

The Role of Digital Capabilities and Human Factors in Enhancing Port Service Performance: A Mediated Model for Eastern Indonesia

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Abstract—This research was conducted in response to the increasingly urgent need for digital transformation in port services in Eastern Indonesia to improve efficiency, transparency, and service quality amid the development of information technology. The research addresses a significant gap by integrating digital capabilities and human factors within the context of port digital transformation in Eastern Indonesia, an underexplored area in the existing literature. The research objective was to examine the influence of digital capabilities, human factors, and information system success on improvements in port service performance. The research method used a quantitative approach, with surveys of service users and system managers to measure technology acceptance and information system success. The number of respondents was 189. The use of a quantitative approach, including surveys and SEM-PLS analysis, is appropriate for testing complex relationships among variables. Based on the measurements, service performance (SP) obtained the highest score ($R^2 = 0.732$), supported by the organization's strong digital capabilities, effective human resources, and successful implementation of information systems. The anticipated outcomes include identifying critical factors that determine the success of digital transformation and developing an integrative model to guide the effective implementation of port services. The model linking digital capabilities, human factors, information system success, and port service performance provides a valuable framework for future empirical research.

Index Terms—Digital capabilities, human factors, information systems success, port service performance, eastern Indonesia.

I. INTRODUCTION

Indonesia, recognized as the world's largest archipelagic nation, consists of more than 17,000 islands spread across a vast maritime area, extending from Sabang in the west to Merauke in the east. This unique geographical configuration creates remarkable cultural, ethnic, linguistic, and natural diversity, making Indonesia one of the most diverse countries in the world. In addition, its strategic location between the Indian and Pacific Oceans positions Indonesia as an important center for international trade, maritime transportation, and global economic activities. However, the widespread distribution of islands also poses significant challenges in infrastructure development, transportation connectivity, equitable public services, and regional economic integration.

This unique geographical condition makes ports a vital component of the country's transportation and logistics infrastructure. The nation relies heavily on ports to connect islands, facilitate the movement of goods and people, support domestic and international trade, and strengthen economic growth across regions. In addition, ports play a strategic role in promoting regional development, reducing disparities between islands, and ensuring national unity and sovereignty. As gateways for commerce and maritime activities, ports are essential for sustaining Indonesia's economic resilience and maintaining connectivity throughout the archipelago [1].

Ports play a strategic role in the development and economic growth of a region [2]. As key gateways for the movement of goods, services, and people, ports facilitate domestic and international trade, contributing significantly to regional and national economies. Efficient port operations can reduce transportation and logistics costs, improve supply chain performance, and increase the competitiveness of local industries in global markets. In addition, ports stimulate investment, create jobs, and encourage the growth of supporting sectors such as transportation, warehousing, manufacturing, tourism, and fisheries. The presence of well-developed ports also enhances regional connectivity, enabling remote areas to access broader markets and essential resources. Therefore, ports are not only transportation hubs but

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also important drivers of economic integration, regional development, and long-term economic sustainability.

Ports are important nodes in the global logistics system; currently, more than 80% of global trade (by volume) is transported by sea, with a total of 11.1 billion tons of goods transported in 2019, despite a significant 9% decline in 2020 [3]. In recent decades, with the development of Industry 4.0, the trend in port operations has shifted from conventional, physical ports to smart, digital ports [4]. Major ports in the world such as the Port of Singapore, the Port of Abu Dhabi, the Port of Busan, the Port of Rotterdam, the Port of Barcelona, and others have utilized the Internet of Things (IoT), Artificial Intelligence (AI), automation, blockchain, virtual reality, smart application/terminal operating system and Big Data to optimize operational efficiency, service transparency and data-based decision making [5].

In the era of Industry 4.0, digital technologies are crucial for upgrading port operations and enhancing operational efficiency worldwide [6]. The digitalization trend in ports accelerates service processes, increases efficiency, enhances transparency, and enables data integration among stakeholders, enabling them to make decisions quickly [7]. The digitalization trend in ports plays a crucial role in transforming port operations by accelerating service processes and improving overall operational performance. By implementing digital technologies such as automated systems, cloud computing, the Internet of Things (IoT), big data analytics, and integrated information systems, ports can streamline administrative and operational activities. Digitalization also creates greater efficiency by reducing manual processes, minimizing operational errors, and shortening cargo handling and vessel turnaround times [8].

According to [9] and [10], stakeholders are all parties that can influence or be influenced by an organization's success in achieving its objectives. These parties may consist of internal stakeholders, such as employees, managers, and shareholders, as well as external stakeholders, including customers, suppliers, government institutions, communities, and business partners. Their involvement and support are considered essential because organizational activities and decisions often have direct or indirect impacts on their interests. Therefore, organizations must establish effective communication and collaboration with stakeholders to achieve organizational goals and ensure long-term sustainability. While [11] defines stakeholders as all parties related to the organization and with an interest in the problems it faces.

In Indonesia, digitalization programs have been initiated by both the government and port operators for some time. Presidential Regulation of the Republic of Indonesia Number 44 of 2018 concerning the Indonesian National Single Window (INSW) [12]. Reference [13] serves as the basis for improving and enhancing national logistics performance, strengthening the investment climate, and increasing the competitiveness of the national economy. The Indonesian government, through the National Logistics Ecosystem (NLE) and Inaportnet programs, is striving to accelerate the digitalization of the port system to create integration among national logistics actors. The

implementation of digitalization of port services is one of the main work programs of PT Pelabuhan Indonesia (Persero) after the merger on October 1, 2021.

The direction of PT Pelabuhan Indonesia (Persero)'s business development after the merger as stated in the State-Owned Port Enterprise Merger Study is to realize value creation through 4 (four) main strategic pillars, these include: (1) the transformation toward world-class ports, (2) strengthening the logistics ecosystem, (3) increasing efficiency in the maritime supply chain, and (4) enhancing the company's overall value. To support the realization of the main strategic pillars so that they can run well and efficiently, 4 (four) drivers have been established, namely: (1) development of an integrated Pelindo organization to encourage efficiency, (2) development of sustainable innovation, (3) development of HR capabilities and quality, and (4) strengthening the utilization of technology and integrated Pelindo information systems.

Digital transformation is necessary to ensure that ports managed by PT Pelindo (Persero) maintain the same service standards, thereby improving efficiency, service speed, and data collection accuracy, and accelerating operational decision-making. [11], The digitalization of ports in Indonesia poses complex challenges, given Indonesia's vast territory and the large number of ports. Although digital technology has been adopted, its benefits are often suboptimal. One contributing factor is the imbalance between technological capabilities and human resources (HR) capabilities. Employees lacking digital skills tend to struggle to use digital systems optimally, leading to managerial decisions that remain intuitive or partial [14]. Furthermore, the impact of digitalization on port service performance is rarely measured empirically. Existing data is often descriptive or limited to technology evaluation, so the contribution of digital capabilities and human factors to achieving port Key Performance Indicators (KPIs) remains unclear [15].

Based on research by [16], the analysis showed that 26 ports had achieved the regional or national integration stage, 18 ports were at the community integration stage, and one port had reached the inter-organizational connectivity stage, with a digital transformation maturity score of 4.507 on a six-point scale. Although the government and port business entities have initiated and implemented various policies to digitalize port services, several major ports in the Western Region of Indonesia have reached a fairly advanced stage, while those in the Eastern Region of Indonesia (KTI) are still at an intermediate level. Ports in the Eastern Region of Indonesia, located in Sulawesi, Maluku, Nusa Tenggara, East Kalimantan, and Papua, have their own characteristics that are different from ports in the Western Region of Indonesia, such as limited infrastructure, geographical conditions, demographic characteristics, human resources, and socio-cultural conditions, as well as limited investment.

Additionally, dimensions including system quality, information quality, service quality, system usage, user satisfaction, and net benefits significantly affect the success of digital transformation [17]. Sustainability orientation is also a

key concern. In addition to improving efficiency, digital transformation should also support energy management, reduce environmental impact, and improve occupational safety [18]. However, most digitalization programs still focus on productivity, while environmental and safety aspects are often not optimally integrated [19].

Therefore, to measure the success of digital transformation in ports in Eastern Indonesia and try to fill the literature gap, we examine the relationship between digital capabilities and human factors on the success of information systems in improving service performance [20], in order to understand the factors that influence the successful implementation of digital transformation in the port services sector. This research is expected to provide a more comprehensive understanding of the theory and practice of port management in the digital era.

II. RELATED WORK

A. Port Management and Stakeholders

Port administration in Indonesia is regulated by Law Number 17 of 2008 concerning Shipping, which has been amended several times, most recently by Law Number 66 of 2024. Ports serve a significant role, as follows:

- Nodes in the transportation network, according to their hierarchy, can be classified into several levels based on their roles, capacities, and strategic importance in supporting the movement of people and goods.
- Gateways to economic activity play a crucial role in facilitating the movement of goods, services, people, and information between regions and countries.
- Locations for transportation mode transfers are essential components of an integrated transportation system, serving as points where passengers or goods move from one mode to another, such as from buses to trains, ships to trucks, or airplanes to public transit.
- Supporting industrial and/or trade activities is a fundamental function of transportation and infrastructure systems in promoting economic development and regional competitiveness;
- Locations for distribution, production, and consolidation of cargo or goods serve as critical elements within logistics and supply chain networks, facilitating the efficient flow of products from manufacturers to consumers;
- Realizing the archipelagic outlook and national sovereignty is a fundamental objective in strengthening national unity, territorial integrity, and sustainable development across Indonesia's vast maritime region.

According to [21], stakeholders in the port are highly diverse in their duties and functions (Table 1).

Table 1.
Summary of Stakeholder Identification in the Port

No	Stakeholder Characteristics	Principal Stakeholders in Port City Management
1	Internal	Port personnel, minority shareholders, port management, board members, port owners (e.g., government or port

2	Public Sector	operators), and port regulatory authorities. Relevant stakeholders include port authorities and port state regulatory bodies, national governments and affiliated ministries such as the Ministry of Transportation, the Ministry of Finance, and the Ministry of Environment, as well as legislative institutions, urban development authorities, and labor organizations.
3	Business Actors and Corporate Entities	Stakeholder organizations include land and maritime transport operators, logistics providers, shipping and transportation companies, and stevedoring firms.
4	Local Communities and Interest Groups	Relevant parties include residents in the vicinity of the port, consumers and taxpayers, non-profit organizations (NGOs), such as environmental organizations, and representatives from the media and press.

B. Previous Studies

The following are previous studies and dimensions of digital transformation maturity for ports, based on the research shown in Table 2.

Table 2.
Dimensions of Digital Transformation Maturity for Ports

No	Ref.	Dimensions	Research Focus
1	[17]	Technology, managerial practices, decision-making procedures, intelligence capabilities, information exchange and accessibility, as well as improvements in key performance indicators (KPIs).	Digital and managerial capabilities in data-driven decision making to improve performance (Key Performance Indicators)
2	[19]	Port Operations, synchromodality, safety and security, energy and environment, capability	Efficient and sustainable port operations and integration of transportation modes (synchromodality)
3	[22]	Development programs, technology, promotion, organization, human factor	Highlights organizational development and human factors in the implementation of technology and development programs in the maritime/logistics sector
4	[15]	Digital transformation of processes, increased efficiency, technological innovation, and improved value creation.	Organizational digital transformation that focuses on enhancing efficiency and creating added value.
5	[14]	Management, human resources, operational functionality, technology, and information.	Emphasizes the importance of management, human resources, and information technology as the foundation for improving organizational function.

From the table above, researchers over the last 5 years have varied in numbers, dimensions, and research focuses. The following is the researcher's analysis regarding this:

- Digital capability is a dominant dimension in almost all studies, except [19]. This fact shows the importance of digitalization and information systems in increasing efficiency and decision-making [23].
- Managerial and organizational aspects also appear consistently, namely [14], [22], and [17]. This consistency shows that technology alone is not enough without managerial and organizational readiness [24].

- Digital capabilities and human factors, namely [14], [22], and [19], are important components in the success of technology adoption.
- Industry-specific context, only [19] focuses on ports and multimodal logistics, while others are more general at the organizational level. The ultimate goals of research vary:
 - Efficiency and added value [15] and [17],
 - Operational sustainability and safety [19],
 - Human resource and organizational development [14] and [22].

Based on the synthesis above, the researcher found a potential research gap that served as the basis for conducting this research, namely integrating digital capabilities and human factors in the port context because most of the studies only highlight one side, namely [15] and [17] only the technological side, while [14] and [22] only the human side, so not many have studied how the two influence each other in the port environment. This study differs from previous works (e.g., by integrating both technological and human dimensions in a single empirical model.

C. Digital Transformation Programs at Ports in Indonesia

This section briefly describes the various digital transformation programs that have been implemented at ports in Indonesia, namely (i) Inaportnet, (ii) Pelindo Terminal Operating System Multipurpose (PTOS-M), PHINNISI, Terminal Operating System Nusantara (TOSNUS), and the Customer Portal application. The following is an explanation:

1) *Inaportnet is a digital service delivered via the internet.*

A platform that integrates standardized port information systems to facilitate the physical handling of ships and cargo involving all relevant agencies and stakeholders at the port. [25]. The Ministry of Transportation developed Inaportnet to integrate port service systems provided by various agencies [26]. The types of services provided at Inaportnet are as follows:

- Incoming ship services,
- Extension of the mooring or anchoring period and ships changing their mooring or anchoring places,
- Outgoing ship services, and
- Procedures for canceling services.

2) *Pelindo Terminal Operating System Multipurpose (PTOS-M)*

A multipurpose terminal service operating system platform developed internally by the Pelindo Group. It is end-to-end, providing fully integrated features for Order Management, Front-End, and Back-End for Multipurpose Terminal Services (Dry Bulk, Liquid Bulk, General Cargo, Receiving & Delivery), as well as Record-to-Report capabilities, within a single configurable, stable, and flexible platform [27]. PTOS-M services include:

- Loading/unloading services,
- Warehouse or yard storage services,
- Rental of owned and unowned equipment,
- Equipment fees,
- Lump-sum warehouse/yard billing,
- Independent weighing services, and
- Items and truck inspections.

3) *PHINNISI*

Phinnisi is a digital system developed by PT Pelabuhan Indonesia (Persero) to provide ship services, from service request and scheduling to service implementation, billing, and reporting, all digitally and promptly [28]. The main features of the Phinnisi application are:

- Ordering,
- Validating,
- Planning,
- Order dispatching,
- Execution logging,
- Billing, and
- Reporting.

4) *Terminal Operating System Nusantara (TOSNUS)*

A digital system platform developed internally by PT Pelabuhan Indonesia (Persero) for service delivery at Container Terminals. The system will create efficient, transparent container management and operational services, with accurate data integrated with other applications/systems, thereby increasing terminal productivity and supporting data-driven decision-making [29]. The modules/functions provided in TOSNUS are as follows:

- Vessel planning & operation,
- Yard planning & management,
- Gate operation,
- Equipment control & monitoring,
- Billing & documentation, and
- Reporting & analytics.

5) *Customer portal application*

This application is a digital platform developed internally by PT Pelabuhan Indonesia (Persero) that allows customers to access port services online without visiting the port office. The customer portal application provides 24/7 digital services for service users, expediting administrative processes and service delivery. This application is also integrated with operational and commercial systems at PT Pelabuhan Indonesia (Persero). The customer portal applications provided by PT Pelabuhan Indonesia (Persero), according to port service segments, are as follows:

- Integrated Billing System (IBS), for multipurpose and non-container port services, and
- PARAMA, for port services at container terminals.

III. RESEARCH METHOD

A quantitative approach with an explanatory research design is used in this study. It is described as a study that aims to test a theory or hypothesis, using the results of previous research to confirm or reject it. The quantitative approach was chosen because this study aims to examine the causal relationship between variables through hypothesis testing based on a previously developed theoretical framework. The explanatory research method is used to examine the direct and indirect influences among the variables of digital capability (DC), human factors (HF), information system success (ISC), and service performance (SP).

This study's population comprises all individuals who use

the port digitalization system, starting from service users consisting of shipping companies, stevedoring companies, sea freight forwarding companies, and related stakeholders and port operational employees and managers involved in decision making, digital technology management, and operational implementation in the port environment both from within PT Pelabuhan Indonesia (Persero) and from the regulator, namely the Harbormaster's Office and the Port Authority.

The study focuses on port digitalization systems implemented in Indonesia, especially under PT Pelabuhan Indonesia (Pelindo). However, the paper does not use a single platform as the research object. Instead, it discusses several digital platforms collectively as examples of port digital transformation. These include: Inaportnet, PTOS-M, Phinnisi, TOSNUS, and the Customer Portal application. Currently, the research treats "port digitalization systems" in general, rather than evaluating one specific system. Table 3 shows the population of this research.

Table 3.
The Population of This Research

No	Port	The number of respondents
1	Makassar	32
2	Balikpapan	61
3	Bitung	43
4	Ambon	11
5	Sorong	4
6	Jayapura	9
7	Manokwari	14
8	Gorontalo	10
9	Pantoloan	5
The total respondents		189

The sampling technique used was purposive sampling. Purposive sampling is a nonprobability sampling method in which researchers intentionally select participants based on specific criteria related to the study's aims [30]. Respondents had to be users or stakeholders involved in the port digitalization system. This fact means that not every individual in the population has an equal opportunity to be chosen; instead, researchers select those deemed "most knowledgeable," "most relevant," or "most appropriate" to answer the research questions. The data collection uses a questionnaire for each construct item for (i) Digital Capabilities 4 indicators, (ii) Human Factors 4 indicators, (iii) Success of Information Systems 3 indicators, and (iv) Service Performance 4 indicators. Table 4 shows indicators for each variable:

Table 4.
Indicators of Each Variable

No	Variable	Indicator
1	Digital Capabilities	• Digital Infrastructure • Data Integration • Automation and Analytics • Decision Intelligence
2	Human Factors	• Digital Skills • Training and Learning • Adaptability • Commitment
3	Success of	• System Quality

Information Systems	• Intensity of use • Benefits and impacts
Service Performance	• Physical evidence • Reliability • Responsiveness • Guarantee

SEM-PLS analysis typically requires a sample size that is approximately five to ten times the number of measurement indicators. Because this study has approximately 4 constructs, the minimum sample size is 75 respondents, with a target of 100–150 respondents for more robust analysis results. The data analysis technique used SmartPLS 4.0 because this research model involves direct relationships, mediation, and moderation between variables [31].

IV. THE PROPOSED MODEL

Based on previous research, the author proposes a model shown in Fig. 1. Figure 1 illustrates a research model that explains how Digital Capabilities and Human Factors influence Service Performance, both directly and indirectly through the Success of Information Systems. The explanation of the model in Fig. 1, digital capabilities (DC) denote the organizational capability to adopt and utilize digital technologies, systems, and infrastructure effectively. Moreover, Human Factor (HF) encompasses human-related aspects such as skills, competence, experience, and user or employee attitudes [32]. The success of Information Systems (SIS) acts as a mediating variable, indicating how well information systems perform in terms of quality, usefulness, and impact [33]. Service Performance (SP) is the dependent variable, reflecting the effectiveness, efficiency, and quality of services delivered.

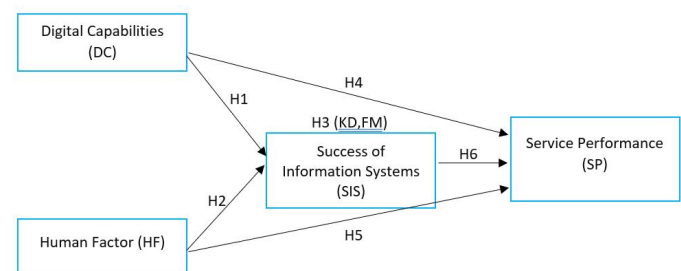


Fig. 1. Proposed model.

The relationships (hypotheses) are as follows:

- H1: Digital Capabilities (DC) play a significant role in enhancing the success of information systems (SIS) by enabling organizations to effectively adopt, manage, and utilize digital technologies in supporting operational and strategic activities. Strong digital capabilities enable organizations to improve system integration, data processing, communication efficiency, and technological adaptability, ultimately contributing to higher system performance and user satisfaction.

- H2: Human Factors (HF) contribute positively to the achievement of Information Systems Success (SIS) by influencing how individuals interact with, utilize, and adapt to information systems within an organization. Human factors such as user competence, technological skills, motivation, communication, collaboration, and acceptance of technology play an essential role in determining the effectiveness and efficiency of system implementation. Employees with adequate knowledge and positive attitudes toward information systems are more likely to use them optimally, reduce operational errors, and improve overall organizational performance.
- H3: Digital capabilities and human factors jointly influence the Success of Information Systems (SIS) by creating a synergistic relationship between technological competence and human readiness in the implementation and utilization of information systems. Digital capabilities provide organizations with the technological infrastructure, technical expertise, and adaptability needed to operate and optimize information systems effectively. At the same time, human factors ensure that users can understand, accept, and use these systems effectively in their daily activities. The integration of strong digital capabilities with supportive human factors such as user competence, motivation, collaboration, and leadership can improve system performance, increase user satisfaction, and enhance organizational productivity.
- H4: Digital Capabilities (DC) have a direct effect on Service Performance (SP) by enabling organizations to use digital technologies more effectively to deliver efficient, responsive, and high-quality services. Strong digital capabilities support the integration of information systems, automation of operational processes, real-time data management, and improved communication channels, all of which contribute to better service delivery and customer satisfaction. Organizations with advanced digital capabilities are also better able to adapt to changing customer needs, optimize resource utilization, and minimize service delays or errors.
- H5: Human Factors (HF) have a direct effect on Service Performance (SP) by influencing the quality, efficiency, and effectiveness of service delivery within an organization. Human factors, such as employee competence, communication skills, motivation, adaptability, teamwork, and commitment, significantly affect how services are delivered to customers or stakeholders. Employees with strong technical and interpersonal skills are better able to respond to customer needs, solve problems efficiently, and maintain high service standards. In addition, supportive leadership, continuous training, and positive organizational culture can improve employee performance and encourage greater engagement in service activities.
- H6: The Success of Information Systems (SIS) has a positive effect on Service Performance (SP) by enabling organizations to deliver services more efficiently, accurately, and responsively through effective technology and information management. Successful information systems support faster data processing, improved communication, better departmental coordination, and more

reliable decision-making, all of which contribute to enhanced service quality and operational effectiveness. In addition, user-friendly, reliable, and well-integrated information systems can increase employee productivity and customer satisfaction by reducing errors, minimizing delays, and ensuring the availability of accurate information. Table 5 and Fig 2 show the SEM-PLS statistical results and diagram the test results of the proposed model.

Table 5.
SEM-PLS Statistical Result

Path	Coefficient	t-value	Result
DC-SIS	0.42	5.21	Supported
HF-SIS	0.37	4.88	Supported
DC-SP	0.28	3.45	Supported
HF-SP	0.31	3.96	Supported
SIS-SP	0.46	6.12	Supported

R^2 SIS = 0.614 and R^2 SP = 0.732

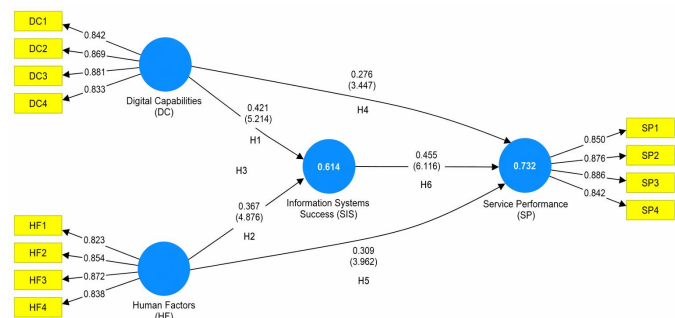


Fig. 2 The result of the test of the proposed model.

The following is an interpretation of the model test results shown in Fig. 2:

- Digital Capabilities, such as IT infrastructure, digital skills, innovation capacity, and technological readiness, significantly improve the success of information systems.
- Human Factors such as employee competence, leadership support, user acceptance, motivation, and collaboration also significantly enhance the success of information systems.
- Both variables (DC and HF) jointly explain the success level of information systems.
- Service Performance improves directly through stronger digital capabilities and better human factors.
- In addition, Information Systems Success acts as a mediating variable, meaning that effective systems help transform digital and human resources into better service outcomes.

Service performance is maximized when organizations possess strong digital capabilities, effective human resources, and successful information systems implementation. Information systems success serves as a strategic bridge connecting internal capabilities to superior service outcomes. Overall, the model shows that service performance is improved not only by supported digital capabilities and effective human factors, but also through the successful implementation and use of information systems, which play a crucial mediating role.

V. CONCLUSION

This study proposes a model to explain how digital capabilities and human factors contribute to improving port service performance in Eastern Indonesia, both directly and indirectly through the success of information systems. The model highlights that digital transformation in port services cannot rely solely on advanced technologies; competent human resources and effective system implementation must support it. Digital capabilities enhance service performance by enabling efficient, transparent, and integrated processes, while human factors play a crucial role in ensuring that information systems are properly adopted and utilized. The success of information systems serves as a key mediating variable, translating technological and human readiness into tangible performance outcomes. This study, which develops a model linking digital capabilities, human factors, information system success, and port service performance, provides a valuable framework for future empirical research.

Overall, this research emphasizes the importance of aligning technological development with human and organizational readiness to achieve sustainable improvements in port service performance. The proposed model provides a theoretical foundation for future empirical testing and can serve as a reference for policymakers and port managers in designing more effective digital transformation strategies. Given the study's conceptual nature, future research should empirically validate the model; subsequent research should test the model across different port contexts and regions. Additional factors such as organizational culture, stakeholder engagement, and environmental sustainability could be incorporated to enrich the model.

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