 to 40th globally and first in ASEAN [3]. In recent years, Thailand 4.0 project

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intends to change the country from a nation with a middle-income to the position of a high-income country by the use of technology, innovation, and attention on the environment. It is consistent with the SDGs and the 12th National Economic and Social Development Plan of the country (2017–2021). The Thailand 4.0 is essential for the advancement of the value-based economic potential of the area. Particular attention should be paid to the fact that specific ports may face obstacles in adopting an acceptable level of digitization, which may be influenced by a range of factors, such as operations, environment, energy, safety, and security. In addition, it confirms the importance of investigating other potential activity domains to be included in their proposed index. As a result, [3] have demonstrated the impact on sustainable performance through a systematic review of the scant literature on smart port pillars with a focus on sustainability. Also, the project focused on developing an integrated smart port indexes that are operation, environment, energy, safety and security [7].
According to the previous studies, integrated smart port indexes have been defined. This study aims at investigating more deeply to the influences of several key factors on the smart port management and sustainable port management by developing a model of causal factors to examine their effects on the long-term development of Laem Chabang Deep-Sea Port in Thailand.

2. Literature Reviews

2.1. Sustainable Port Management

A sustainable port is one that implements development plans and actions to fulfill the demands of people who use it in order to increase its competitive potential, while conserving and sustaining the three dimensions of environmental, economic, and social sustainability. These three elements were highlighted by [5] as crucial components of sustainability in container port operations. The International Maritime Organization (IMO) implemented this plan by adopting the UN's 17 SDGs, which include: no poverty, no 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, and life below water. Technology, which is considered an element of the Fourth Industrial Revolution (4IR), is a crucial aspect in achieving these aims [8].

2.2. Smart Port

In the past, port operations were mainly considered from the perspective of scale: quay length, number, efficiency of cranes, etc. To date, ports and maritime sectors have been considered to be lagging behind others in digitalization [3] but more recently Industry 4.0 technologies have been gaining more ground [2][3]. Building on the impact of Industry 4.0 on other sectors, ports are also expected to see similar adoption of new technologies and new business models [5]. Industry 4.0 is defined in the literature as "the intelligent networking of machines and processes for industry with the help of information and communication technology"[3]. The term Port 4.0, in turn, is considered as the application of Industry 4.0 in the port environment. Scholars and practitioners also use the term "smart port" instead of Port 4.0. However, there is no clear difference between these two terms and they are used interchangeably [10]. Based on various descriptions provided in the literature, smart port is defined as a port that is automated, collaborative and green [11]. Smart port can utilize various technologies.

The prospect of Thailand is one of sustainable energy, sustainable innovation, and sustainable development, in which nature and technology improve the lives of its in habitants across the globe. The primary objective of sustainable ports is to decrease environmental and social consequences while bolstering marine transport operations and the economy as a whole [12]. The combination of Smart Ports and sustainable ports is the optimal strategy for the long-term growth and management of ports. Ports that are intelligent and sustainable include all of the most essential factors, including the environment, society, and economics. It seems that establishing a smart and sustainable port would need enormous expenditures in port infrastructure and technology, but this is a worthy long-term investment.

3. Study Framework and Methodology

3.1. Conceptual Framework

In this study, four key factors are taken into the investigation, including operation, environment, energy, and security and safety.

Operation: Smart Ports aims to integrate cutting-edge information technology, innovative and effective management models, as well as automated and intelligent mechanical equipment, into the daily production and operation management of ports. This will improve the efficiency of port operations, increase productivity, and lower associated costs. Productivity, automation, and intelligent infrastructure are sub-domains of Smart Port operations. Smart Ports increase a port's daily operating efficiency and increase its benefits by facilitating seamless connectivity and synergy among carriers, boats, personnel, cargoes, and many port systems [13]. In addition to opening up digital merchandise management systems to the port in terms of production and operation systems, the Smart Port offers applications of cutting-edge information technology at ports [14]. This enables an enhancement that is secure, affordable, practical, eco-friendly, and long-lasting and improves ports' overall competitiveness [15].

Environment: The creation of a green port should be a port's primary objective, and the Smart Port improvement mode should be its primary technological tool [16]. Low energy use, low emissions, and low pollution are all results of the port's green growth, according to [17]. Ports are the source of environmental pollution through land and sea transport because of emissions, noise pollution, water consumption, and waste generation, which endanger living things. Smart Ports seek solutions to environmental problems through the verification of port environmental management systems (EMS) and activities to reduce pollution and manage water and waste. The following environmental effects of port activity are focused on for the purposes of this study: air emissions, noise pollution, water pollution and consumption, and garbage creation. Environmental management systems, emissions and pollution control, and waste management are sub-domains of smart environments [18].

Energy: According to Chang et al. [19], the port is one of the biggest users of energy as a result of the growth in industrial operations, even with the consideration of the port's budget and the limited energy sources available. The smart indicator attempts to cut emissions by using renewable energy sources and using less electricity. [16] concurred that ports are one of the sectors with significant energy demand as a consequence of port activities. Two key issues for ports are the growing cost of energy and the accessibility of alternative energy sources. To supply logistics, ports must undertake an energy-efficient renovation. As part of a smart and sustainable port development process, port authorities should focus on energy management as a significant issue [18].

Security and safety: There are an urgent need to increase transportation safety. Smart transportation systems are necessary to maintain a high degree of transport safety and a low possibility for mishaps as part of multimodal transportation in many industrialized nations as well as emerging ones [19]. According to study, ports are subject to numerous safety and security issues. Smart port on the other hand is used as regulations, standards, staff training, periodic monitoring of facilities, risk assessment, and control systems to detect any security problem and increase and improve port readiness. Port authorities must give safety and security a higher priority than productivity, environmental awareness, and energy efficiency within the Smart Port framework. Both employee training and ongoing supervision are necessary prerequisites. The smart safety and security component includes data security and privacy management, integrated monitoring and optimization systems, port safety management systems, and security management systems [21].

Based on a theoretical and empirical study of relevant variables, a conceptual framework for this study is exhibited in Figure 1, and the four following hypotheses are tested.

H1: Operation has a positive effect on Long-Term Development of Laem Chabang Deep Sea Port.

H2: Environment has a positive effect on Long-Term Development of Laem Chabang Deep Sea Port.

H3: Energy has a positive effect on Long-Term Development of Laem Chabang Deep Sea Port.

H4: Safety and Security has a positive effect on Long-Term Development of Laem Chabang Deep Sea Port.

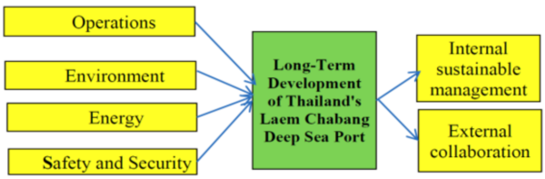

Figure 1. Conceptual Framework

3.2. Measures and Data Analysis Methods

A questionnaire survey is developed in order to collect quantitative data. The questionnaire is divided into five sections. The first section gathers general characteristics of the respondents. The second section, by following [16] suggested, collects intellectual capital under three capital traits: human capital, structural capital, and relational capital. The third section, the innovative capabilities, obtains data such as product and process innovation and market innovation. These aspects are adapted and utilized from organizational innovativeness, according to [15]. The fourth section, dynamic capacity, is following [17] by dividing the section into five subsections: sensing, seeking, seizing, shifting, and shaping. The last section, according to [21], competitive advantage, collect the three types of generic competitive strategies, i.e., cost leadership, differentiation, and focus.

To assess the quality of the questionnaire developed, the content validity has been undertaken. Item-Objective Congruence (IOC) scores are found to be more than 0.6 for all items. The questionnaire is also evaluated with 30 community business entrepreneurs who are not part of the study target group. The dependability rating is calculated using Cronbach's alpha to confirm that the items are internally consistent. Cronbach's alpha scores vary between 0.969 and 0.989 – all of which are considerably higher than 0.70 cutoff suggested by [19].

Eventually, two-step model-building technique suggested by [22] are used to generate the structural equation model, with validation by a measurement model of latent variables followed by an analysis utilizing the structural equation model to evaluate the hypotheses in the proposed model. The structural equation modeling analysis program employs maximum likelihood estimation.

4. Research Results

The results of the smart port component analysis are shown in Table 1. It is found that all four factors are rated at high-level of importance with the overall score of 4.38 from 5-point Likert scale. Considering each aspect individually, operation is found to be the most important factor with the average score of 4.43. Environment is rated the second with the average score of 4.39. Safety and security are found to be the third with the average score of 4.38. The energy comes at last, however with the average score of 4.33 which are not much different from other factors.

On the other hand, the result of the sustainable deep sea smart port development factor component analysis is shown in Table 2. It is found that the overall development of the deep-sea smart port is at high-level with the average score of 4.44. Considering each aspect individually, sustainable internal management is rated as high level of importance with the average score of 4.45, while the external cooperation is also at high-level of important with the average score of 4.43

Table 1. Presents the mean and standard deviation of the smart port components

Smart Port Components	$\bar{X}$	S.D.	Significance Level
operation	4.43	0.54	High
environment	4.39	0.58	High
energy	4.33	0.61	High
safety and security	4.38	0.6	High
Overall	4.38	0.53	High

Table 2. Presents the mean and standard deviation of the sustainable smart seaport development.

Sustainable Deep Sea Smart Port Development	$\bar{X}$	S.D.	Significance Level
Sustainable internal management	4.45	0.56	High
external cooperation	4.43	0.6	High
Overall	4.44	0.56	High

According to the results from Second Order Confirmatory Factor Analysis (SCFA), it is found that the criteria for harmonization with the empirical data are not yet passed. The model is therefore improved by considering the Modification Indices [16]. The value of results obtained from the packaged program is considered with theoretical academic principles to eliminate some improper observational variables one by one. The new model evaluation is performed continually until the model is obtained with all four statistical values. The model is therefore considered to be in harmony with the empirical data. The results from developed model are demonstrated in Table 3 and Table 4.

Table 3. Second Order Confirmatory Factor Analysis (SCFA) of the smart port components after model adjustment.

Statistical index	Criteria	Pre-improvement	Post-improvement
Chi–Square	0.05 <	0	0.117
CMIN/df	2.00 >	2.938	1.094
GFI	0.90 <	0.823	0.946
RMSEA	0.08 >	0.07	0.015

Results presented in Table 3 show that the empirical data analysis is consistent with the theoretical measurement model. Smart port components are found to be positively influencing with the statistically significant at the 0.001 level. After model adjustment, it is found that all four factors are classified as smart port factors. The most influential factors are the environment, followed by safety and security, operations, and energy, respectively. Therefore, it can be seen that all questions of the smart port factor components are consistent with the empirical data as shown in Figure 2.

The prosperous development of the deep-sea smart port is found to be positively influencing with the statistically significant at the 0.001 level. It is found that all four factors are classified as smart port factors for sustainable deep sea port development. Meanwhile, the results of the SCFA of sustainable deep sea smart port development shows the most influential factor is external cooperation and the least is sustainable internal management. Therefore, it can be seen that all questions of the sustainable deep sea smart port development are consistent with the data. empirically as illustrated in Figure 3.

Table 4. Second Confirmatory Factor Analysis (SCFA) of Sustainable Deep Sea Smart Port Development after model adjustment

Statistical index	Criteria	Pre-improvement	Post-improvement
Chi–Square	0.05 <	0	0.068
CMIN/df	2.00 >	10.43	1.282
GFI	0.90 <	0.675	0.976
RMSEA	0.08 >	0.154	0.027

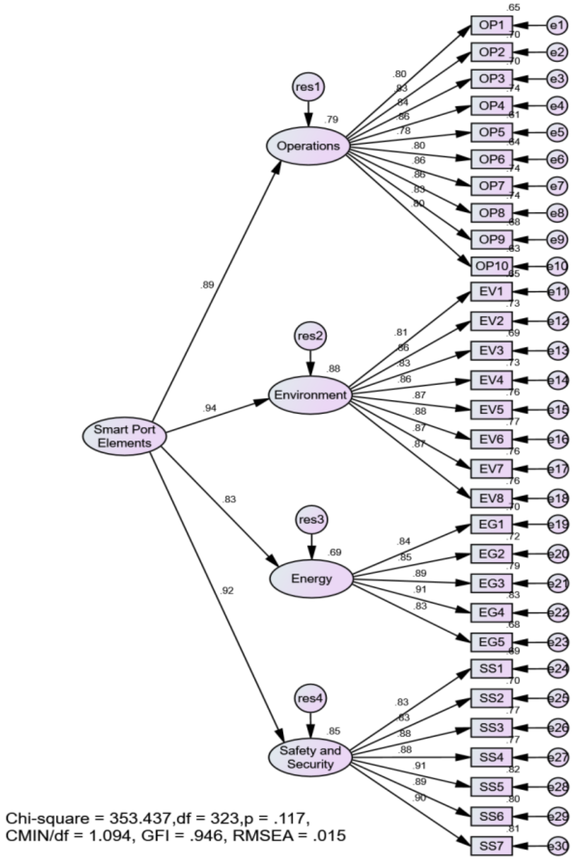

Figure 2. The results of the second order confirmatory component analysis (SCFA) of the Smart Port Components showing the standardized solution after model fitting.

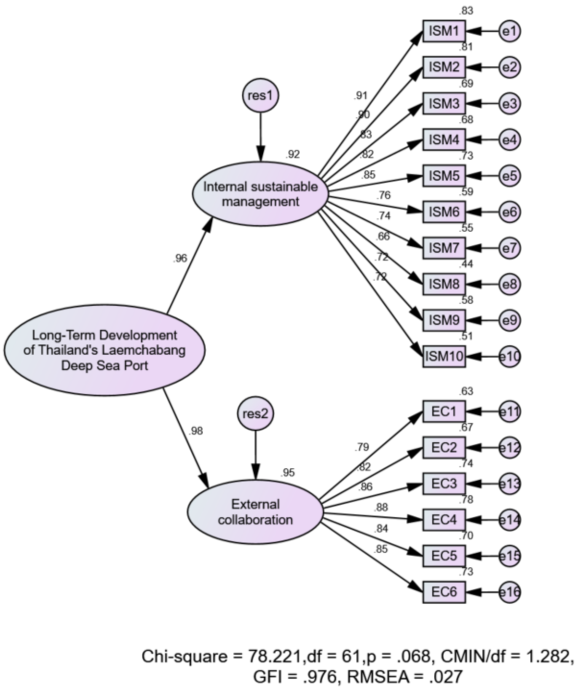

Figure3 . The results of the second order confirmatory factor analysis (SCFA) of the Sustainable Deep Sea Smart Port Development, showing the standardized solution after model adjustment.

5. Discussions

From the overall result of this study, the combination of smart ports and sustainable ports is the optimal strategy for the long-term growth and management of ports. Intelligent and sustainable port should include essential concerns, i.e., the environment, society, and economics. Smart Ports aims to integrate cutting-edge information technology, innovative and effective management models, as well as automated and intelligent mechanical equipment, into the daily production and operation management of ports. Smart port improves port daily operating efficiency and increase its benefits by facilitating seamless connectivity and synergy among carriers, vessels, personnel, cargo, and several port systems [18]. The following environmental effects of port activity are focused on for the purposes of this study: emissions, noise pollution, water pollution and consumption, and garbage creation. Environmental management systems, emissions and pollution control, and waste management are sub-domains of smart environments [14]. The smart indicator attempts to cut emissions by using renewable energy sources and using less electricity. As [17] concurred; ports are one of the sectors with significant energy demand as a consequence of port activities. There is an urgent need to increase transportation safety. Smart transportation systems are necessary to maintain a high degree of transport safety and a low possibility for mishaps as part of multimodal transportation in many industrialized nations as well as emerging ones [12].

6. Conclusions and Recommendations

This study aims at developing and validating a model of causal factors potentially affecting long-term development of Laem Chabang Deep-Sea Port in Thailand. The data collected by a questionnaire survey has been analyzed by a measurement model of latent variables. Several key hypotheses have also been tested by the proposed model. According to the model analysis, it is found that the empirical data analysis is consistent with the theoretical measurement model. The results from the SCFA shows that there are two factors considered as key success factors for smart port implementation at the port. The most influential factor was external cooperation, followed by sustainable internal management, respectively.

The study not only develops conceptual model that can explain the influences of smart port components on the adoption of a more sophisticated business model for Laem Chabang Deep Sea Port from a managerial perspective. These components focus on improving the efficiency and effectiveness of port, operation, environment, energy, Safety and Security of smart port.

Operation: The operation component of a smart port focuses on the efficient movement of goods and people through the port. This includes areas such as cargo handling, vessel traffic management, and intermodal transport.

Environment: The environment component of a smart port focuses on minimizing the environmental impact of port operations. This includes reducing carbon emissions, noise pollution, and waste generation. Smart ports use green technologies such as renewable energy, energy-efficient lighting, and electric vehicles to achieve this.

Energy: Energy management is a critical component of a smart port. The use of renewable energy sources, such as solar and wind, is increasingly being adopted to power the port's infrastructure. In addition, smart grids are being used to manage energy demand and supply more efficiently, reducing energy costs and carbon footprint.

Safety: Safety is of utmost importance in port operations. Smart ports use advanced technologies such as sensors, video surveillance, and drones to improve safety and security measures. Predictive analytics and machine learning are also being used to identify potential hazards and prevent accident. Security is another key component of a smart port. The use of biometric identification systems, access control mechanisms, and surveillance technologies help to enhance the security of the port. Advanced analytics and machine learning algorithms are also being used to detect and prevent potential security threats.

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