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A TOGAF-based Framework for the Enterprise Architecture Development of Smart Digital Port: A Case of Container Port in Indonesia

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***Abstract*— Smart ports can be perceived as a viable solution to address the emerging complexities confronting international trade and logistics systems. Through the deep integration of digital technologies, including the Internet of Things, big data analytics, cloud computing, and artificial intelligence, smart ports stand to substantially enhance their capacity for intelligent operations and efficient resource allocation within port activities. In this paper, an architecture development using TOGAF with a case of Container Port A in Indonesia is conducted by analyzing the existing core business operation with smart port targeted. The development in business, information systems, and technology is discussed, and both existing problems and key research gaps in Container Port A are identified. As a result, main technology in automation and digital twin are needed with supporting information system and technology architecture. These innovations work together to create more efficient, automated, and interconnected port operations. By leveraging these technologies, smart ports can significantly enhance productivity, lower operational costs, and contribute to improved environmental sustainability within the maritime industry. The use of automation technology streamlines various operational processes, while tracing systems ensure accurate tracking and management of container. This synergy not only boosts efficiency but also promotes eco-friendly practices, aligning with the broader goals of Industry 4.0. However, further investigation to define the portfolio and feasibility study if initiatives is needed.**

Keywords— TOGAF, enterprise architecture, digitalization, smart port, container

I. INTRODUCTION

A port is pivotal in the holistic maritime transportation network, serving as an end-to-end logistics chain. In the Industry 4.0 era with the emerging technologies such as the Internet of Things (IoT), big data analytics, cloud computing, and artificial intelligence (AI), have become integral components permeating various aspects of supply chains, particularly in the port evolution. In response to many evolving factors and impacts, ports increasingly recognize the imperative of embarking on the journey towards smart port transformation [1]. The concept of smart ports is characterized by their intrinsic capacity to orchestrate the complete automation of cargo handling operations and the efficient management of vessel movements [2]. Applying the advanced technology, for instance, IoT, in the logistics domain, encompassing cargo transportation and warehousing management, leads to cost reduction and improved sales performance. Providing high-caliber maritime logistics services hinges significantly upon the efficiency of ports. This aspect can be enhanced through rigorous cost control measures, efficient and sustainable operational and organizational practices, and due consideration for environmental conservation [1]. The conceptualization and evolution of a smart port aspire to attain the objective of intelligent and eco-conscious operations in both their execution and management [3]. To proactively address forthcoming trends, a smart port should allocate resources towards research and development endeavors aimed at pioneering innovative technologies and applications [3], [4]

Container Port A, among the prominent ports in Indonesia, holds significant promise for business expansion and revenue enhancement. Nonetheless, it has several challenges within its operational aspects, such as operational errors, congestion, delays, information deficits, and concerns about environmental sustainability and energy efficiency. These challenges can potentially affect the integration of the port chain with its associated industries. Consequently, the conceptualization of a smart port arises as a strategic response aimed at mitigating and resolving these issues. As the largest container port in East Java, efficiency is crucial not only for planning future activities and developing strategies but also for demonstrating the port's commitment to sustainability.

The need of transform Container Port A digitalization is highly important to facilitating the advancement of smart ports. Enterprise Architecture (EA) frameworks have proven their effectiveness in enhancing enterprise operations by offering a comprehensive vision of the organization that aligns with its strategic objectives [5]. To effectively support business goals and strategies, the enterprise IT architecture must be aligned with them. However, current methods for designing enterprise IT architectures offer limited guidance for smart port environments, which are characterized by their complexity and few operational boundaries. Smart port initiatives aim to remove specific obstacles within ports. These initiatives primarily focus on specialized IT applications and regulation-based approaches in the context of smart ports. IT plays a crucial role in advancing smart ports by enhancing knowledge sharing and information analysis. This, in turn, improves operational efficiency, energy efficiency, and environmental sustainability. The proposal involves key TOGAF phases, including architecture vision, business architecture, information systems architecture, and technology architecture. In this context, the enterprise architecture (EA) framework with TOGAF standard, emerges as a valuable tool for systematically acquiring and organizing pertinent information essential for the progressive maturation of smart ports. TOGAF serves the purpose of accumulating data and facilitating its conversion into meaningful information during every phase of development [5], [6]. The incorporation of TOGAF yields a structured progression in the evolution of smart ports, guided by the implementation of three overarching construction phases: Business Architecture, Information Systems (Application and Data) Architecture, and Technology Architecture.

This article is structured as follows: Section 1 is introduction. In section 2, the theoretical framework of smart digital concept is presented. In section 3, the methodology is demonstrated. Finally, the result and discussion of the work are presented in the section 4.

II. THE CONCEPT OF SMART DIGITAL PORT

The landscape of global maritime trade is undergoing a profound metamorphosis driven by digitalization. These developments empower the real-time remote monitoring of cargo and vessels in the maritime domain. [7] conceptualized a smart port as one that revolves around the deep integration of cutting-edge information technologies, including 5G communication, the IoT, big data analytics, and AI into port services. [8] underscored the pivotal role of information technologies, defining smart ports as fully automated port facilities wherein all devices are interconnected via the IoT. Port digitalization entails the digital metamorphosis of port-related procedures, characterized by a continual accumulation of new data, evolutionary progression, and adaptive learning. This dynamic evolution bestows upon stakeholders a contemporary comprehension of all transpiring events within their operational milieu. Achieving comprehensive digitalization of operations necessitates the wholehearted engagement of all stakeholders, given its pervasive influence spanning the entirety of the supply chain.

The development of smart ports can be ascribed to incorporating Industry 4.0 principles, as depicted in Figure 1. The status of Container Port A is in the Phase 3, as the logistics/ supply chain port with partial digitalization. Furthermore, the evolution of smart ports must underscore the paramount significance of advanced technologies. Based on Figure 1, port development can be categorized into four generations. The first generation, until the 1960s, functioned primarily as loading and unloading ports. The second generation, lasting until the 1980s, evolved into industrial ports. Post-1980s, the third generation emerged as logistics and supply chain ports. Each generation introduced new functions and focuses. The third generation shifted from being service and regulator-oriented to acting facilitators. Today, with the increasing need for digital integration, ports are transitioning into data service providers rather than just offering physical services like towage and crane operations. The fourth generation represents the digitalization of port activities, where new digital services either replace or enhance traditional port services. The advancements encompassed by Industry 4.0, encompassing, among others, the domains of extensive data analytics, autonomous robotic systems, and augmented reality (AR), present promising avenues for utilization of smart ports [1], [8]. Smart ports recognize that optimizing performance plays a pivotal role in securing their competitive edge.

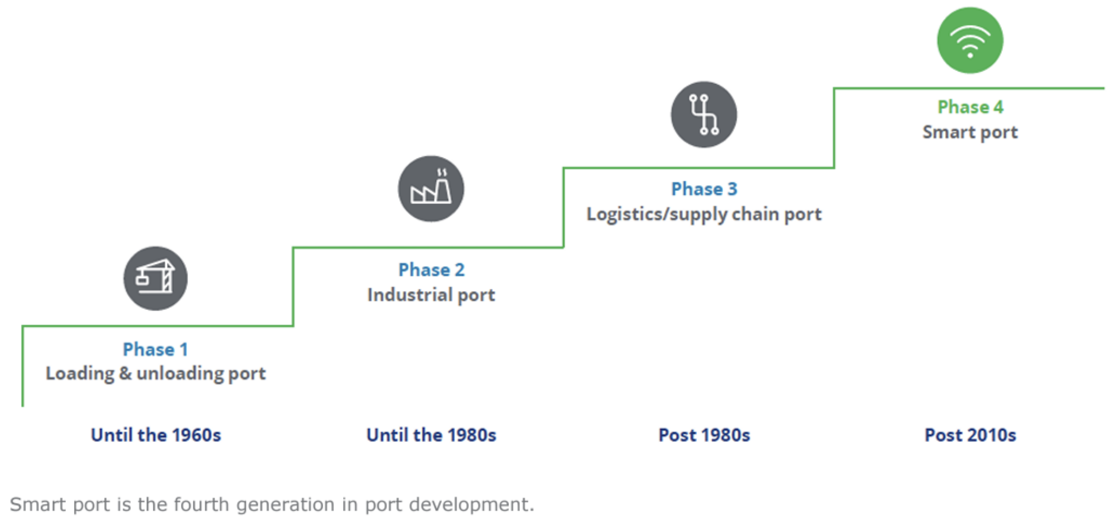

FIGURE I. PORT TRANSFORMATION (SOURCE: DELOITTE REPORT, 2017)

The concept of a Smart Port involves leveraging smart technologies to enhance a port's efficiency, performance, innovation, flexibility, environmental safety, and economic competitiveness [9]. Transitioning to a true Smart Port—one that fully utilizes the potential of an IoT network and smart data solutions—requires a port to identify and capitalize on new business models within the larger ecosystem [10]. A true Smart Port must use its position in the supply chain to add value by effectively utilizing data generated by the embedded IoT infrastructure. While the data alone does not add value, aggregating different data sources and applying the appropriate business rules for analysis can transform it into valuable insights.

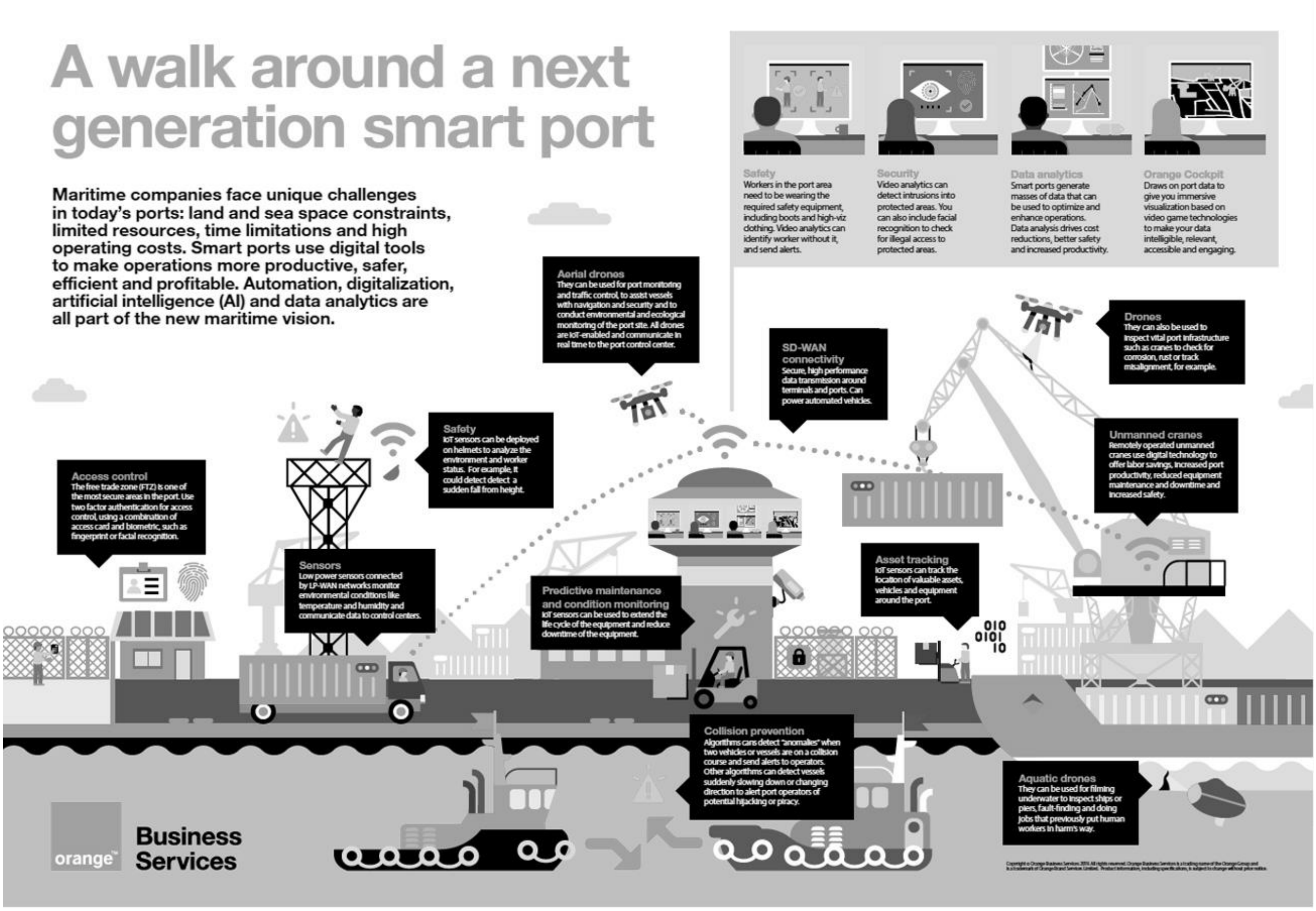

FIGURE II. SMART PORT CONCEPT(SOURCE: DANPASSARO.CO.UK)

III. METHODOLOGY

The Open Group Architecture Framework (TOGAF) stands as one of the preeminent Enterprise Architecture (EA) frameworks, extensively employed by major corporations. It incorporates the Architecture Development Method (ADM) to encapsulate the body of knowledge utilized in examining and establishing EA within an organizational context [11], [12]. This method is exceptionally comprehensive, encompassing all stages involved in the design of enterprise architecture.

Regarded as a theoretical framework for developmental purposes, TOGAF combines information and technology system architectures to pursue the objectives of both the corporate and information technology teams. This integration ensures the entire construction and management process harmonizes with the company's ultimate goal. TOGAF is openly available for utilization by businesses and organizations, constituting a highly commendable standard for corporate development due to its pragmatic and precise nature [13]. This study focuses on employing only three key phases from the TOGAF standard for digital port development. These phases include Business Architecture, Information System (Application and Data) Architecture, and Technology Architecture, all interconnected in a layered structure depicted in Figure III. TOGAF Phases.

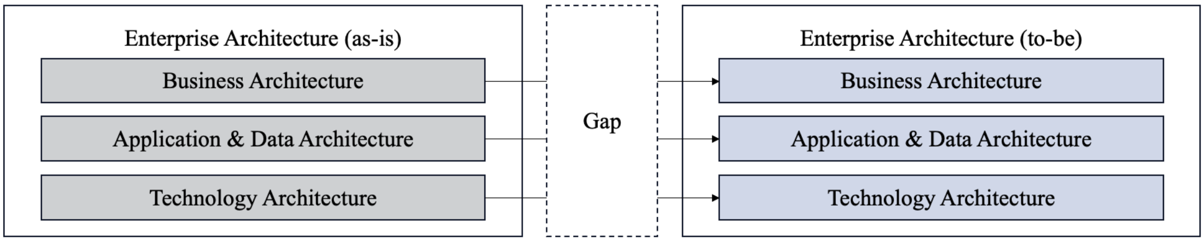

FIGURE III. TOGAF PHASES

The Business Architecture layer, situated at the foundation of our architectural construct, assumes a crucial role in the overall development process. It entails the definition of the motivation and function behind the architectural endeavor. Within the Data Architecture layer, we establish the framework for storing the information needed by the Application Architecture layer, which in turn puts into action the previously specified business functions. Lastly, the Technology Architecture layer brings together the technological resources necessary to implement the architectural design within the context of an information system structure.

We observed Container Port A as the top ten biggest Port in Indonesia. The qualitative approach was conducted to get the initial condition of the business, application, data, and technology aspects. The interview with operational managers and staff was scheduled to get the observation details of as-is framework, with the detail of each informant are explained in the Table I Informant Details. After gap was identified, the EA to-be will be defined.

TABLE I. INFORMANT DETAILS

Informant	Description	Interview Details
Manager of Information Technology Department (Informant 1)	Informant 1 is Manager of Information Technology Department and has the authority and responsibility to conduct supervision on Information Technology management in Container Port A. Not only to manage technology operational related problems, the informants along with the team also developed innovations in supporting technology application.	An informal discussion related to technology used in the port operation, a total duration of 60 minutes.
Manager of Port Operation (Informant 2)	Informant 2 is an Manager of Port Operation who has the authority to coordinate the daily container operation.	An informal discussion related to whole container operation phase, a total duration of 60 minutes.
1 Information Technology Development Staff (Informant 3)	Informant 3 is a development staff of the Information Technology Department of Container Port A since 2010 which has the authority to innovate in building applications that support the performance and business processes of port operation.	An informal discussion regarding the technology and application development, a total duration of 120 minutes.
4 End Users (Informant 4,5,6,7)	End users consists of user of Gate Operation Staff, Planning Operation Staff, Yard Operation Staff, and Maintenance Staff	An informal discussion related to application and technology implementation, a total duration of 60 minutes for each informant.

IV. FINDING AND DISCUSSION

A. *Business Architecture*

Container Port A plays a vital role as container terminal operator which completes the logistics and supply chain, especially on export-import and domestic containers business. For container operations, both for the export-import of containers via external trucks entering the terminal area and loading and unloading at the gate, yard, and dock areas. Technological trends in recent years have changed conventional business processes in port operations. In this case, Container Port A refers to a Smart Port that is fully supported by the implementation of IoT, automation based on advanced analytics and dynamics scheduling. For the current status, Container Port A already implements Smart Port partially, while several business processes are still handled in manual operation. The observation of the as-is condition and targeted was conducted to achieve a fully digital port.

TABLE II. BUSINESS IMPLICATION

Number	Observation	Implication	Initiative
1	The container identification process at the gate already uses Optical Character Recognition (OCR) technology, but it is not yet able to identify container damage detection and seal number identification automatically.	Provision of system support for container damage detection to improve the operational activity in the gate area from the data.	AI-Gate Automation
2	The truck identification process at the gate is still manual through tally input, have not captured automatically and integrated through the system yet.	Provision of system support for identification of seal numbers on containers.	AI-Gate Automation
3	The process of assigning equipment, especially for internal vehicle terminals	Provision of ITV assignment system support based on the closest route between ITV and the assignment location that	Digital twin implementation

Number	Observation	Implication	Initiative
	(ITVs) has not been done fully based on the location of the ITV with the nearest activity. The confirmation process for container allocation also still requires manual confirmation through the operator.	supports the principle of dual cycle operation and is integrated with the terminal operating system through IoT technology. Furthermore, comprehensive operational planning activities integrated with the terminal operating system are also needed, which are supported by manpower planning for human resource allocation in operational activities.	
4	The process of identifying container damage in the dock area has not been carried out comprehensively. Regarding loading and unloading activities, there is no system support to monitor operator activities and verification.	The need for system support for container damage detection in the dock area starts from capturing container images, processing images according to specified parameters, and identifying containers that do not match the parameters.	Digital twin implementation

The digital twin, positioned as a monitoring solution, transcends the confines of a singular product or technology; instead, it constitutes a synergistic of diverse technological components to empower ports in the monitoring of their assets [14], [15]. The utility of a digital twin in a port is multifaceted, encompassing vital domains such as fortifying port security, orchestrating the strategic planning and design of new infrastructure, empowering maintenance requirements for crucial assets via asset control signaling and real-time sensor-driven monitoring systems, and even conducting environmental assessments [16].

The idea of using OCR for gate automation has been around for a few decades. Using AI for gate automation in ports results in enhanced security, increased efficiency, accurate data collection, cost savings, real-time monitoring, predictive maintenance, improved traffic management, better customer experience, scalability, and environmental benefits . Current OCR solutions exhibit a pronounced dependency on hardware infrastructure, characterized by metallic gates equipped with the cameras and detection sensors. Leveraging the capabilities of artificial intelligence and deep learning, notably through neural network implementations, attains the highest levels of recognition accuracy, even under the most demanding operational circumstances [17]. Neural networks which is integrated into gate automation systems will demonstrate a commendable resilience to a spectrum of distortions and deformations, encompassing factors such as motion, blurriness, dust, and dirt interference. Such robustness holds paramount significance, particularly when scrutinizing freight assets with a history of extensive global travel in arduous environmental conditions.

B. Application and Data Architecture

Application architecture describes the structure and interaction of applications as a group of capabilities that provide support to business functions and manage data assets. The purpose of developing application architecture is as a blueprint that can be used to analyze and identify current application capabilities, application support for business processes, interactions between applications, and formulate future application and data capabilities. Data architecture defines the structure and meaning of data. The purpose of defining information and systems architecture is to reuse information and data by describing the data flow with different applications, either by integrating and sharing data in a single database or exchanging data by other means such as information and file transfer. For business operations, Container Port A is already supported by the terminal operating system and related applications. From the application observation in the business implication, the result of application observed will be defined on Table III. Application and Data Implications.

TABLE III. APPLICATION AND DATA IMPLICATIONS

Number	Observation	Application to-be featuring capability
1	The operation planning has been accommodated in the terminal operating systems, but some planning is manually through excel, for instance, berth planning. In addition, there are no tools to support the quality control process and data analysis as a basis for more efficient operational planning.	1. The system can input ship planning in user friendly. 2. The system can register stakeholders involved in operational activities. 3. The system can allocate stakeholders according to the capacity and load of operational activities. 4. The system can be integrated with TOS to obtain information related to operational activity planning. 5. The system can monitor the implementation of operations following the plans that have been prepared.
2	There is no feature to recommend the closest route to make the transportation of containers from the dock to the yard more efficient	1. The system can analyze the assignment of receiving/delivery activities on ITV based on boxes ready to be taken to the dock or yard. 2. The system can document which containers will be receiving/delivered based on the position and availability of the truck. 3. The system can display the number of transportation equipment currently carrying out loading and unloading containers in the dock area. 4. The system can still provide work order assignments to each tool. 5. The system can display a list of work orders for each assigned conveyance.

Number	Observation	Application to-be featuring capability
		6. The system can display live container images
3	The lack of data integration between application systems has caused many processes to be carried out manually and the lack of ability to monitor business performance through currently available data in real-time. In addition, the unavailability of data analysis is carried out to support the implementation of company operations.	All the data needed to be analyzed has been stored into big data. Data related to operations, maintenance, and other data needs will be analyzed through analytical tools to support the operational implementation of the main business lines.

The specified architectural framework is oriented towards facilitating the integration of Industry 4.0 technologies, including but not limited to Big Data, automation, AI and IoT to enhance efficiency, safety, and sustainability within port terminal operations [18], [19], [20]. Container Port A should undertake a series of enhancements, encompassing the augmentation of sensor networks embedded in port equipment, the development of Big Data infrastructure and predictive analytics capabilities, the deployment of AI solutions, and the provisioning of Business Intelligence (BI).

C. Technology Architecture

Technology architecture supports Container Port A's initiatives and system improvement. This can help the business units, especially IT, define technologies that must be maintained or updated according to the improvement of Container Port A applications. The detail of technology observation is identified in Table IV. Technology Implications.

TABLE IV. TECHNOLOGY IMPLICATIONS

Number	Observation	Targeted
1	The server infrastructure for the terminal operating system at Container Port A uses server devices that almost achieve their end-of-support life (EoSL) period.	Upgrade the server infrastructure devices.
2	The level of support for High Availability capabilities on core application servers is still different. The implementation of High Availability on core applications still requires manual switchover.	Using technologies such as load balancing and clustering to improve the High Availability capability of core applications.

It is essential to elevate the existing infrastructure to the targeted standards to empower the implementation of the initiatives. Moreover, considering the vast expanse of Container Port A, encompassing extensive cargo ship berths spanning hundreds of acres, the intermittent and limited availability of public 4G coverage had resulted in data loss. This situation presented an opportune moment to embark on the 5G deployment as a strategic endeavor, one that held the promise of enhancing operational efficiency and potentially introducing novel services to cater to the needs of its clientele. The advanced attributes of a 5G network, particularly its reliability, security features, and minimal latency, are essential in facilitating the integration of emerging technologies in container port operations.

Developing new process technologies and practices is crucial for enhancing port operations. A key aspect of this development involves planning and managing validations for potential technology projects. These validations are essential to assess the technical, financial, and organizational feasibility of projects and to gather data for measuring their benefits, which can support further funding decisions [6]. At a strategic level, validation follows four defined phases: Enterprise Definition, Project Definition, Experiment Planning and Execution, and Results Analysis [21]. However, future research suggests that validation processes may become more complex and time-consuming.

V. CONCLUSION

This paper reports on the case study of Container Port A, as the top ten biggest port in Indonesia to achieve Smart Digital Port phase. The process model of TOGAF consist of business, information systems (architecture and data), and technology architecture analysis. The identification of current condition of Container Port A in core business sector as container operation terminal was conducted. The targeted condition also identified based on standard and trend of Smart Port. The findings highlight two main initiatives in automation and digital twin trends, supported by application and technology advancement to support the digitalization. In summary, the concept of smart ports for Container A embodies the principles of Industry 4.0 by integrating advanced technologies such as robots and tracing systems to create more efficient, automated, and interconnected port operations. This synergy leads to enhanced productivity, reduced operational costs, and improved environmental sustainability in the maritime industry. Furthermore, the roadmap and feasibility study of implementation still needed to identify about the technology investment and revenue projection.

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