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BARRIERS AFFECTING DIGITALISATION OF THE MARITIME INDUSTRY IN SRI LANKA

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ABSTRACT

This study examines the digital transformation of Sri Lanka's maritime industry, focusing on identifying key barriers, analysing their interconnections, and assessing the digitalisation potential in import, export, and freight forwarding operations. Through a systematic review, this study identifies five primary categories of barriers to digitalisation: organisational and management-related, operational, resource-related, market-related, and technological barriers. A structured questionnaire was distributed to 148 professionals in the maritime sector, including stakeholders from shipping agencies, freight forwarders, and port authorities, who were selected using the snowball sampling method. The collected data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) to assess the influence of each barrier on the digitalisation level of Sri Lanka's maritime industry. The findings confirm that all five barrier types significantly hinder digitalisation, with organisational and management-related barriers having the strongest and most negative impact. Additionally, ordinal data analysis was used to evaluate the current and potential digitalisation levels in imports, exports, and freight forwarding. The results reveal significant gaps between the existing and potential states, particularly in critical operations. These insights can help stakeholders address key barriers and implement targeted actions to boost digital adoption, improve efficiency, and enhance global competitiveness in the industry. The findings contribute not only to the academic discourse on maritime digitalisation but also serve as a practical guide for policymakers, industry leaders, and practitioners navigating the complexities of digital transformation in Sri Lanka's maritime sector.

Keywords: *Digitalisation barriers, freight forwarding, import and export operations, maritime industry*

1. INTRODUCTION

1.1. Sri Lankan Maritime Industry

Sri Lanka's maritime industry is a cornerstone of its economic framework, serving as a pivotal conduit for international trade and significantly bolstering the nation's economic growth. Strategically situated along major east-west shipping routes in the Indian Ocean, Sri Lanka has leveraged its geographical advantage to enhance its maritime capabilities [1]. The Port of Colombo has emerged as one of the world's busiest transshipment hubs, facilitating the efficient movement of a diverse array of goods, including textiles, tea, and rubber, which are key exports integral to the country's economic portfolio [1]. In 2022, Sri Lanka's exports totalled approximately $13 billion, with apparel accounting for $5.6 billion. The United States has consistently been Sri Lanka's largest export market, with exports exceeding $3.3 billion in 2022 [2].

The maritime sector's contribution to employment is substantial, encompassing a wide range of activities from port operations to logistics and fisheries [2]. The Sri Lanka Ports Authority alone employs over 8,500 individuals, and when considering related entities such as customs, shipping agencies, and the broader import-export community, the sector’s role as a significant source of job creation becomes evident. Recognising the sector’s potential, initiatives such as the Colombo International Maritime Conference have set ambitious targets to elevate the maritime economy’s contribution to 6% of the national GDP by 2030 [3].

However, the industry faces several challenges, including the need for technological integration and infrastructure modernisation to maintain competitiveness in the global maritime arena. Addressing these challenges is crucial for sustaining and enhancing the maritime industry's role in Sri Lanka’s economic growth.

1.2. Current State of Digitalisation of the Sri Lankan Maritime Industry

The current state of digitalisation in Sri Lanka’s maritime industry reflects both significant progress and considerable challenges [4]. While there is increasing recognition of the importance of digital technologies, the overall level of digitalisation remains relatively low compared to other industries and maritime sectors globally [4]. Traditional processes, characterised by manual documentation and fragmented systems, continue to dominate the industry's operations. Despite some positive steps towards digital integration, the adoption of advanced digital technologies such as automation, blockchain, and artificial intelligence remains limited [5]. This digital gap is largely driven by various barriers, including outdated infrastructure, a lack of standardised systems, and a shortage of skilled workforce [5].

The Sri Lankan maritime industry has made progress towards digitalisation, particularly in the port sector. For example, the Sri Lanka Ports Authority (SLPA) has taken steps to upgrade port facilities and implement digital platforms, such as the Port Community System (PCS), which facilitates data sharing among port stakeholders. This system has improved operational efficiency by streamlining communication between customs, shipping agencies, and terminal operators [5]. Additionally, Sri Lanka's South Asia Gateway Terminals (SAGT) partnered with TradeLens, a blockchain-based platform, to digitise key processes, enhance supply chain transparency, and reduce administrative costs [5]. However, despite these advancements, the level of digitalisation remains fragmented, with many industry players still relying on paper-based systems and manual interventions, particularly in customs procedures, freight forwarding and other ancillary services [6].

The reluctance to fully embrace digital technologies in the maritime industry is partly attributed to high implementation costs, resistance to change among industry players, and a lack of understanding of the potential benefits of digitalisation [4]. Moreover, the absence of a cohesive digital transformation strategy and inadequate regulatory frameworks to support digital innovation have contributed to the slow pace of adoption [6]. Although large stakeholders, such as port authorities and major shipping companies, have begun integrating digital tools into their operations, small and medium-sized enterprises (SMEs) in the maritime sector face greater challenges owing to limited resources and technical expertise [5].

Furthermore, cybersecurity remains a significant concern for the industry, with stakeholders hesitant to adopt digital solutions because of the risk of cyber threats. This concern further hinders the speed of digital transformation, as companies fear the exposure of sensitive data and the operational risks associated with technology adoption [6]. The need for a standardised and interoperable digital infrastructure is critical for overcoming these challenges. In particular, there is a call for greater coordination among stakeholders, including government agencies, port authorities, and private sector actors, to develop and implement a unified digital framework that addresses both technical and regulatory challenges [5].

In conclusion, although there are isolated instances of digital adoption in the Sri Lankan maritime sector, the overall level of digitalisation remains limited and fragmented [6]. Key challenges, such as outdated infrastructure, lack of standardisation, high implementation costs, and cybersecurity concerns, impede the industry's ability to fully embrace digital transformation. A more concerted effort involving both public and private sector collaboration is needed to address these barriers and create a digital ecosystem that can enhance the competitiveness of Sri Lanka's maritime industry in the global market [5].

1.3. Problem Statement and Objectives of the Study

Although the Sri Lankan maritime industry is crucial to the nation's economy, it continues to face significant challenges owing to its reliance on outdated, paper-based processes [4]. This dependency severely limits the industry's ability to compete effectively in an increasingly digitalised global marketplace. While the global maritime sector has embraced digital technologies to streamline operations, Sri Lanka's maritime industry remains hindered by its limited adoption of such innovations. This lack of digitalisation contributes to inefficiencies, increased operational costs, and failure to meet international digital standards, ultimately compromising the industry's competitiveness [5]. To address these issues, it is crucial to identify and understand the barriers to digitalisation. This will allow the development of targeted strategies aimed at overcoming these barriers, ensuring that the maritime industry can enhance its operational efficiency and align with global digital standards, thus improving its overall competitiveness [6].

The primary aim of this study is to explore and enhance digitalisation efforts within Sri Lanka's maritime industry. To achieve this, this study was guided by the following specific objectives:

- **RO1:** Identify the barriers affecting digitalisation in the maritime industry in Sri Lanka.
- **RO2:** To identify the current and potential levels of digitalisation of focused areas within import, export, and freight forwarding operations in the Sri Lankan maritime industry.
- **RO3:** Develop a framework with highly related barriers affecting digitalisation.
- **RO4:** To provide recommendations for enhancing the digitalisation of the maritime industry in Sri Lanka.

By achieving these objectives, this study provides a comprehensive roadmap for advancing digital transformation within Sri Lanka's maritime industry, contributing to its growth and global competitiveness.

2. LITERATURE REVIEW

2.1. The Role of the Maritime Industry in Sri Lanka

Sri Lanka's maritime industry is a vital pillar of the national economy, capitalising on the country's strategic location along key east–west shipping routes in the Indian Ocean [1]. Positioned at the centre of major sea lanes, Sri Lanka enables efficient regional and global connectivity, offering low deviation times for vessels and easy access to major ports in the Indian subcontinent, particularly India [2], [7], [8], [9].

These geographic advantages make the island an attractive hub for transshipment and trade [10], [11].

The Port of Colombo plays a central role, handling approximately 70% of transshipment cargo, supported by the export of key commodities such as tea, garments, and rubber-based products [13],[14]. To further enhance competitiveness, Sri Lanka has launched infrastructure projects such as the Maritime Facilitation Centre (Rs. 6,200 million) and the New Workshop Building Complex (Rs. 1,090 million), aimed at expanding processing capacity, reducing congestion, and improving turnaround times [14].

Key terminals, such as the Jaya Container Terminal (JCT) and Colombo East Container Terminal (CECT), are equipped with modern facilities and contribute to the country's rising transshipment volumes [15]. Beyond cargo handling, the maritime sector supports employment in logistics, fisheries and boat manufacturing. The marine sector employs over 115,000 people directly and an additional 100,000 indirectly, with boat manufacturing alone generating more than $200 million in export income from 2019 to 2023 [16].

Recognising its economic potential, Sri Lanka aims to increase the maritime sector's contribution to GDP through infrastructure development, technology integration, and expanded services, thereby strengthening its role in global maritime trade [17].

2.2. Level of Digitalisation of the Sri Lankan Maritime Industry

The global maritime industry has increasingly embraced digital technologies to enhance operational efficiency, reduce costs, and improve service quality [15]. In contrast, Sri Lanka's digital transformation in the maritime sector has progressed more slowly, constrained by outdated systems, inefficiencies, and a continued reliance on manual processes [11]. Although several digital frameworks, such as ASYCUDA and Electronic Data Interchange (EDI), have been introduced, the full transition to digital operations remains incomplete [12].

Sri Lanka's digitalisation journey began in the early 1990s with the introduction of ASYCUDA, followed by EDI adoption in 2002 to streamline customs clearance and reduce manual documentation [18]. Despite these efforts, adoption has been inconsistent across institutions. For example, as of 2009, approximately 81% of customs declarations (CUSDECs) were still processed manually, highlighting resistance and limitations in institutional readiness [18]. These challenges reflect deeper systemic issues, including uneven digital capabilities among key stakeholders and fragmented implementation approaches.

The slow and uneven pace of digital adoption can be attributed to the lack of full integration among port authorities, customs, and shipping agencies. While some entities have adopted digital tools, others continue to depend on paper-based systems, undermining the benefits of automation and reducing process efficiency [19], [22]. This disjointed implementation has hindered seamless trade facilitation and limited the impact of valuable digital investments.

Recently, Sri Lanka has taken significant steps to enhance maritime digitalisation. The introduction of ASYHUB in 2024, a cloud-native platform designed to connect customs and cross-border regulatory authorities, marks a milestone in the country's efforts to modernise trade processes [20]. ASYHUB enables end-to-end visibility, enhanced risk management, and improved operational efficiency in the logistics process. Complementing this, the launch of the Single Window Portal by Sri Lanka Customs allows traders to submit and track documents online, facilitating paperless processing and reducing delays [20]. These platforms reflect the growing institutional awareness of the need to transition to fully integrated digital systems.

Nevertheless, studies continue to identify persistent challenges, including poor inter-agency collaboration, limited technological infrastructure, and low stakeholder readiness [21], [22]. For example, many smaller logistics firms lack access to adequate digital tools and training, contributing to sector-wide disparities in digital maturity. Furthermore, cybersecurity concerns and resistance to change remain ongoing issues that restrict broader adoption [21].

Emerging technologies such as blockchain offer promising solutions. For instance, the South Asia Gateway Terminals (SAGT) partnered with the TradeLens platform to digitalise supply chain operations, enabling real-time tracking and document sharing [23]. The use of blockchain enhances transparency and operational speed while reducing paperwork and fraud risks. However, such initiatives remain isolated, and their broader implementation across the industry is still lacking.

Despite these advancements, Sri Lanka's maritime digitalisation efforts continue to face structural and operational constraints. The absence of a unified digital transformation strategy, unequal progress among stakeholders, and outdated regulatory frameworks limit the sector's ability to fully modernise. Although initiatives such as ASYHUB, Port Community Systems (PCS), and Single Window Portals signal progress, they require stronger policy backing, infrastructure investment, and coordinated action among public and private actors to deliver their full potential.

In conclusion, although Sri Lanka's maritime industry has made meaningful strides in adopting digital tools, significant barriers persist, particularly in terms of

integration, stakeholder collaboration, and system readiness. To fully realise the benefits of digitalisation, Sri Lanka must continue to invest in digital infrastructure, close institutional gaps, and promote a shared vision of transformation. Strengthening the local research base and developing context-specific solutions are crucial for guiding national policy and ensuring that digitalisation efforts are both inclusive and sustainable.

2.3. Barriers Affecting the Digitalisation of the Maritime Industry

The maritime industry, which plays a crucial role in global trade and transportation, has witnessed an increasing shift towards digitalisation in recent years. This transition is essential for improving operational efficiency, safety, and sustainability of the sector. However, despite their significant potential benefits, the adoption of digital technologies in the maritime sector faces various challenges.

The maritime industry, a key component of global trade and transportation, is gradually shifting towards digitalisation to enhance efficiency, safety, and sustainability. However, despite these clear benefits, the adoption of digital technologies in the sector continues to face a range of significant barriers.

A major organisational challenge is the lack of risk-based thinking, which limits proactive decision-making and hampers the effective integration of digital strategies [24], [25]. This is often accompanied by the absence of a clear vision for digitalisation, making it difficult to align stakeholders and ensure focused efforts, which can result in fragmented initiatives and poor resource allocation [26]. Many maritime organisations experience partial or piecemeal digital transformation, where only select departments or processes adopt digital tools, leading to inefficiencies and missed opportunities for broader improvements [27]. This situation is compounded by traditional organisational cultures that resist change and innovation, which further hinders the successful implementation of new technologies [28].

Inefficiencies also arise due to hierarchical decision-making structures and cumbersome approval processes that slow the implementation of digital initiatives [29]. Furthermore, limited collaboration across departments can lead to siloed operations, obstructing the flow of critical information necessary for effective digital transformation [30]. Operationally, the involvement of multiple stakeholders in decision-making often causes delays, especially when their priorities and expectations differ [31], [32]. Although essential, regulatory frameworks can sometimes be overly restrictive, reducing the flexibility required to adopt emerging technologies [33]. The lack of standardisation in data formats and processes across organisations creates integration challenges that hinder smooth collaboration and digital tool adoption [34].

Data-related concerns are also a key operational issue. Organisations are often reluctant to share sensitive process-related information, and low data transparency between departments makes it difficult to coordinate efforts effectively [35]. In terms of resources, financial constraints pose a considerable barrier, limiting investment in digital infrastructure, advanced technologies, and employee training [35]. A shortage of skilled personnel, both at the managerial and operational levels, further restricts the ability to lead, implement, and manage digital projects [33], [34], [36]. Many employees lack the necessary technical knowledge, and organisations frequently underinvest in building digital competencies [33], [35].

From a market perspective, slow adoption rates among industry partners and the persistence of conventional practices create friction that delays collective progress [24], [30], [34], [36]. Concerns over cybersecurity and data breaches also make stakeholders hesitant to embrace digital platforms or openly share data [32], [33]. The burden of complying with multiple regulatory requirements adds complexity to digitalisation efforts [32]. In some areas of the industry, particularly traditional shipping, the lack of customer demand for digital services reduces companies' incentive to invest in digital transformation [33].

Technological challenges are equally significant in this regard. A lack of strong information security measures makes organisations vulnerable to cyber threats, creating a barrier to the adoption of digital systems [34]. Internal systems are often outdated and poorly integrated, and external collaboration is hindered by limited interoperability with stakeholders' ICT systems, such as those used by port operators and customs authorities [32], [33], [35]. Many organisations also lack sufficient IT infrastructure and have underdeveloped IT departments, making it difficult to support ongoing digital initiatives [34], [36]. Additionally, the limited capacity to upgrade existing technology restricts their ability to keep pace with rapid digital advancements [35], [36].

2.4. Research Gap

The digitalisation of Sri Lanka's maritime industry remains underexplored, with limited research addressing specific barriers. Most existing studies focus primarily on qualitative or quantitative approaches in isolation, leading to fragmented insights into the barriers and opportunities for digital adoption in healthcare. A significant gap exists in identifying the most prominent barriers that hinder the industry's progress, as there is little comprehensive research that thoroughly examines these challenges in depth. Additionally, the lack of up-to-date data on the current level of digitalisation among key stakeholders, such as ports, shipping companies, and government agencies, complicates efforts to assess progress and formulate targeted strategies.

Furthermore, the absence of structured frameworks for digital transformation leaves stakeholders without clear guidelines for evaluating, prioritising, and implementing new technologies in the construction industry. Addressing these gaps is essential for developing a more strategic, data-driven approach to modernisation, which would ultimately enhance efficiency, productivity, and competitiveness in the maritime industry.

3. METHODOLOGY

3.1. Research Design

The research process for identifying the barriers affecting digitalisation in the Sri Lankan maritime industry follows a structured approach to ensure a comprehensive analysis and actionable outcomes. It begins with a systematic literature review to understand the current knowledge of digitalisation and identify key barriers. The identified barriers were then categorised using thematic analysis into five groups: organisational and management-related, technological, operational, resource-related, and market-related. These barriers were incorporated into a conceptual framework, and hypotheses were developed to test their influence on the level of digitalisation, which served as the dependent variable in the study.

To contextualise the framework and understand practical processes, expert interviews were conducted to map key operations within the import, export, and freight forwarding functions. Based on these insights, a single structured questionnaire was developed, comprising two parts. The first part was designed to evaluate the influence of the identified barriers on digitalisation using a Likert scale suitable for PLS-SEM analysis. The second part aimed to assess the current and potential levels of digitalisation in key operational processes using ordinal data from the survey.

Primary data were collected from 148 maritime industry professionals, including freight forwarders, shipping agents, and port authority personnel, using the snowball sampling method. This approach allowed the researchers to access a specialised and industry-informed population through professional referrals. The collected data were analysed using PLS-SEM to validate the conceptual model and test the hypotheses, while ordinal data analysis was applied to evaluate the levels of digitalisation across key maritime functions. Figure 1 presents an overview of the research design used in this study.

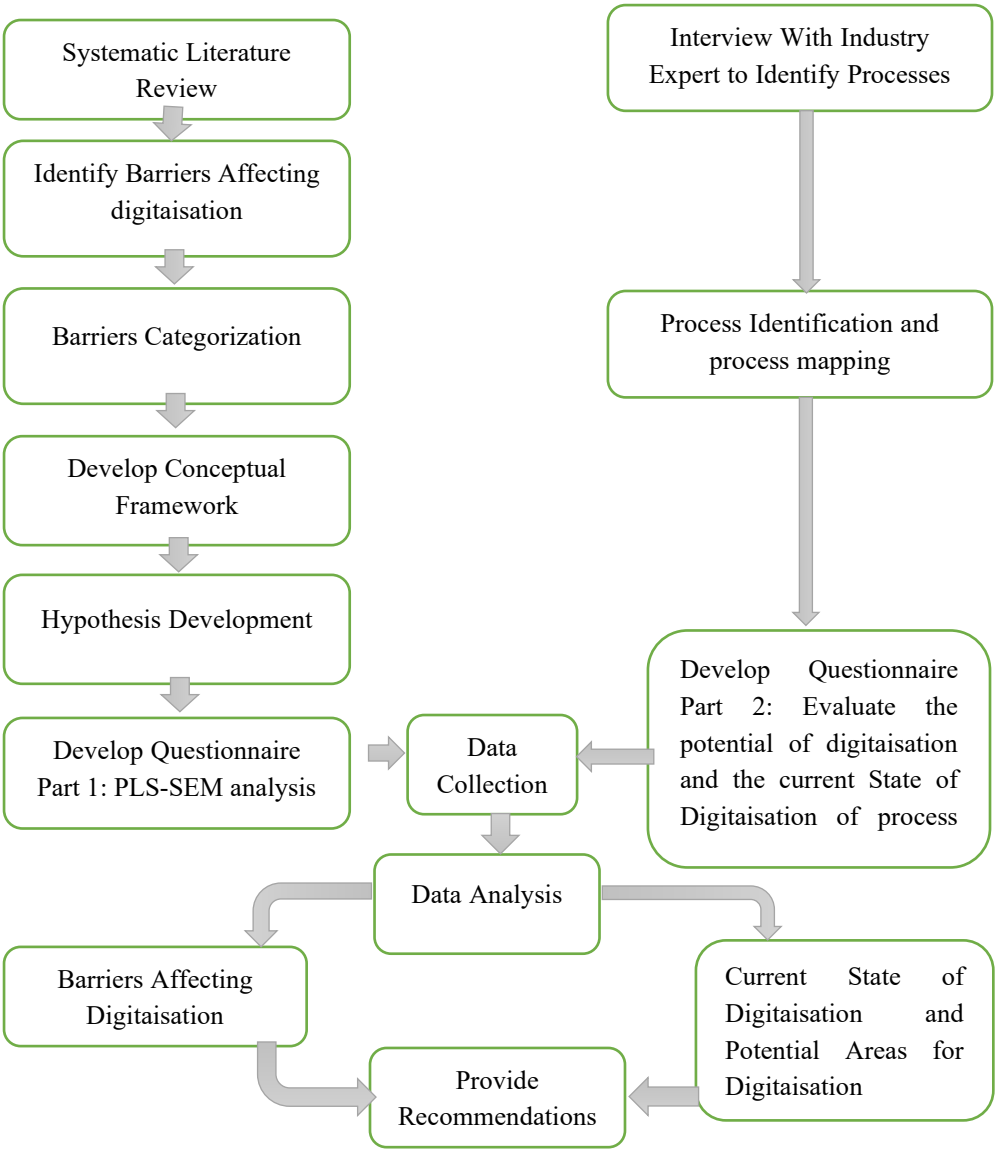

Figure 1: Research design

3.2. Conceptual Framework

Figure 2 presents the conceptual framework for this study, developed through a systematic literature review and expert validation, to analyse the barriers that may impact the level of digitalisation in Sri Lanka's maritime industry. This framework is based on globally recognised barriers identified in existing research, which were examined in the Sri Lankan maritime context to assess their relevance and influence.

The framework incorporates five key independent variables: organisational and management barriers, operational barriers, resource-related barriers, market-related barriers, and technological barriers. These barriers have been widely discussed in the literature as critical challenges affecting digitisation across industries, including the maritime sector worldwide. To ensure their applicability to Sri Lanka, these barriers were systematically reviewed and validated by industry experts, forming the basis for this study. The dependent variable in this study is the level of digitalisation in Sri Lanka's maritime operations. It was measured using responses to multiple Likert-scale items in the first section of the structured questionnaire. These items assessed respondents' perceptions of digital adoption across various operational areas, capturing the extent to which digital technologies have been implemented in their organisations. The responses were then aggregated to form a composite construct representing the digitalisation level, which was used in the PLS-SEM analysis. Figure 2 presents the conceptual framework of this study.

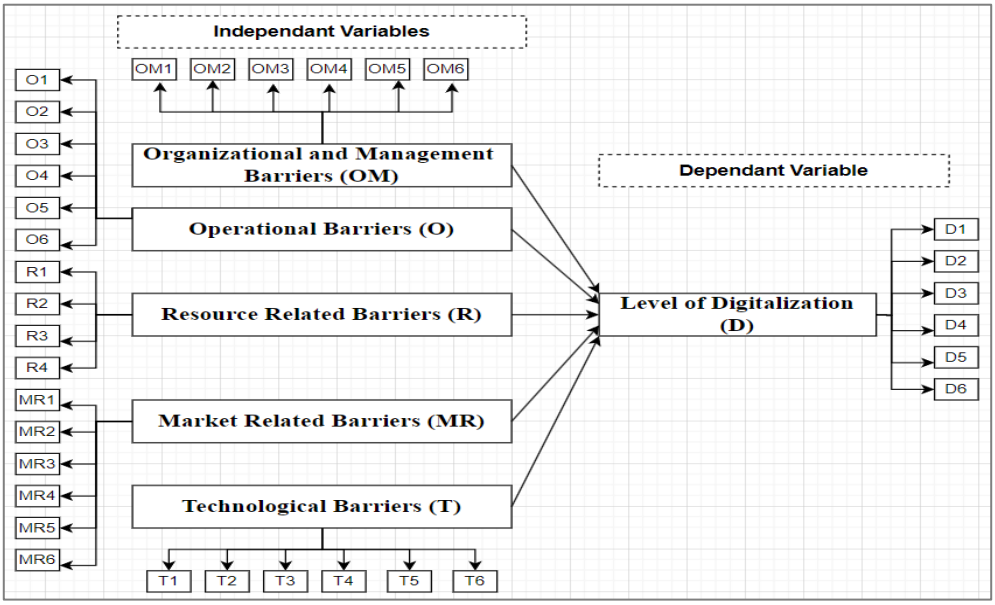

Figure 2: Conceptual framework

3.3. Hypothesis Development

Building upon the conceptual framework developed for this study, five hypotheses were established to explore the barriers influencing the level of digitalisation in Sri Lanka's maritime industry. The hypotheses are formulated as follows:

- H1: Organisational and management barriers significantly impact the level of digitalisation in Sri Lanka's maritime industry.

- H2: Operational barriers significantly impact the level of digitalisation in Sri Lanka's maritime industry.
- H3: Resource-related barriers significantly impact the level of digitalisation in Sri Lanka's maritime industry.
- H4: Market-related barriers significantly impact the level of digitalisation in Sri Lanka's maritime industry.
- H5: Technological barriers significantly impact the level of digitalisation in Sri Lanka's maritime industry.

3.4. PLS-SEM Method

This study employed PLS-SEM as the primary statistical technique for data analysis. PLS-SEM is widely recognised for its ability to examine complex causal relationships among latent constructs, making it particularly suitable for exploratory research [51]. This method is especially advantageous in cases where data distributions are non-normal or when sample sizes are relatively small, as it does not require strict parametric assumptions [51]. Given the nature of this study, which seeks to analyse multiple interrelated barriers affecting digitalisation in Sri Lanka's maritime industry, PLS-SEM was chosen for its ability to handle high-dimensional data while providing meaningful insights [51]. To ensure accuracy and reliability, each latent variable in the model was assessed using several indicators. These indicators were carefully derived from a systematic review of the literature, ensuring that the constructs were well-grounded in existing research.

The measurement model followed a reflective approach, meaning that the observed variables were considered to be manifestations of their respective latent constructs. This approach aligns with the best practices in PLS-SEM, ensuring that the indicators collectively represent the underlying barriers to digitalisation.

Furthermore, this study adhered to rigorous validation procedures to confirm the reliability and validity of the measurement model. Convergent and discriminant validity tests were conducted to verify that each construct accurately measured its intended concept while maintaining its distinctiveness from other constructs in the model. The assessment of indicator reliability, composite reliability, and average variance extracted (AVE) further reinforced the robustness of these findings.

Table 1 provides a comprehensive summary of how each variable was operationalised, including the specific indicators used for measurement. This structured approach ensures that the study's findings are both statistically sound and practically relevant for understanding the barriers to digitalisation in Sri Lanka's maritime industry.

Table 1: Operationalisation table

Barrier	Notation	Indicator	Statement	Resources
Organizational and Management Barriers (OM)	OM1	Lack of risk-based thinking.	Our organisation lacks active incorporation of risk-based thinking in strategic decisions.	[24], [25], [26]
	OM2	Lack of clear vision.	Our organisation lacks a clear, strategic vision.	[24], [26], [27]
	OM3	Limited digital transformation impact.	There's limited awareness of how technology can benefit our operations.	[24], [27], [29]
	OM4	Nature of organisational culture.	Our organisation's culture finds it difficult to adopt new initiatives.	[24], [28], [30]
	OM5	Less effective decision-making hierarchy.	The decision-making structure in our organisation lacks effectiveness.	[24], [29], [30]
	OM6	Lack of Inter-departmental collaboration.	Our organisation lacks strong collaboration and communication between departments.	[24], [30], [31]
Operational Barriers (O)	O1	Lengthier approval procedures.	Our approval processes are time-consuming and involve many stages.	[24], [31], [34]
	O2	High Number of parties involved in decision-making.	Decision-making in our organisation involves input from multiple parties.	[32], [33], [34]
	O3	Strict rules and regulations related to the process.	We follow strict rules and regulations in operations.	[24], [33], [34]
	O4	Lack of standardisation.	We lack consistent, standardised processes across departments.	[34], [31], [36]
	O5	Confidentiality of process-related information.	Most of our process-related information is very confidential.	[24], [32], [35]

Barrier	Notation	Indicator	Statement	Resources
	O6	Lack of data transparency in the departments.	We experience a lack of data sharing across the departments, leading to a lack of transparency.	[24], [35], [36]
Resource Related Barriers (R)	R1	Insufficient Financial resources for investments.	We lack sufficient financial resources for investments.	[24], [35], [36]
	R2	Insufficient Investment in employee knowledge.	There is insufficient investment in employee knowledge development.	[24], [30], [35]
	R3	Lack of technology-related skills among managers.	Our managers lack the skills needed to support initiatives.	[24], [33], [36]
	R4	Technology-related skills of employees.	Lack of technology-related skills among employees	[24], [34], [36]
Market-Related Barriers	MR1	MR1 - Conventional practices of the partners.	Within a short period of time, we can sell our inventory.	[24], [30]
	MR2	MR2 - Technology adoption rates of the partners.	We convert the inventory to sales more frequently in our organisation.	[24], [34], [36]
	MR3	MR3 - Data security concerns of the industry.	Compared to the average inventory value, we have a reasonable sales value in our organisation.	[24], [32], [33]
	MR4	MR4 - Regulatory compliance pressures.	We have a reasonable inventory holding cost per unit in our organisation.	[24], [33], [35]
	MR5	MR5 – Less Customer expectations on digital solutions.	The product damage cost per unit is bearable in our organisation.	[24], [30], [33]
	MR6	MR6 - Data transparency of the industry.	The ordering cost per unit in our organisation is reasonable.	[24], [33], [34]
Technological Barriers (T)	T1	T1 – Lack of Information security measures.	We lack active measures to enhance information security.	[24], [34], [35]

Barrier	Notation	Indicator	Statement	Resources
	T2	T2 – Lack of System interconnectivity within organisation.	Our internal systems are not well integrated.	[24], [32], [36]
	T3	T3 - Lack of Integration with external stakeholders' ICT systems.	External stakeholders are not well integrated with our systems.	[24], [33], [35]
	T4	T4 - Insufficient IT infrastructure.	We lack sufficient IT infrastructure and resources for ongoing initiatives.	[24], [34], [36]
	T5	T5 - Not having and not expanding IT department.	We don't have a dedicated IT department and aren't expanding it as needed.	[24], [33]
	T6	T6 - Limited technology upgrade potential.	We have limited potential to upgrade current technologies.	[24], [35], [36]

3.5. Data Collection

This study employed a combination of structured surveys and semi-structured interviews to investigate the barriers to digital transformation in Sri Lanka's maritime industry. The survey component utilised a Likert scale to collect quantitative data from 148 respondents, exceeding the minimum required sample size of 130, as determined based on Cohen's statistical power guidelines (1992) for studies involving six variables, with a significance level of 0.05, statistical power of 0.80, and medium effect size, as referenced in [37]. This ensured the statistical adequacy of the analysis. In addition to the survey, semi-structured interviews were conducted with industry professionals, including freight forwarders and shipping agents, to gain qualitative insights into key operational areas such as import, export, and freight-forwarding processes. These interviews provided a deeper understanding of the practical challenges faced by maritime stakeholders in adopting digital solutions in the industry.

By integrating both quantitative and qualitative research methods, this mixed-methods approach facilitated a comprehensive examination of the research problems. The combination of statistical data from surveys and in-depth perspectives from interviews allowed for a comprehensive analysis, ensuring that both measurable trends and contextual industry experiences were considered in evaluating the barriers to digitalisation.

4. ANALYSIS AND FINDINGS

A preliminary analysis was conducted to ensure the quality and reliability of the data. This process involved data screening, in which incomplete responses were eliminated using mandatory fields. Additionally, suspicious response patterns were identified and removed to ensure data integrity. Statistical outlier detection was performed to exclude any extreme values that could distort the analysis, and distribution assessment was performed using histograms and evaluation of skewness and kurtosis values to confirm data normality.

Of the initial 148 responses collected, 142 met the validity criteria and were deemed suitable for further analysis. This rigorous data validation process ensured that the findings of this study were based on accurate and high-quality data.

4.1. Demographic Analysis

The demographic analysis of the respondents indicates that a significant proportion of companies fall within the small-to-medium-sized category, with 36.5% employing between 25 and 50 staff members. Additionally, 35.8% of these companies are well established, having been in operation for over a decade. In terms of respondent profiles, most respondents held managerial positions (37.8%) or worked as junior executives (36.5%). Regarding industry experience, 35.1% of respondents had been in the maritime sector for less than five years, while 31.8% possessed between five and ten years of experience.

4.2. PLS-SEM Analysis

PLS-SEM analysis comprises two main components: the structural model, which illustrates the relationships between latent variables, and the measurement model, which establishes the links between the latent variables and their corresponding indicators.

4.2.1. Assessing the Measurement Model

In PLS-SEM, a conceptual model can be interpreted in terms of measurement and structural models. In the measurement model, latent variables are measured based on the indicators attached to them, and the structural model measures all dependencies based on path analysis [38].

Assessment of the measurement model includes 3 steps as:

i. Measuring internal consistency and validity
ii. Measuring the convergent validity
iii. Measuring discriminant validity

Measuring Internal Consistency Reliability

Internal consistency and reliability were assessed to ensure consistent results across all items within a test. This involves determining how closely a respondent's observed score aligns with their true score when measured using a flawless instrument. In practice, two widely used methods to evaluate internal consistency within a measurement model are

i. Cronbach's alpha
ii. Composite reliability.

In this study, a reliability analysis was conducted using SmartPLS software. Cronbach's alpha and composite reliability (CR) values were used to assess the internal consistency. All constructs recorded Cronbach's alpha and CR values exceeding 0.7, indicating acceptable reliability and internal consistency of the measurement model. These results confirm that the selected indicators effectively represent the constructs. Table 2 presents a summary of these reliability values.

Table 2: Cronbach's alpha and composite reliability values

Construct	Cronbach's Alpha	Composite Reliability
Organisational and Management Barriers (OM)	0.922	0.925
Operational Barriers (O)	0.876	0.912
Resource Related Barriers (R)	0.914	0.927
Market Related Barriers (MR)	0.840	0.847
Technological Barriers (T)	0.904	0.910
Level of Digitalisation (D)	0.780	0.937

Measuring Convergent Validity

Convergent validity refers to the extent to which a measurement item positively correlates with other items within the construct. To evaluate the convergent validity of reflective constructs, two key measures can be used: outer loadings of indicators (which assess indicator reliability) and average variance extracted (AVE). These measures help to determine whether the indicators effectively represent the underlying construct.

1. Outer Loadings

The outer loadings for each reflective indicator were evaluated to ensure the reliability and validity of the measurement model. Indicators with loadings below

0.40 were considered for removal; however, none met this criterion. For indicators with loadings between 0.40 and 0.70, their impact on internal consistency was assessed. If removing an indicator improved the reliability metrics, it was excluded; otherwise, it was retained. Based on this assessment, indicators D2, MR4, MR6, O5, R3, and T5 were removed from the model. Indicators with loadings above 0.70 were retained, as they demonstrated strong reliability and theoretical alignment with their constructs. Table 3 shows the initial and revised outer loadings of the indicators.

Table 3: Outer loadings of the data set

	Initial Values						Revised Values					
	D	**MR**	**O**	**OM**	**R**	**T**	**D**	**MR**	**O**	**OM**	**R**	**T**
D1	0.752						0.749					
D2	0.636											
D3	0.923						0.930					
D4	0.926						0.932					
D5	0.897						0.912					
D6	0.884						0.878					
MR1		0.835						0.854				
MR2		0.876						0.889				
MR3		0.716						0.719				
MR4		0.566										
MR5		0.814						0.818				
MR6		0.443										
O1			0.801						0.799			
O2			0.832						0.834			
O3			0.765						0.753			
O4			0.834						0.842			
O5			0.679									
O6			0.817						0.836			
OM1				0.809						0.808		
OM2				0.901						0.902		
OM3				0.833						0.832		
OM4				0.844						0.844		
OM5				0.864						0.865		
OM6				0.899						0.900		

	Initial Values						Revised Values					
	D	MR	O	OM	R	T	D	MR	O	OM	R	T
R1					0.832						0.835	
R2					0.964						0.975	
R3					0.540							
R4					0.950						0.960	
T1						0.897						0.900
T2						0.892						0.902
T3						0.844						0.864
T4						0.794						0.809
T5						0.645						
T6						0.779						0.759

2. Average Variance Extracted (AVE)

Another way to assess convergent validity is to examine the values of AVE, which is a commonly used measure in research. AVE measures the extent to which the average variance of the items is accounted for by a variable. According to Fornell and Larcker (1981), AVE values of 0.5 or higher are indicative of greater convergent validity of the indicators of the constructs. The AVE values for this model are given in table below. As shown in Table 4, the constructs exhibit AVE values greater than or around 0.5, indicating that the constructs have met convergent validity.

Table 4: AVE values

Construct	AVE Value
Organisational and Management (OM)	0.738
Operational (O)	0.622
Resource Related (R)	0.856
Market-Related (MR)	0.677
Technology Related (T)	0.720
Digitalisation Level (D)	0.780

Measuring Discriminant Validity

Discriminant validity refers to the degree to which a construct is distinct from other constructs in the model, based on empirical standards. When constructs in a model demonstrate discriminant validity, it means that they are unique with respect to one another and are not merely reflections of one another. Three different methods have

been used in previous studies to test the discriminant validity of constructs, and this study has utilised all three: cross loadings, Fornell-Larcker criterion (Fornell & Larcker, 1981), and Heterotrait Monotrait Ratio of Correlations (HTMT). In the cross-loading method, each measuring item's loading should be higher than all of its cross-loadings to establish discriminant validity (Chin, 1998). In all models examined in this study, the indicators' loadings were higher than their corresponding cross-loadings.

1. Cross Loading

In the cross-loading method, each measuring item's loading should be higher than all of its cross-loadings to establish discriminant validity [39]. In the model examined in this study, the loadings of the indicators were higher than their corresponding cross-loadings. The values are listed in Table 5.

Table 5: Cross-loading values

	D	MR	O	OM	R	T
D1	0.749	-0.549	-0.398	-0.512	-0.528	-0.542
D3	0.930	-0.684	-0.573	-0.655	-0.649	-0.755
D4	0.932	-0.693	-0.609	-0.643	-0.666	-0.731
D5	0.912	-0.677	-0.603	-0.612	-0.649	-0.707
D6	0.878	-0.704	-0.592	-0.661	-0.583	-0.699
MR1	-0.618	0.854	0.647	0.540	0.520	0.609
MR2	-0.717	0.889	0.684	0.729	0.652	0.728
MR3	-0.479	0.719	0.563	0.407	0.460	0.547
MR5	-0.630	0.818	0.663	0.650	0.626	0.714
O1	-0.352	0.528	0.799	0.399	0.414	0.449
O2	-0.454	0.586	0.834	0.466	0.482	0.539
O3	-0.372	0.496	0.753	0.334	0.369	0.424
O4	-0.679	0.751	0.842	0.720	0.613	0.760
O6	-0.580	0.706	0.836	0.582	0.600	0.643
OM1	-0.490	0.496	0.436	0.808	0.538	0.578
OM2	-0.630	0.618	0.569	0.902	0.709	0.760
OM3	-0.568	0.661	0.576	0.832	0.603	0.700
OM4	-0.608	0.604	0.613	0.832	0.657	0.737
OM5	-0.626	0.610	0.545	0.865	0.717	0.739
OM6	-0.669	0.709	0.606	0.900	0.709	0.760
R1	-0.572	0.628	0.605	0.726	0.835	0.768

	D	MR	O	OM	R	T
R2	-0.687	0.663	0.588	0.722	0.975	0.785
R4	-0.674	0.636	0.575	0.691	0.960	0.757
T1	-0.711	0.742	0.702	0.822	0.781	0.900
T2	-0.746	0.735	0.643	0.715	0.765	0.902
T3	-0.639	0.671	0.635	0.635	0.693	0.864
T4	-0.623	0.677	0.640	0.760	0.680	0.809
T6	-0.586	0.531	0.443	0.594	0.585	0.759

2. Fornell-Larcker Criterion

The Fornell-Larcker criterion involves comparing the AVE of each construct with the shared variance between the variable and all other variables in the model. Discriminant validity is established if a variable's AVE value is higher than its shared variance with all other variables. The results of the Fornell-Larcker criterion for the model in this study are presented in the tables below. The results in Table 6 indicate that the model demonstrated discriminant validity for all variables, which supports the findings from the cross-loadings.

Table 6: Fornell-Larcker criterion

	D	MR	O	OM	R	T
Digitalisation Level (D)	0.883					
Market-Related (MR)	-0.752	0.823				
Operational (O)	-0.634	0.779	0.813			
Organisational and Management (OM)	-0.701	0.721	0.653	0.859		
Resource Related (R)	-0.699	0.693	0.634	0.768	0.925	
Technology Related (T)	-0.783	0.795	0.726	0.833	0.830	0.849

3. Hetorotrait - Monotrait Ration (HTMT)

The Heterotrait-Monotrait (HTMT) method is a third approach for assessing the discriminant validity of constructs and was introduced by [37]. The key principle of this test is to determine whether the HTMT ratio approaches 1.0. This ratio is calculated by dividing the average correlation between the different constructs by the geometric mean of the average correlations within the indicators of the same construct. If the HTMT ratio is close to or exceeds 1.0, it suggests that discriminant validity has been compromised. In this study, all HTMT values were below 1.0, as shown in Table 7. Therefore, it can be concluded that the model maintains an acceptable discriminant validity.

Table 7: HTMT values

	D	MR	O	OM	R	T
Digitalisation Level (D)						
Market-Related (MR)	0.841					
Operational (O)	0.656	0.874				
Organisational and Management (OM)	0.749	0.797	0.675			
Resource Related (R)	0.757	0.787	0.682	0.834		
Technology Related (T)	0.850	0.905	0.772	0.905	0.916	

In summary, out of three criteria to measure the discriminant validity, the measurement model of this study satisfies the discriminant validity by cross loadings, Fornell – Larcker criterion, and HTMT method. Since discriminant validity was achieved by all tests to establish discriminant validity, it was concluded that the variables of the models had discriminant validity.

4.2.2. Structural Model Analysis

Structural model assessment was conducted to evaluate five hypotheses (H1–H5), which explored the relationships between the independent variables and the level of digitalisation in Sri Lanka's maritime industry. The analysis revealed that all five independent variables had a statistically significant impact on digitalisation. As presented in Table III, each hypothesis (H1–H5) was supported at a 95% confidence level, as all p-values were below the 0.05 threshold, indicating strong statistical significance [40].

Furthermore, the explanatory power of the model was assessed using the Coefficient of Determination (R^2), which was determined to be 0.664. This implies that 66.4% of the variation in the level of digitalisation within Sri Lanka's maritime sector can be attributed to the independent variables in the model. An R^2 value of this magnitude signifies a moderately strong predictive capability, suggesting that the identified barriers play a crucial role in shaping the industry's digitalisation landscape. These findings validate the proposed framework and underscore the importance of addressing these barriers to accelerate digital transformation in Sri Lanka's maritime industry. The results of the structural model are presented in Table 8.

Table 8: Structural model results

Hypothesis	Path Coefficient	T Value	P Value	Outcome
H1: Organisational and Management barriers have a significant impact on the	-0.702	10.327	0.000	Accepted

Hypothesis	Path Coefficient	T Value	P Value	Outcome
level of digitalisation in the maritime industry in Sri Lanka.				
H2: Operational barriers have a significant impact on the level of digitalisation in the maritime industry in Sri Lanka.	-0.636	11.269	0.000	Accepted
H3: Resource-related barriers have a significant impact on the level of digitalisation in the maritime industry in Sri Lanka.	-0.699	11.169	0.000	Accepted
H4: Market-related barriers have a significant impact on the level of digitalisation in the maritime industry in Sri Lanka.	-0.343	2.603	0.009	Accepted
H5: Technological barriers have a significant impact on the level of digitalisation in the maritime industry in Sri Lanka.	-0.636	2.392	0.017	Accepted

4.3. Analysis of Current and Potential Digitalisation Levels in Sri Lanka's Maritime Industry

The data analysis in this study aimed to assess both the current level of digitalisation and the potential for future digitalisation across various processes involved in import, export, and freight forwarding operations within Sri Lanka's maritime industry. These processes were initially identified through qualitative interviews with industry professionals, providing valuable insights into existing operational workflows and digitalisation barriers.

Following the qualitative phase, the identified processes were incorporated into a structured survey that was distributed to 148 maritime industry experts, including freight forwarders, shipping agents, and logistics professionals. The survey was designed to capture industry perceptions regarding the extent of digital adoption within the respective organisations. After data screening and validation, 142 responses were deemed valid for the analysis.

To quantify the level of digitalisation, respondents were asked to evaluate the current and potential future states of digitalisation for each process using a five-point Likert scale. The collected data were primarily ordinal, enabling a comparative analysis of digital adoption levels across different operational functions. By leveraging quantitative methods, this study aimed to identify critical gaps between the existing and ideal levels of digitalisation, highlighting key areas for improvement.

Figures 2, 3, and 4 provide a visual representation of the average digitalisation levels (on a scale of one to five) for the import, export, and freight forwarding processes. These figures summarise the collective responses of industry experts, offering a comprehensive overview of the current utilisation of digital technologies and the potential for further advancements in digital transformation across Sri Lanka's maritime sector.

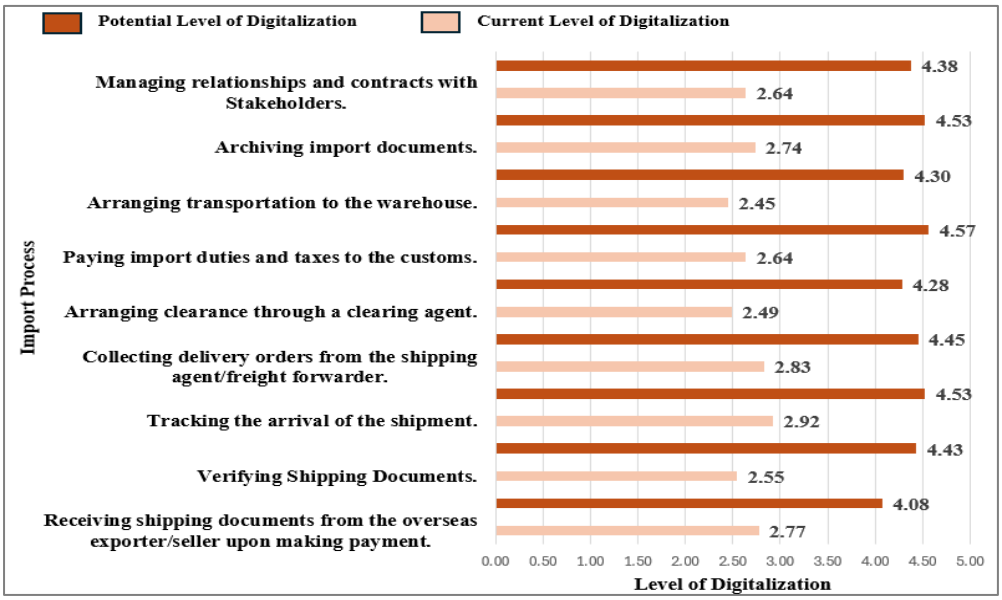

Figure 3: Import process analysis

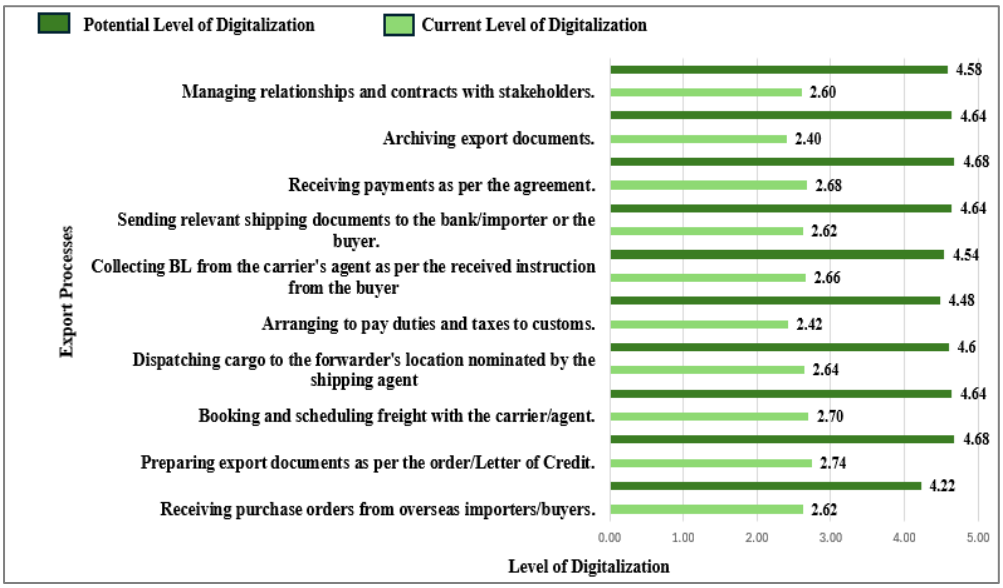

Figure 4: Export process analysis

The findings from this analysis serve as a foundation for understanding the barriers to digitalisation and formulating strategies to enhance digital adoption in the industry. Figures 2, 3, and 4 present a summary of the digitalisation levels (on a scale of five) for the import, export, and freight forwarding processes, determined by averaging the responses from all participants.

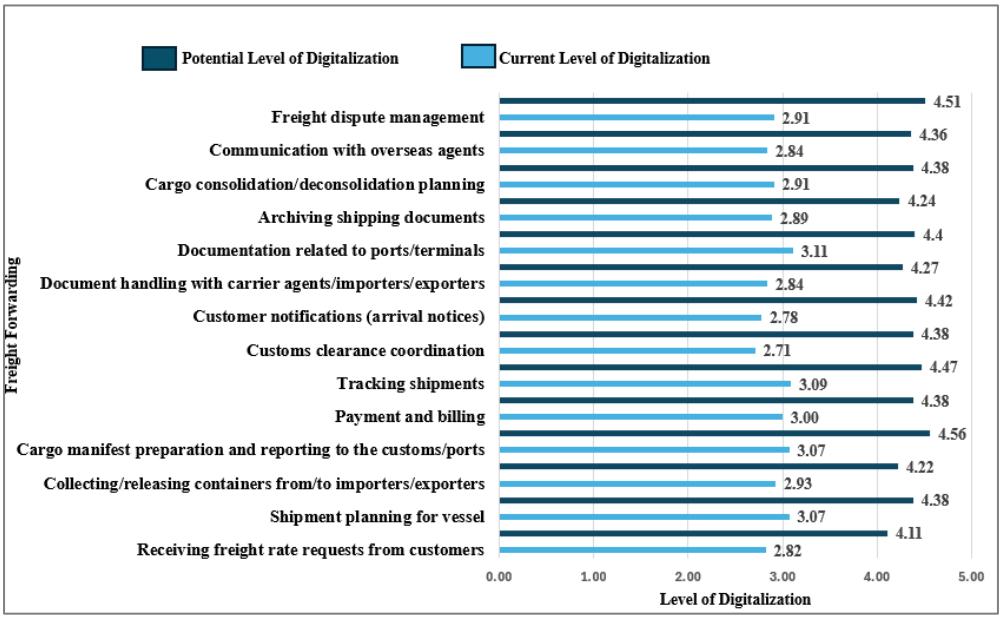

Figure 5: Freight forwarding process analysis

5. DISCUSSIONS AND IMPLICATIONS

5.1. Discussion Based on the PLS-SEM Analysis

The findings highlight several critical barriers that significantly hinder the digital transformation of Sri Lanka's maritime industry. These barriers stem from organisational inefficiencies, resource constraints, technological limitations, market-related pressures, and operational bottlenecks, all of which collectively slow the adoption of digital solutions across the sector.

Among these, organisational and management barriers exerted the most substantial negative impact, as indicated by a path coefficient of -0.702. This result underscores the importance of strategic leadership and internal alignment in enabling digital transformation. Weak leadership commitment, the absence of a clear digital vision, and limited awareness of digital benefits significantly contribute to resistance. Additionally, internal cultural resistance to change and poor cross-departmental communication intensify these challenges. Addressing these issues requires focused

leadership development, clearly defined digital strategies, and the promotion of a digital-first culture that supports innovation and adaptability.

Resource-related barriers also emerged as major constraints. Financial limitations restrict investments in digital infrastructure and tools, whereas gaps in employee and managerial skills hinder effective implementation. High technology costs and insufficient digital training contribute to the slow adoption pace. Addressing this requires targeted workforce upskilling and stronger collaboration between academia and industry to build the relevant digital competencies.

Technological barriers, including outdated IT infrastructure and limited system interoperability, pose significant obstacles to digital integration. The absence of standardised technologies and incompatible platforms hampers seamless data exchange and collaboration. Enhancing IT capabilities, adopting interoperable systems, and investing in modern infrastructure are essential to overcome these limitations.

Market-related challenges also affect digital progress. Regulatory complexity, slow partner adoption, and fragmented coordination among stakeholders create friction in transformation efforts. Many existing regulations fail to keep pace with emerging technologies, and inconsistent engagement among port authorities, government agencies, and private operators reduces the momentum. Addressing these issues requires modernised regulatory frameworks, coordinated stakeholder engagement, and active support for digitalisation initiatives at the national and industry levels.

Operational barriers, such as bureaucratic approval procedures, redundant workflows, and a lack of standardisation, further delay progress. The persistence of manual and paper-based systems limits operational efficiency and responsiveness. Implementing digital automation, enabling real-time data access, and standardising operational processes are key steps to improving performance.

Together, these findings emphasise the complex, interconnected nature of digitalisation barriers and the need for an integrated response. By strategically addressing these issues across multiple dimensions–leadership, resources, technology, regulation, and operations–Sri Lanka's maritime sector can accelerate its digital transformation and strengthen its competitiveness in the global maritime landscape.

5.2. Discussion Based on the Analysis of Current and Potential Levels of Digitalisation

Evaluating the current and potential levels of digitalisation across key maritime processes has revealed significant discrepancies that must be addressed to enhance the overall efficiency and digital maturity within the sector.

Within the import process, the payment of import duties and taxes to customs exhibits the highest level of digitalisation, with a score of 4.57, reflecting the effectiveness of established and standardised digital procedures. In contrast, arranging transportation to warehouses is the least digitised activity, scoring only 2.45. The complexity of logistics coordination, coupled with a low degree of automation, significantly hampers progress in this area. The most substantial gap in the import process is observed in managing relationships and contracts with stakeholders, where the potential digitalisation level is 4.38, while the current level remains at 2.64. This highlights the critical need for improved digital tools and integrated platforms to facilitate seamless stakeholder engagement.

For export operations, the preparation of export documents has reached the highest level of digitalisation, with a score of 4.68, owing to the standardised nature of the documentation processes and the widespread availability of digital tools. Conversely, the archiving of export documents remains the least digitalised function, with a score of only 2.40. This is primarily due to the unstructured nature of document storage and the lack of prioritisation in digitising archival records. Similar to the import process, the most significant digitalisation gap in export operations is in managing stakeholder relationships and contracts, where the potential level is 4.58, but the current level is only 2.60. Addressing this issue is crucial for enhancing operational transparency and efficiency.

In the freight forwarding domain, the payment and billing processes demonstrated the highest level of digitalisation, with a score of 4.56. This is largely attributed to the transactional nature of these operations, which have been widely digitised through standardised financial systems. In contrast, receiving freight rate requests from customers exhibited the lowest level of digitalisation, with a score of 2.82. The lack of structured communication channels and limited automation tools contribute to inefficiencies in these areas. The most pronounced gap in freight forwarding is in freight dispute management, where the potential digitalisation level is 4.51, and the current state remains at 2.91. This underscores the necessity of streamlined dispute resolution mechanisms supported by digital platforms to enhance efficiency and reduce processing delays.

These findings indicate that while some progress has been made in specific areas, substantial gaps persist in critical processes across the maritime industry. The identified discrepancies highlight the urgent need for industry stakeholders to prioritise digital transformation efforts in key areas, particularly in improving stakeholder relationship management, enhancing document archiving solutions, and optimising freight rate request handling. By addressing these barriers, Sri Lanka’s

maritime industry can significantly advance its digitalisation maturity, ensuring greater efficiency, transparency, and competitiveness on a global scale.

5.3. Implications of the Research

This study offers several important implications for research, practice, and policy in the context of digital transformation in Sri Lanka's maritime industry.

From a practical perspective, the findings provide valuable guidance for industry leaders, port authorities, and logistics firms by identifying the barriers that most critically affect digitalisation efforts. The strong negative influence of organisational and management barriers underscores the need for immediate investment in leadership development, digital change management strategies, and the establishment of a clear digital vision across maritime institutions. Furthermore, the observed gaps in digitalisation across operational processes, such as stakeholder relationship management and document archiving, point to specific functional areas where digital tools and process automation should be prioritised to improve efficiency and transparency.

For policymakers and regulatory bodies, this study highlights the need to reform outdated maritime regulations and foster a more coordinated digital agenda across government agencies and private sector actors. Addressing fragmented stakeholder involvement and regulatory bottlenecks through cohesive digital policy frameworks and inter-agency collaboration is essential for accelerating transformation at the national scale.

In terms of technological infrastructure, the study's insights stress the importance of improving IT systems, enhancing interoperability, and developing digital platforms that facilitate data sharing between internal and external maritime stakeholders. Supporting infrastructure upgrades, particularly in under-digitalised functions such as freight dispute resolution and logistics coordination, are vital for raising the sector's digital maturity.

From a social and workforce development perspective, this study highlights the pressing need to strengthen digital literacy and technical competencies among maritime employees and managers. Investment in targeted training programs and stronger academia–industry partnerships can help bridge the digital skills gap, ensuring that the workforce is equipped to support ongoing and future digital initiatives.

Finally, this study contributes to the academic literature by empirically validating a conceptual model that integrates key categories of digitalisation barriers in a developing country context. This study provides a foundation for future research to

explore the interrelationships between these barriers in greater depth and examine the long-term impact of targeted interventions. The analysis of current and potential digitalisation levels across import, export, and freight forwarding functions also offers a novel perspective for evaluating digital maturity in the maritime domain.

Overall, this study presents a clear call to action for industry, government, and academia to work collaboratively to remove structural and systemic barriers to digitalisation. By doing so, Sri Lanka's maritime sector can enhance its operational efficiency and global competitiveness and serve as a model for digital transformation in other developing maritime economies.

6. CONCLUSION

This study successfully achieved its objectives by identifying the key barriers to digitalisation and analysing the gaps between the current and potential levels of digital transformation in Sri Lanka's maritime industry. The findings confirm that organisational, resource-related, technological, market-related, and operational barriers significantly hinder digital adoption. These insights underscore the urgent need to address these barriers to enhance process automation, strengthen stakeholder collaboration, and facilitate seamless integration of advanced technologies. Additionally, the research highlights considerable gaps in digitalisation across import, export, and freight forwarding operations and offers practical recommendations for prioritising critical areas requiring improvement. Bridging these gaps will not only improve operational efficiency and transparency but also position the maritime sector to remain competitive in a rapidly evolving global digital landscape.

Beyond identifying barriers, this study provides a roadmap for industry stakeholders to strategically navigate digital transformation. By implementing targeted interventions, businesses and policymakers can develop structured frameworks that foster innovation, improve data-driven decision-making and streamline regulatory processes. Encouraging investment in digital infrastructure, workforce upskilling, and cross-sector collaboration is crucial for accelerating digital adoption. Furthermore, aligning digitalisation strategies with global best practices can enable Sri Lanka's maritime industry to enhance its resilience and adaptability in an increasingly technology-driven economy.

Despite its contributions, this study has some limitations that should be considered. The findings are specific to Sri Lanka's maritime industry, which may limit their applicability to other industries and geographical contexts. The study treated the five identified categories of barriers—organisational and management-related,

technological, operational, resource-related, and market-related—as independent constructs to maintain a clear and focused model within the PLS-SEM framework. However, the potential interdependencies among these categories may have affected the results. Future research could examine these interrelationships using advanced modelling approaches, such as second-order constructs or mediation analysis. Additionally, the sample size and demographic scope could impact the generalisability of the results across the broader sector. Moreover, external influences such as global economic trends, policy changes, cybersecurity concerns, and rapid technological advancements were not extensively explored but may significantly affect digitalisation. Future research should focus on assessing the long-term impact of digital transformation, evaluating the effectiveness of policy interventions, and exploring emerging technologies such as blockchain, artificial intelligence, and the Internet of Things (IoT) in maritime operations.

By addressing these barriers and leveraging emerging digital opportunities, Sri Lanka's maritime industry can achieve a more integrated, data-driven, and efficient ecosystem, ultimately enhancing its role in global logistics.

REFERENCES

[1] Maritime Industry Foundation, "Shipping Facts: Key Data on Shipping," 2022. [Online]. Available: https://www.shipping-facts.com [Accessed: Aug. 1, 2025].

[2] UNCTAD, "Review of Maritime Transport 2022," 2022. [Online]. Available: https://unctad.org/webflyer/review-maritime-transport-2022 [Accessed: May 25, 2025].

[3] World Bank, "Sri Lanka Overview," 2022. [Online]. Available: https://www.worldbank.org/en/country/srilanka/overview [Accessed: Aug. 15, 2025].

[4] Central Bank of Sri Lanka, "Annual Report 2021," 2022. [Online]. Available: https://www.cbsl.gov.lk/en/publications/economic-and-financial-reports/annual-reports [Accessed: Aug. 8, 2025].

[5] Sri Lanka Ports Authority, "Port of Colombo," 2022. [Online]. Available: http://www.slpa.lk/ [Accessed: Aug. 12, 2025].

[6] Ministry of Ports and Shipping, Sri Lanka, "National Port Master Plan," 2019. [Online]. Available: http://www.mots.gov.lk [Accessed: Aug. 2, 2025].

[7] International Chamber of Shipping, "Shipping and World Trade," 2022. [Online]. Available: https://www.ics-shipping.org/shipping-facts/shipping-and-world-trade [Accessed: July 25, 2025].

[8] M. D. S. Jayasundara, H. K. S. Premarathne, and K. A. L. C. Perera, "Digitalization of Port Operations in Sri Lanka: A Study on Colombo Port," Journal of Marine Science and Engineering, vol. 9, no. 5, Art. no. 531, 2021, doi: 10.3390/jmse9050531.

[9] IMO, "Maritime Digitalization and Cybersecurity," International Maritime Organization, 2022. [Online]. Available: https://www.imo.org/en/OurWork/Security/Pages/Cybersecurity.aspx [Accessed: Aug. 25, 2025].

[10] UNESCAP, "Maritime Connectivity and Digitalization in Asia and the Pacific," United Nations ESCAP, 2022. [Online]. Available: https://www.unescap.org [Accessed: May 25, 2025].

[11] BIMCO, "Shipping Industry Guidelines on Cyber Security," 2022. [Online]. Available: https://www.bimco.org [Accessed: Aug. 25, 2025].

[12] International Maritime Organization, "e-Navigation Strategy Implementation Plan," 2019. [Online]. Available: https://www.imo.org [Accessed: May 5, 2025].

[13] European Maritime Safety Agency, "Digital Services for the Maritime Sector," 2021. [Online]. Available: http://www.emsa.europa.eu [Accessed: April 28, 2025].

[14] World Economic Forum, "Digital Transformation Initiative: Logistics Industry," 2016. [Online]. Available: https://reports.weforum.org [Accessed: March 2, 2025].

[15] DNV, "Maritime Forecast to 2050," 2022. [Online]. Available: https://www.dnv.com [Accessed: Aug. 7, 2025].

[16] PwC, "The Future of the Logistics Industry," 2020. [Online]. Available: https://www.pwc.com [Accessed: Aug. 5, 2025].

[17] McKinsey & Company, "The Future of Automated Ports," 2018. [Online]. Available: https://www.mckinsey.com [Accessed: March 16, 2025].

[18] Baltic and International Maritime Council (BIMCO), "The future of e-navigation and digital shipping," 2020. [Online]. Available: https://www.bimco.org [Accessed: May 5, 2025].

[19] Lloyd's Register, "Maritime Industry Technology Trends," 2021. [Online]. Available: https://www.lr.org [Accessed: Aug. 6, 2025].

[20] Clarkson Research, "Shipping Intelligence Network," 2022. [Online]. Available: https://sin.clarksons.net [Accessed: Jan 12, 2025].

[21] Drewry Shipping Consultants, "Container Market Outlook," 2022. [Online]. Available: https://www.drewry.co.uk [Accessed: Aug. 25, 2025].

[22] Statista, "Global Container Throughput," 2022. [Online]. Available: https://www.statista.com [Accessed: June 9, 2025].

[23] KPMG, "Digital Transformation in Shipping," 2021. [Online]. Available: https://home.kpmg [Accessed: June 13, 2025].

[24] Y. Liu, Z. Gong, and W. Wu, "Maritime big data: The state-of-the-art and future directions," Journal of Marine Science and Engineering, vol. 7, no. 8, Art. no. 276, 2019, doi: 10.3390/jmse7080276.

[25] N. K. Malhotra and D. F. Birks, Marketing Research: An Applied Approach, 4th ed. Harlow, England: Pearson Education, 2007.

[26] J. W. Creswell and J. D. Creswell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 5th ed. Thousand Oaks, CA: SAGE Publications, 2018.

[27] C. Shi, Y. Wu, and H. Lin, "Applications of blockchain in the maritime industry: A comprehensive review," Journal of Marine Science and Engineering, vol. 8, no. 9, Art. no. 662, 2020, doi: 10.3390/jmse8090662.

[28] S. Bryman and E. Bell, Business Research Methods, 4th ed. Oxford, UK: Oxford Univ. Press, 2015.

[29] T. Notteboom, W. P. Wong, and M. S. Yap, "Port economics, management and policy," Maritime Economics & Logistics, vol. 23, pp. 1–25, 2021, doi: 10.1057/s41278-021-00174-4.

[30] K. Yin, Case Study Research and Applications: Design and Methods, 6th ed. Thousand Oaks, CA, USA: SAGE Publications, 2018.

[31] M. Saunders, P. Lewis, and A. Thornhill, Research Methods for Business Students, 8th ed. Harlow, U.K.: Pearson Education, 2019.

[32] F. Yang, H. Chen, and S. Zhao, "Artificial intelligence applications in port logistics," Journal of Marine Science and Engineering, vol. 9, no. 11, Art. no. 1248, 2021, doi: 10.3390/jmse9111248.

[33] OECD, "Digitalisation and Ports," Organisation for Economic Co-operation and Development, 2020. [Online]. Available: https://www.oecd.org [Accessed: Aug. 25, 2025].

[34] S. L. Panayides and D. Song, "Maritime logistics: Contemporary issues," Maritime Policy & Management, vol. 40, no. 6, pp. 567–583, 2013, doi: 10.1080/03088839.2013.851455.

[35] M. Stopford, Maritime Economi cs, 3rd ed. London, UK: Routledge, 2009.

[36] H. Haralambides, "Gigantism in container shipping, ports and global logistics: a time-lapse into the future," Maritime Economics & Logistics, vol. 21, pp. 1–60, 2019, doi: 10.1057/s41278-018-00116-0.

[37] P. Cariou and F. Notteboom, "Towards a sustainable maritime transport system: Green shipping and eco-efficiency," Maritime Policy & Management, vol. 47, no. 7, pp. 878–894, 2020, doi: 10.1080/03088839.2020.1732085.

[38] R. Bergqvist and J. Monios, "Green ports in theory and practice," Research in Transportation Business & Management, vol. 22, pp. 21–25, 2017, doi: 10.1016/j.rtbm.2016.12.002.

[39] Y. Wang, M. Zhen, and J. Xu, "The impact of digital technologies on supply chain resilience in the shipping industry," Transportation Research Part E: Logistics and Transportation Review, vol. 147, 2021, doi: 10.1016/j.tre.2021.102247.

[40] G. Acciaro, "Corporate responsibility in the shipping industry," Research in Transportation Business & Management, vol. 17, pp. 1–4, 2015, doi: 10.1016/j.rtbm.2015.10.001.