Smart Port Management Practices and Implementation: An Interpretive Structural Modelling Approach

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Abstract

Port operations and management, like other industries, are undergoing a digital transformation process that influences existing business models and operational practices in a multifaceted way. The transformation in the industry through the adoption of different technological devices, mainly termed smart port, could bring profitability, sustainability, and operational efficiency in the port operations and systems. The study aims to explore the smart port management framework, practices, and barriers to implementing smart port practices in considering the context of Chattogram port authority (CPA). Existing literature has rigorously been analyzed to frame the smart port structure. Furthermore, the three related groups of CPA, namely port users, port administrators and wider port communities, have been surveyed to investigate the barriers to implementing smart port practices. In that case, interpretive structuring modeling (ISM) has been used to find the cause-and-effect relationship among the drivers. It has been identified that the technological knowledge of port users and employees and resistance to changing the status quo are the influential barriers to implementing smart port practices at CPA. However, the barriers of the port governance model and govt. patrons and support have been found as the driving factors in implementing smart port practices. The study expects to have an immense impact on the adoption of smart port practices in developing countries like Bangladesh.

Keywords: Smart port, digitalization, automation, barriers, ISM.

Introduction

The efficient port function facilitates international trade and helps boost the economic development of a country. In keeping with rapid digital transformation in other industries, the port operation is undergoing a tremendous transformation to digitalization (Solmaz, 2021). The adoption of information communication and

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technology has grasped a noticeable attraction and user-friendliness from port users and industries. The extent of which is sometimes termed as the smart port. With the usage of several digital technologies, such as the Internet of Things (IoT), Blockchain, and digital twin, digital transformation has advanced and the groundwork for smart ports has been created (K. Wang et al., 2021). However, the embracing of the smart port has been divided into many parts based on the degree of adoption. Being the premier port in Bangladesh, Chittagong port handles almost 92% of the export-import cargo (Chowdhury & Munim, 2022). The port has been working as the gateway for the country, embracing new technologies gradually to provide faster and more efficient delivery of services. However, the transformation to a smart port by Chittagong port still requires audacious initiatives since the port functions within a complex structure of engaging multi-stakeholders. To this end, the study envisages exploring the smart port framework considering the context of Chittagong port and identifying the barriers to implementing the smart port operations at Chittagong port.

Literature Review

Conceptual Discourse

A large number of studies have been conducted on the smart port and related areas of the smart port. Most of the studies tried to define and conceptualize the smart port concept. The adoption of smart ports suggests the automated operation of ports and terminals, intriguing the Internet of Things (IoT) (Yang et al., 2018) with its system for efficient port productivity and sustainable operation (Jun et al., 2018). However, the smart port does not merely trigger automation but rather adopts technological instruments and equipment like artificial intelligence, big data, cloud computing, and automatic information system-based vessel monitoring systems (Jia & Cui, 2021). Concisely, a smart port substantiates the required infrastructure that employs automation, integration of services, digitalization, and data-driven methodologies to operate and handle the cargoes, containers, and other port activities with less human intervention (see Figure 1).

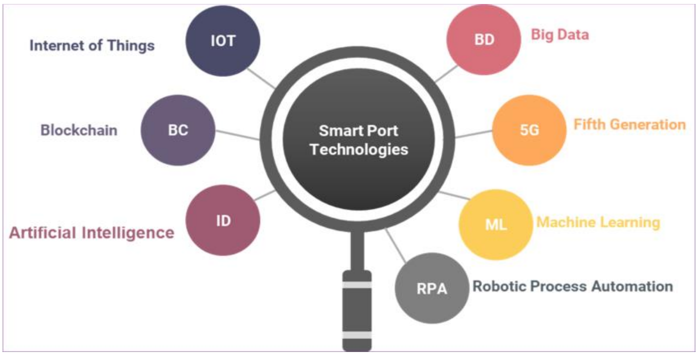

Figure 1: Smart port technologies adapted from Rajabi et al. (2018)

Therefore, a smart port can be defined as a port that pursues port facility automation and becomes an autonomous port with integrated information management, rational decision-making, and efficient use of resources through the 4IR technologies (Othman et al., 2022). In other words, it means a port that optimizes its operations by applying advanced technologies and improving business processes, thereby reducing costs, and processing time, increasing port productivity and efficiency and minimizing the impact on the environment (Kang & Kim, 2017).

Levels of Transformation into a Smart Port:

To achieve a smart port, there are four levels of concrete actions within the digital transformation process (Philipp, 2020). A port is a complex system, and transforming one of its components does not make the entire port smart. Instead, a holistic digital transformation on these four levels needs to take place in order to achieve this goal (see figure 2).

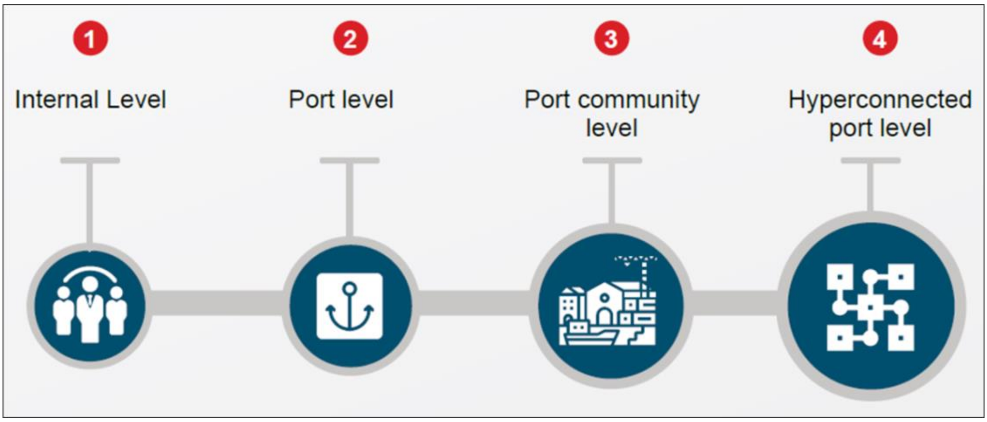

Figure 2: Levels of digital transformation into smart port adapted from Heilig et al. (2017)

Why Do Smart Ports Matter?

In today's maritime world, ships are increasing in size, the population is growing, ports are crowding, and with a globalized economy, goods need to move faster. In less than ten years, vessels are projected to sail autonomously, and so becoming smart is no longer just an option but necessary to remain competitive in the shipping market and at capacity (Kretschmann et al., 2017). Technology development is fundamental to improving surrounding cities. Competition between ports is more and more important, so making business practices and operations smarter means making them more attractive. The maritime industry, once seen as resistant to change, will soon adopt the technology of great power that is the way of the digitalized future (Y. Wang et al., 2018). Ports must be knowledgeable about the market, players, and stakeholders in their industry and must have a competitive strategy, or they will not remain competitive as the international supply chain and maritime sector change. Ports are also responsible for the safety and security of employees and affected stakeholders. Specifically, the Port Harbor Master Division must oversee – collision prevention, protected environmental areas, environmental pollution prevention, and worker safety. The technology used by Smart Ports can help the Port Harbor Master Division to better prevent safety issues and improve predictive analysis.

Smart Ports around the World

Smart port adoption and related operation have been seen in many ports in developed countries. The review of the initiatives taken by some ports has been shown in the following figure.

Table 1: Worldwide Smart Port Practices

Port	Smart Port Initiative
Port of Rotterdam	The port has a Digital Twin system which is an entirely digital replica of their port that provides insight into how the port's machinery interacts with each other. This also allows them to oversee all processes in real-time (K. Wang et al., 2021). The Internet of Things mechanisms the help detecting water velocity, turbidity, and pressure to assure compliance with environmental water requirements (Mary et al., 2021). Moreover, a facility, namely HavenLeerWerkPlaats is allowing port companies, workers, and job-seekers to discover labor possibilities at the port, integrating communities into the port (Sinay, 2021).
Port of Hamburg	The port has its own smartPORT ideology and programs, as well as an official IoT Project for tracking various types of pollutants (Schirmer et al., 2016). The implementation of integrated solutions for safety, real-time navigational data, and energy sources for port operation. Furthermore, they have installed IT systems by which port stakeholders and users can easily track and identify their cargo and operational status (Molavi et al., 2020). The port of Hamburg's control systems enables the interplay of sensor technologies, analytics, prediction, and systems engineering, providing considerable efficiency gains (HPA, 2020).

Port of Antwerp	Antwerp Port Information & Control Assistant (APICA) is the central processing unit that enables the 3D interface with real-time data for visualizing the ships of docking, anchoring, and berthing (Peña Zarzuelo et al., 2019). Antwerp port is collaborating with a number of partners to construct a network of autonomous drones to enhance the vast and complicated port region to be safer, more effective, and smarter (de la Peña Zarzuelo et al., 2020). Using a variety of sensors, the port aims to improve its remote control and intelligence. In addition, they utilize sensors to check the aquatic environment at the terminals and to improve the lifespan of asphalt. In turn, 3D-sonar sensors enable autonomous navigation. Last but not least, iNoses detect dangerous gases at the port (D'Amico et al., 2021).
Port of Singapore	The Vessel Traffic Information System (VTIS), Computer Integrated Terminal Operations System (CITOS), PORTNET, Marinet, TradeNet, and TradeXchange were developed by the Port of Singapore (Yap & Lam, 2018). These technologies are designed to handle various areas of the port and supply chain and serve distinct purposes. The Port of Singapore has introduced digitalPORT@SGTM, a centralized platform for legal operations. Phase One of digitalPORT@SGTM intends to streamline vessel, immigration, and port health clearances across several organizations by merging 16 unique forms into a unified platform (Menon, 2022).

Barriers to Implement Smart Port Practices in Chittagong Port:

Table 2: Exploration of Drivers to Implement Smart Port Practices at CPA

Barriers	Related Literature
Technological Knowledge of Port Users and Employees (B1)	(Jia & Cui, 2021), (Min, 2022), (Othman et al., 2022), (Lin et al., 2022), (Boullauazan et al., 2022), (Kassou et al., 2021)
Technical and Maintenance Support (B2)	
Port Governance Model (B3)	
Motivation of Employees (B4)	
Resistance to Change (B5)	
Cost of Set up and Operation (B6)	
Govt. Patrons and Support (B7)	

Data Collection and Methodology

The study adopts a comprehensive mechanism of data collection and analysis. The data collection and adopted methodology for the study has been explained in the following section.

Data Collection:

The study aims to identify the barriers to implementing the smart port at Chittagong port. Hence, the survey has been conducted among the designated three stakeholders of Chittagong port, i.e., port users, port employees and stakeholders. A panel of three members of each group has been formed and simulated through the SmartISM software. Four years of experience and a bachelor degree have been kept as the minimum requirement to filter the respondents. Since the ISM model analyzes the cognitive view of the respondents, a careful and timely survey process has been conducted to have a true and fair view.

Methodology:

Interpretive Structural Modelling (ISM) is a widely used and accepted model developed by (Warfield, 1974). The method helps to explore a set of different directly and indirectly related elements structured into a comprehensive systematic model (Sage, 1977; Warfield, 1974) and to investigate the cause-and-effect relationship among the factors. The method uses Structural Self-Interaction Matrix (SSIM) to show the pairwise matrix among the factors.

Framework and Design Process of the Study

The study has followed the process shown in the following figure (see Figure 3).

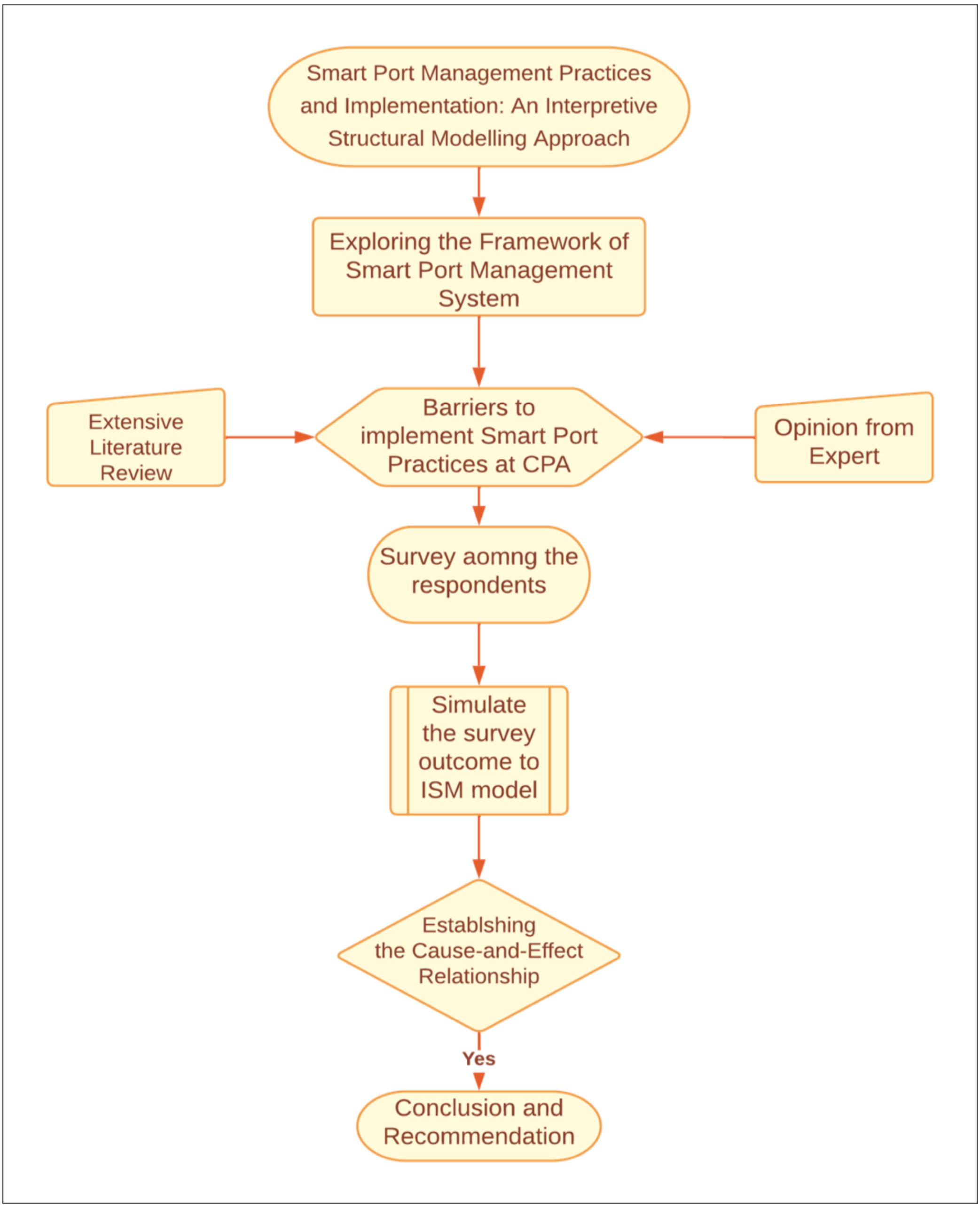

Figure 3: Research Framework and Design of the Process

Analysis and Findings

The study adopted interpretive structural modeling (ISM) to explore the causal relationships among the drivers to implement smart port practices at Chattogram port. The analysis was shown based on the survey simulated through the ISM model.

Final Reachability Matrix

The Final Reachability Matrix (FRM) is developed by identifying the transitivity in the matrix, which is an indirect relationship between variables (Kumar & Singh, 2019). The matrix explains that if driver *i* is related to drive *j* and the barrier *j* is related to a third drive, namely *k*, barrier *i* is concurrently related to driver *k*.

Table 3: Final Reachability Matrix

Variables	1	2	3	4	5	6	7	Driving Power
Technological Knowledge of Port Users and Employees	1	0	0	0	1	0	0	2
Technical and Maintenance Support	0	1	0	0	0	0	0	1
Port Governance Model	1	1	1	1	1	1	1	7
Motivation of Employees	1	1	0	1	1	0	0	4
Resistance to Change	0	0	0	0	1	0	0	1
Cost of Set up and Operation	0	1	0	0	0	1	0	2
Govt. Patrons and Support	1	1	0	1	1	1	1	6
Dependence Power	4	5	1	3	5	3	2	

Table 3 shows the factors of driving power and dependence power to implement the smart port practices at CPA through FRM. It is noted that technical and maintenance support is the main driver in implementing smart port practices at CPA. However, the port governance model has been the less influential driver in this case.

MICMAC Analysis

A large number of studies have used the MICMAC (Matrice d'Impacts croises-multiplication application) with ISM to curve easier decision-making. MICMAC was recommended to deal with complex issues. It is divided into four groups based on two variables: driving power and dependency power. A variable has driving power if its action can influence the variables that precede it and has a considerable effect on the system. Moreover, if a variable's behavior is dependent on other factors, this variable has dependency power (Yu et al., 2022). The fourth cluster consists of elements with substantial driving forces but limited dependency. The stimulating driver-dependency matrix reveals the following outcomes:

Quadrant I: The factors in quadrant I are independent, with weak dependency and weak driving power. These factors may be addressed independently during the intervention and have less impact on the system as a whole. Therefore, few direct connections have been discovered across the system.

Quadrant II: The factors considered in this quadrant have a high dependency power and a low driving power. As they are weak factors, addressing them has less priority.

Quadrant III: In this quadrant, the factors have the threshold of high dependency power and a high driving power. The factors are dynamic in this quadrant; influence the other factors and support the feedback

Quadrant IV: In quadrant IV, the factors have superlative influential power but less likely dependence power. They have a tremendous impact on the mechanism and drive the elements above them.

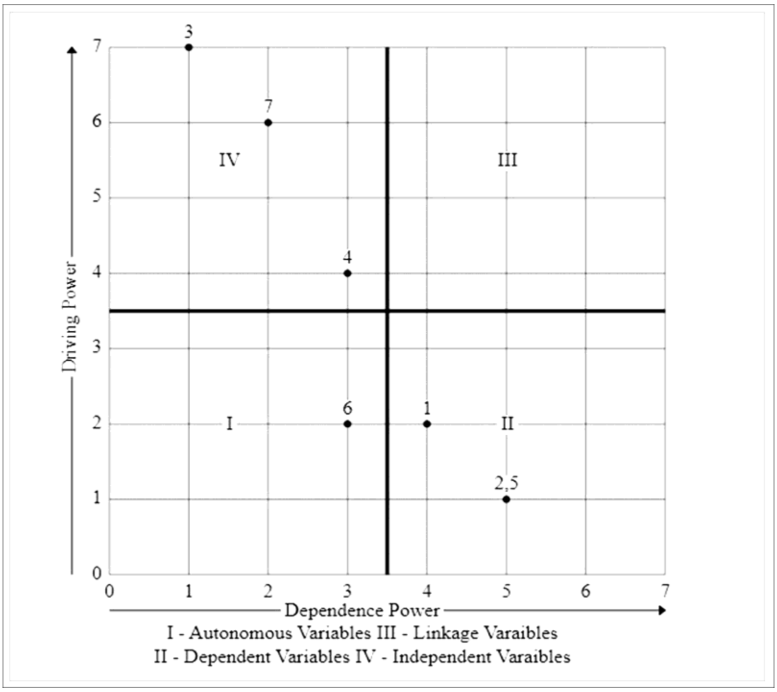

Figure 4: MICMAC Analysis

Figure 4 displays the distribution of seven barriers to implement smart port practices at CPA. It is found that set up cost and operation (B6) have the crucial role in implementing the smart port practices. Port governance model (B3) and govt. support and patron (B7) are laying on the IV quadrant, which is independent factors. On the other hand, technological knowledge of port users and employees (B1), technical and maintenance support (B2), and resistance to change (B5) are positioned in the dependent quadrant (III). It can be concluded that the port governance model and govt. support has an influence on the technological knowledge of port users and employees, technical and maintenance support, and resistance to change in implementing the smart port practices at CPA.

Final Model

The ISM model shows the hierarchical flows of factors among the driving factors and dependency factors. Figure 5 displays the final model of the upward hierarchical flow of barriers to implementing the smart port practices at Chattogram port. Based on the figure's hierarchical structure, the higher sub-factor has a significant impact on the sub-factor below it. Hence, the main influencing factor is port governance model followed by govt. support and patrons and motivation of the employees respectively.

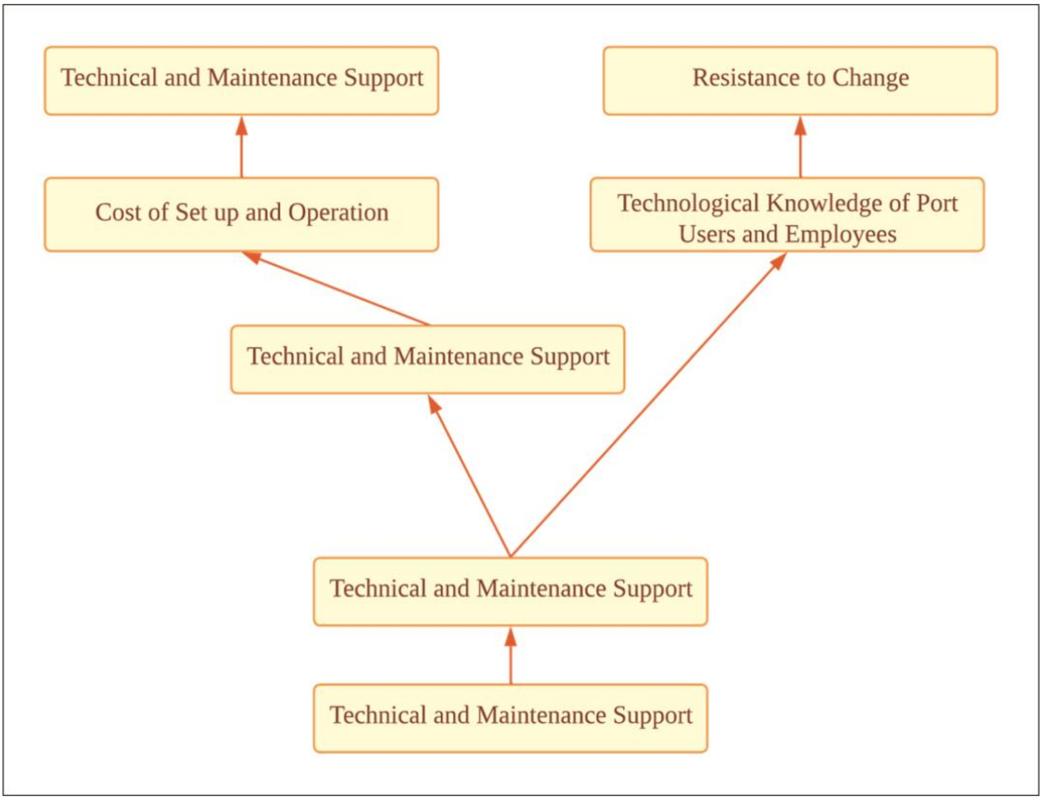

Figure 5: ISM Hierarchical Model of Barriers to Implement Smart Port

Technological knowledge of port users and employees and the cost of set up and operation are positioning parallel and influencing resistance to change and technical and maintenance support, respectively

Conclusion and Recommendation

The concept of a smart port highly relies on using smart and green technologies to increase a port's efficiency and improve performance, innovation, flexibility, environmental safety, and economic competitiveness. The transformation of the sector via the implementation of various technology devices, commonly referred to as smart ports, might increase the profitability, operational efficiency, and sustainability of port operations and systems. The purpose of this study is to investigate the framework, procedures, and challenges to implementing smart port practices in the context of the Chattogram port authority (CPA). Existing literature has been extensively examined in order to outline the smart port architecture. In addition, the three associated CPA groups, namely port users, port administrators, and wider port communities, were polled to determine the obstacles to implementing smart port practices. In this instance, interpretative structuring modeling (ISM) was utilized to establish the cause-and-effect link between the drivers. The technological understanding of port users and workers, as well as aversion to change, have been highlighted as the most significant obstacles to the implementation of smart port practices at CPA. However, the hurdles posed by the port governance model and government patronage and support have been identified as the driving forces behind the implementation of smart port practices. The project intends to have a significant effect on the adoption of smart port techniques in developing nations such as Bangladesh. Based on the analysis, the study comes up with the following recommendations:

- An integrated collaboration among the port stakeholders should be formed to incorporate smart port practices in the port operation.
- Technological knowledge of port users and employees, as well as technical and maintenance support, should be enhanced in adopting smart port measures to a port.
- The Port governance model and government support could highly help to transform the port operation practices into smart practices.

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