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Article

Influence of digitalization and sustainability initiatives on competitiveness of Colombo Port

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ABSTRACT

Digitalization converts maritime transportation activities into futuristic and sustainable operations in the maritime supply chain. Colombo port plays a pivotal role in the maritime logistics adapting sustainability initiatives for the port operation. The main objective of the research is to identify the impact of the digitalization on port competitiveness with the mediating effect of sustainable initiatives in the port of Colombo. Results show the positive influence of these directions, and ICT and safety and security were the ideals among these directions. The impact of automation, connectivity, and environmental management on port competitiveness is fully mediated by sustainability initiatives as an indirect relationship. That means digitalization impact port competitiveness through sustainability initiatives. Also, the impact of ICT, safety, and security on port competitiveness is partially mediated by sustainability initiatives. Both have direct and indirect relationships with each other. Considering the higher level of impact of sustainability initiatives on port competitiveness, the study can conclude that the port operation is aligned with sustainability in the Colombo port. However, automation, connectivity, and environment management need more concern through developing infrastructure, investment, governance practices, trading partnerships, legal frameworks, and capacity building due to full mediation. Also, ICT, safety, and security also need further attention for those initiatives aimed at enhancing the competitiveness of the port of Colombo.

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Introduction

Ports have been competing within maritime logistics and creating new insights into the shipping industry. Sustainable ports implement development strategies, policies, and activities that protect the environment, economy, and social dimensions of the port while matching the needs to maximize competitiveness (Sankla & Muangpan, 2022). In this digital age, the ability of port businesses to adapt to changing business requirements is critical to their sustainable development and competitive advantage (Othman et al., 2022). As a result, global ports have been introducing technological innovations as part of sustainable port management. Recently, in spite of the findings of previous research and studies, an association has been established between approaches and practices of technology, smart ports, and sustainable performance, and it is an essential requirement to address those issues practically among ports, mainly in developing countries (Othman et al., 2022).

In recent years, a new pillar of technology has emerged (Russo & Musolino, 2021). The focus of innovation is on digitalization, which will make ports more automated, environmentally friendly, and collaborative (Heikkilä et al., 2022). Also, port management and technology have been major driving forces in establishing green competitiveness, which can be identified due to greater usage of the technology by the ports (Kuang et al., 2023). Jun et al. (2018) have mentioned that those ports can be considered autonomous ports, robotic ports, and intelligent ports. Meanwhile, this innovative improves operational efficiency through information and communication technology, improves the quality of life, and increases port competitiveness. That means it ensures the needs of current and future generations, considering the environmental, economic, and social dimensions (Othman et al., 2022).

The main use of the Colombo Port is for containers. Colombo, Sri Lanka, was the best-performing port in South Asia and ranked 24th among the top ports in 2021 (UNCTAD, 2022). The Colombo port, which is cargo originating to destined, connects Europe, East and South Asia, the Persian Gulf, and East Africa effectively, efficiently, and appropriately. And also, it is one of the busiest ports in the world and provides an opportunity for the Indian region's development. Annually, 700,000 TEU are handled by this port, which is in 8th place in Asia (UNCTAD). Further, it has the opportunity to operate more TEUs due to enabling a healthy maritime trading environment through the economic, social, and environmental pillars of the port operation. Meanwhile, Colombo port is competing with other regional ports. Specially, world trading is attracted by Singapore,

Vietnam, India, Malaysia, and Dubai (Figure 1.1). They have been utilizing the applications of digitalization and developing terminal operations for trading. Such as the Sagarmala mega project, which is a development strategy for the coastal ports with the aim of enhancing the operational efficiency of the ports (Kannangara, 2019).

According to the Frontier Technology Readiness Index (Table 1.1), Sri Lanka is ranked 89 in 2022 (UNCTAD, 2023). The countries in the region have been utilizing digital technologies for port activities than Sri Lanka. As a result of the competitiveness of the regional ports has been increased. Comparing with regional countries, Sri Lanka is lacking. Digitalization has been adapting to their port activities. It has been creating a critical environment for maritime trading through the booming competitiveness of Colombo port. According to Logistics Performance Index, Sri Lanka is ranked 73 among 140 in 2023. This indicates the requirement of whole logistics sector in the country; improvements in clearance process, development of transport and trade related infrastructure, shipping cost, quality of logistics service etc… (World Bank, 2023). These indexes highlight the current situation of the maritime logistics and further involvement to improve the logistics capabilities. In other hand port sustainability and digitalization play a critical role at this juncture in the other countries and Sri Lanka is require to make the port resilience through enhancing competitiveness.

According to literature, researcher could identify the various approaches to digitalization and their benefits for maritime transportation and other logistics services. Such as Automation (Yang, et al., 2022; Heikkilä, et al., 2022), Efficient information flow (Serra, et al., 2022; Caldeirinha & Nabais, 2022; Sahu , et al., 2022), Monitoring and traceability (Caldeirinha & Nabais, 2022; Zhou, et al., 2022; Hake, et al., 2023), Security

(Ibrahim, 2022; Tsvetkova & Hellström, 2022; Serra, et al., 2022). Mthembu & Chasomeris, (2022) has mentioned role of the port users and other stakeholders are important to develop the Port Community System (PCS). It determines port competitiveness, and productivity throughout the supply chain whiles enhancing the attractiveness through the better connectivity. Further the rapid growth of technology during the past few years has become a part of maritime logistics. Therefore, directions have been changing from time to time according to the digital transformation. Further, Othman & El-gazzar (2022) have mentioned that the new business environment and digital transformation have been challenging to the global supply chain and that port users need to address these challenges by adapting new technology and smart management. The integration of the core players, ports with inland logistics providers and

government intervention, integration of new technologies (Lin & Chang, 2022), green competitiveness (Kuang, et al., 2023) and hinterland connectivity (Gleser, et al., 2023) can improve the same as mentioned by Mthembu & Chasomeris, (2022) and furthermore supply chain resilience. These studies mainly focus on the advantageous of the digitalization and their implications for the port competitiveness. Therefore this study base on, what is the involvement of digitalization and sustainability initiatives to enhance the port competitiveness in port of Colombo. Accordingly, current study focuses on investigating the mediating effect of sustainability initiatives between the digitalization and port competitiveness through statistical analysis since mediating impact of sustainability has not been addressed by past researches. Therefore main research's objectives are:

RO1: Identify the important factors of port competitiveness and digitalization of port of Colombo.

RO2: Investigate the impact of digitalization on competitiveness of the port of Colombo

RO3: Investigate the impact of digitalization on sustainability initiatives of the port of Colombo

RO4: Investigate the impact of sustainability initiatives on competitiveness in the port of Colombo

RO5: Evaluate the mediating impact of sustainability initiatives on the link between of digitalization and competitiveness of the port of Colombo

This paper consists of five sections. Initially, introductions give the background, problem of the research, and objectives. The second is about a literature review, and the third section presents the conceptual model, hypothesis development, and analysis techniques. The fourth section describes the findings and discussions, and the final chapter outlines the conclusion and recommendations.

2. Literature review

2.1 Port Competitiveness

Ports and maritime transportation have significant positive associations (Igemohia & Faghawari, 2022). However, in maritime transportation, enhancing the competitiveness and efficiency of the port is a critical requirement in the current global supply chain (Mouafo Nebot & Wang, 2022). Competitiveness can be identified as a comparison between two or more factors that are engaged in maritime economics, port management, and maritime logistics (Rozar et al., 2022). In the current maritime context, factors of competitiveness vary according to the requirements of port users. Scholars and professionals have recently investigated those factors, considering their importance (Table 2.1). Meantime, Port rivalry is so complex; it is not a well-defined term. Therefore, among other factors, the nature and characteristics of competition rely on the type of port (gateway, local, transshipment, etc.) and the commodity (containers, liquid bulk, etc.) (Notteboom & Yap, 2012). Therefore the many parties participating in the port business will therefore undoubtedly have different interpretations, measurements, and implications of these aspects. Additionally, the competitive offering will need to take into account what the port community as a whole, not just the container terminal operator, has to offer (Notteboom & Yap, 2012.).

2.2 Competitiveness of the Port of Colombo

The strategic location of the Colombo port is a main pillar measuring competitiveness, like other global ports like Singapore, Shanghai, Hong Kong, Bussan, Rotterdam, and Hamburg. It shows the capacity to compete and collaborate with other ports (Russo & Musolino, 2021). Colombo port is competing with other regional ports. Specially, world trading is attracted by Singapore, Vietnam, India, Malaysia, and Dubai. They have been adopting applications of digitalization and developing terminal operations trading (Kannangara, 2019). Kavirathna et al. (2018)

have mentioned that compared with Singapore, Colombo has low competitiveness due to its relatively low market share. It was affected by the performance of the components, such as monetary, time, location, operation, and related costs. Colombo port is located in the Indian Ocean, which is a major East-West shipping route (Hales et al., 2016).

A port is an organic organization within the context of the region's geo-socio-political-economic system (Lee, 2022). Obviously, the OBOR project of China is making a new silk route for maritime trading, and they are developing and operating ports under their management for trading facilitation, such as Gwadar, Hambanthota, Colombo, Kolkata, Kuala Lampoor, Nirobi, etc. Sagarmala project has been leading the port development in India that aim to enhance efficiency of operation and connect the coastal line ports in India (Kannangara, 2019). It has been spending over USD 140 billion for enhancing the port infrastructure, transformation with new technology, new ports expansion, hinterland connectivity with rail and road (Kannangara, 2019). India and Russia are developing a new trade corridor called the International North-South Transport Corridor (INSTC), which connects both countries through internal roads bypassing major maritime routes to European and central Asian markets (Lee, 2022).

2.3 Digitalization in Port Operation

The rapid growth of technology during the past few years has become a part of maritime logistics (Iman et al., 2022). The new business environment and digital transformation have been challenging to the global supply chain, and port users need to address these challenges by adapting new technology and smart management. Othman & El-Gazzar (2022) have mentioned that smart ports and technology can address these challenges successfully.

Digital transformation has many benefits for maritime shipping. It produces recognition from the customers, improves efficiency, and builds relationships with customers and sustainability (Kuo et al., 2022). Information flow can integrate the network and develop connectivity among the stakeholders. Digitalization facilitates communities to play on keeping a single platform, supporting each other through sharing real-time information (Caldeirinha & Nabais, 2022; Serra et al., 2022). It helps to monitor the visualization and audible operation of terminal and yard operations (Zhou et al., 2022; Cil et al., 2022). And identify container movement on a global scale (Aksentijevi´c & Tijan, 2022). Not only does it improve efficiency, but it also ensures the security of maritime trading (Serra et al., 2022). And mitigate the human-related risks, threats, and vulnerabilities (Ibrahim, 2022). According to UNCTAD (2023), new technologies in trading can be identified under the 16 categories of technologies. Table 2.2 shows the digitalization of maritime logistics.

2.4 Approaches of Digitalization

According to literature, author could identify the various approaches to digitalization and their benefits for maritime transportation and other logistics services. The aim of this study is to identify the impact of digitalization and the mediating role of sustainability initiatives. Considering the various approaches, author could identify the current and future approaches of digitalization through various empirical evidence (Table 2.3).

2.4.1 Automation

Amarathunga (2022) has mentioned the configuration of an automated port as seaside, quayside, and landside. It consists of quayside automation, horizontal transport (seaside), yard side automation, horizontal transport (landside), and gate automation. Terminal automation mainly focuses on transportation, yard automation, and quayside areas (Amarathunga, 2022).

Figure 1.1: Major port competitors of Sri Lanka

Such technology is used for automated guided vehicles (AGV), automated rail-mounted gantries (ARMG), automated and unmanned tractors, runners, cranes, shipping equipment to shore, equipment in the yard, and container movement from berth to yard. Also, they have used various technologies for that, such as radio frequency identification (RFID) and optical character recognition (OCR) (Knatz et al., 2022).

2.4.2 Connectivity

Relationships between stakeholders: port authorities, ministries, harbormaster's offices, freight forwarders, agents, and terminal operators can be enhanced by adapting technology (Jovic et al., 2022). Most of the port recognizes the importance of not only investing in infrastructure but also smart technologies and integration within the port community (Othman et al., 2022). Digitalization integrates all the parties into a single port and connected all the ports (Farah et al., 2022). Also, it makes bridges, gives power (Liu et al., 2022), reduces costs, and enhances the maritime supply chain's efficiency (Gavalas et al., 2022; Liu et al., 2022). Shipping professional organizations and associations are providing standards, guidelines, and recommendations for the shipping industry considering the new trend of the digital transformation (Kuo et al., 2022).

Table 1.1: The Frontier Technology Readiness Index (Rank) – 2023

Country	2023	2021
Singapore	3	5
Malaysia	32	31
United Arab Emirates	37	42
India	46	43
Saudi Arabia	47	50
Indonesia	85	82
Sri Lanka	89	86

Source; (UNCTAD, 2023)

Table 2.1: Factors of Port Competitiveness

Factors	Source
Terminal operation	Jiang, et al., 2022; Mouafo Nebot & Wang, 2022; Jiang, et al., 2023; Ambrosino & Xie, 2022
Digital transformation	Jiang, et al., 2022; Lin & Chang, 2022; Othman, El-gazzar, & Knez, 2022vKuang, Zhu, & Bai, 2023; Hong, Guo, & Wang, 2023; Iman, Amanda, & Angela, 2022; Mthembu & Chasomeris, 2022; Gracia, González-Ramírez, Ascencio, & Mar-Ortiz, 2022
Efficiency of the operation	Li, Jiang, Liu, & Su, 2022;Lin & Chang, 2022; Igemohia & Faghawari, 2022; Rozar, Kamaruddin, Ashari , Usman, & Alown, 2022; Iman, Amanda, & Angela, 2022; Mohseni, Sys, & Vanelslander, 2023
Maritime shipping network	Bernacki & Lis, 2022; Zhou, Shi, & Wang, , 2022; Gracia , González-Ramírez, Ascencio, & Mar-Ortiz, 2022; Notteboomand & Rodrigue, 2022; Shi, Chen, Xu, DiI, & Qu, 2022
Maritime logistics capabilities and service	Wagner, Kotowska, & Pluci ´ nski, 2022; Costa & Soares-Filho, 2022; Igemohia & Faghawari, 2022; Iman, Amanda, & Angela, 2022; Ambrosino & Xie, 2022; Tsantis, Mangan, & Roberto Palacin, 2022; Notteboomand & Rodrigue, 2022; Shi, Chen, Xu, DiI, & Qu, 2022
Low carbon emission	Wagner, Kotowska, & Pluci ´ nski, 2022; Jiang, et al., 2023; Hong, Guo, & Wang, 2023
Sustainable port performance	Othman, El-gazzar, & Knez, 2022; Kuang, Zhu, & Bai, 2023; Barreiro-Gen, Lozano, Carpenter, & Bautista-Puig, 2022

Source: Developed by author

Table 2.2: Usage Digitalization Approaches in the Maritime Logistics

Author	Usage of Digitalization
Heikkilä, et al., (2022)	Applications of Smart port 4.0: renewable energy, hybrid, electric based terminal equipment and container tracking system
Alamoush, et al., (2021)	Digitalization – single window system, port community system which give service to ship and land transportation for other users also. E-document management system (EDI – Electronic Data Exchange, E-document program, RFID). Technologies for connectivity and analysis of data (IoT, big data, cloud and edge computing). Block chains (digitalized ledger system, e-bill of lading). Measures of cyber security
Sankla & Muangpan, (2022)	Smart port applications for environment, economic and social aspects.
Jun, et al., (2018)	Practices of smart ports; environment, energy, operational, safety, security, people factor
Sankla & Muangpan, (2022)	Internet of Thing (IoT) – exchanging of information about the climate, position, sea route and specifications of cargo. Big Data (BD) – for the purpose of analysis of low enforcement and cargo owner, shippers etc… Block Chain (BC) – facilitate the monetary transactions between the stakeholders and digital ledgerization Artificial Intelligence (AI) – space allocations, security detection and actions, allocations of containers automatically Digital Twin – interface and simulations of physical movement and live seen
Mudronja, et al., (2022)	Drones, G networks, fuel technology, internet of Vehicles etc…

Source: Developed by author

Table 2.3: Digitalization

Approaches	Source
Operational efficiency	Kuo, Chen, & Yang, 2022; Gavalas, Syriopoulos, & Roumpis, 2022; Tsvetkova & Hellström, 2022; Serra P. , Fancello, Tonelli , & Marchesi , 2022; Farah , et al., 2022; Othman & El-gazzar, 2022; Othman, El-gazzar, & Knez, 2022;Han, et al., 2022
Maritime logistics capabilities	Iman, Amanda, & Angela, 2022; Serra P., Fancello, Tonelli, & Marchesi, 2022; Tsvetkova & Hellström, 2022; Zeng, Fang, & He, 2022
Contribution of maritime institution	Kuo, Chen, & Yang, 2022; Vitellaro, Satta, Parola, & Buratti, 2022; Clott & Hartman, 2022
Strategies for digitalization and port sustainability	Kuo, Chen, & Yang, 2022; Jugovi´c, Siroti´c, & Poletan Jugovi´c, 2022; Akkerman, Lalla-Ruiz, Mes, & Spitters, 2022; Belmoukari , Audy, & Forget, 2023; Heikkilä, Saarni, & Saurama, 2022; Othman & El-gazzar, 2022; Othman, El-gazzar, & Knez, 2022; Clott & Hartman, 2022
Stakeholder connectivity	Iman, Amanda, & Angela, 2022; Serra, et al., 2022; Caldeirinha & Nabais, 2022; Jovi´c, Tijan, Vidmar, & Pucihar, 2022; Serra P. , Fancello, Tonelli, & Marchesi, 2022; Farah , et al., 2022; Heikkilä, Saarni, & Saurama, 2022; Othman, El-gazzar, & Knez, 2022
Efficient information flow	Serra, et al., 2022; Caldeirinha & Nabais, 2022; Sahu , Pani, & Santos, 2022; Serra P. , Fancello, Tonelli, & Marchesi, 2022; Li, Li, Zhang, Xiao, & Sun, 2022; Monzon Baeza & Ortiz, 2022; Clott & Hartman, 2022
Automation	Yang, Meng, & He, 2022; Heikkilä, Saarni, & Saurama, 2022
Decarbonize	Yang, Meng, & He, 2022; Farah , et al., 2022; Monzon Baeza & Ortiz, 2022
Monitoring and traceability	Caldeirinha & Nabais, 2022; Zhou, Fu, Zhang, Li, & Gao, 2022; Aksentijevi´c, Tijan, Kapidani, & Žgalji´c, 2022; Cil, Abdurahman , & Cil, 2022; Hake, Lippmann, Alkhatib, Oettel, & Neumann, 2023; Li, Li, Zhang, Xiao, & Sun, 2022; Monzon Baeza & Ortiz, 2022; Sahu , Pani, & Santos, 2022
Security	Ibrahim, 2022; Tsvetkova & Hellström, 2022; Serra P. , Fancello, Tonelli, & Marchesi, 2022; Farah , et al., 2022; Han, et al., 2022

Source: Developed by Author

2.4.3 Information Communication System (ICT)

The flow of goods (cargo), information, and finance can be efficiently and effectively transferred within the decision-makers through ICT as a single-port operation. It helps to make decisions for the different decision-makers (Russo & Musolino, 2021). ICT gives a better interface with stakeholders, assisting them to maximize the bottlenecks, plan well, and achieve the expected gains from international trade (Calatayud et al., 2020). Another important thing is that it guarantees information's relevancy, integrity, and consistency through the sharing and storage of information. And it gives a better economic outcome through better decision-making supported by an information system (Knatz et al., 2022). Also, the information system automatically gives safe guide lines for operating ships with the correct position, speed, path, route, and course (Tran, 2022).

2.4.4 Safety and Security

Ports are facing vulnerabilities in safety and security matters. Digitalization can solve these problems, ensure productivity, address environmental aspects, and use energy efficiently (Othman et al., 2022). Digitalization facilitated efficient supervision of the port area and better identification of the persons, equipment, and treats, which can be further analyzed through ICT (Rodeigue & Notteboom, 2021). Smart port impact on productivity, value-added services, and employment as a result, all parties can ensure cargo movement is safe without any internal harm and ensure the safety of the employees (Rodeigue & Notteboom, 2021). Applications of smart ports in Egypt could ensure the safety and security of the ship, solving the uncertainty in the trading pattern (Othman et al., 2022).

2.4.5 Environment Management System (EMS)

Environmental degradation occurs through maritime activities. Smart ports highlight the importance of the role of a variety of indicators in economic, social, and environmental performance. Those indicators provide benefits for all the stakeholders in maritime logistics by achieving environmental objectives (Othman et al., 2022). Smart and sustainable port operations ensure functions related to economic, environmental, and social smart ports (Sankla & Muangpan, 2022).

2.5 Sustainable Initiatives of the Port

Sustainable initiatives are defined clearly by the American Association of Port Authorities (AAPA) as strategies, policies, and actions that meet the needs of present and future stakeholders of the port while ensuring the protection and sustainability of natural and human resources (Degens, 2008). Most industries in the world have been facing novel, unpredictable, and extraordinary challenges. As a result, operational decisions made by them are liable, accountable, and reflect sustainable initiatives (Cavalli et al., 2021). Sustainable initiatives are. required for the maritime business as an emerging trend in the shipping industry. As a result, port authorities have been influenced to adapt this green governance practice in the port (Jugovic et al., 2022).

Port stakeholders have been implementing a variety of measures to enhance the port's sustainability and meet the challenges of social, economic, and environmental conditions (Hossain et al., 2021). Therefore, these three dimensions are most important when pursuing sustainable development in the port (Cavalli et al., 2021). On the other hand, port sustainability is an international obligation that is programmed as the Sustainable Development Goals (SDG) promulgated by the United Nations (Jun et al., 2018).

Increasing trade flows require port development, which drives economic growth. Port authorities need to increase port expansion and infrastructure development while meeting economic, social, and environmental objectives and goals (ESCAP, 2021). That means while reducing environmental negative impact and improving social welfare, ports need to operate with higher economic performance (Sankla & Muangpan, 2022). WPSP (2020) mentions the main five areas covering the activities, responsibilities, and competencies of port participants. Such as strong infrastructure, community and stakeholder participation, safety and security, governance, and ethics.

This analysis of digitalization, sustainability initiatives, and port competitiveness identifies a positive relationship between digitalization and port competitiveness and sustainability initiatives. Moreover, the literature highlights that there is a moderate effect of policies and strategies related to sustainability on digitalization and port competitiveness. However, the researcher identified a meticulous gap in the current research in which there has not been conducted an assessment of the influence of directions of digitalization on the port competitiveness of Colombo with the mediating effect of sustainability initiatives.

According to Kavirathna et al. (2018), who provide information about Colombo's transshipment port competitiveness in her study. She has highlighted the need for future research to focus on new phenomena and factors that she was not focusing on during her study, which are based on cost, charges, time, location, etc. Parola et al. (2016) have also mentioned the development of sophisticated criteria and provided different kinds of criteria for future research. Like green competitiveness, innovations, social and political factors, etc. Therefore, this research has found a research gap through the limitations and suggestions of previous research. Considering that, a research methodology will be developed to address this gap and the objectives of the study within the next chapter.

3. METHODOLOGY

3.1 Conceptual Framework

Based on the comprehensive literature review and opinions of the specialists, conceptual formwork is illustrated as follows: It measures the impact of digitalization on the port competitiveness of the port of Colombo, with the mediating effect of sustainability initiatives.

According to Figure 3.1, there are relationships among digitalization, sustainability initiatives and port competitiveness. First, digitalization serves as independent variables that influence sustainability initiatives. Therefore, sustainability initiatives serve as the dependent variable here. Next, again, digitalization serves as the independent variable, which impacts port competitiveness, which serves as the dependent variable.

Thirdly, sustainability initiatives serve as the independent variable that influences port competitiveness,

where port competitiveness is the dependent variable. Finally, the impact of digitalization on port competitiveness is mediated by sustainability initiatives, where digitalization, port competitiveness, and sustainability initiatives serve as the independent variables, dependent variables, and mediating variables, respectively.

Based on the developed conceptual framework, this research is also going to examine the impact of digitalization on port competitiveness and the mediating effect of sustainability initiatives. Therefore, the following hypothesis is proposed:

H_4 : Sustainability initiatives significantly mediate the link between digitalization and port competitiveness

Base on H_1, H_2, H_3 and H_4 following hypothesis were derived to address the research questions and objectives of the study in-depth manner.

H_{1a} : There is a significant impact of automation on competitiveness of the port of Colombo

H_{1b} : There is a significant impact of connectivity on competitiveness of the port of Colombo

H_{1c} : There is a significant impact of ICT on competitiveness of the port of Colombo

H_{1d} : There is a significant impact of safety and security on competitiveness of the port of Colombo

H_{1e} : There is a significant impact of environment management on competitiveness of the port of Colombo

H_{2a} : There is a significant impact of automation on sustainability initiatives of the port of Colombo

H_{2b} : There is a significant impact of connectivity on sustainability initiatives of the port of Colombo

H_{2c} : There is a significant impact of ICT on sustainability initiatives of the port of Colombo

H_{2d} : There is a significant impact of safety and security on sustainability initiatives of the port of Colombo

H_{2e} : There is a significant impact of environment management on sustainability initiatives of the port of Colombo

H_{3a} : There is a significant impact of sustainability initiatives on competitiveness of the port of Colombo

H_{4a} : Sustainability initiatives significantly mediate the link between automation and competitiveness of port of Colombo

H_{4b} : Sustainability initiatives significantly mediate the link between connectivity and competitiveness of the port of Colombo

H_{4c} : Sustainability initiatives significantly mediate the link between ICT and competitiveness of the port of Colombo

H_{4d} : Sustainability initiatives significantly mediate the link between safety and security and competitiveness of the port of Colombo

H_{4e} : Sustainability initiatives significantly mediate the link between environment management and competitiveness of the port of Colombo

3.3 Population and Study Sample

As per Gao et al., (2018), Quanzhou Port's competitiveness in China was successfully measured through the data collecting of port management, students, researchers, university and enterprises as the main respondents. Considering the purpose and reflection of the port operation, employees who are working in shipping lines, container terminal operators, the Sri Lanka Port Authority, and Sri Lanka Customs are the target population in this study. They directly deal with the activities of the port. Considering the purpose of this research, it is required to collect validity data from experienced, well-educated, and professional employees. Therefore, this study is going to use stratified sampling, which is often more convenient than other sampling techniques. According to that, 250 employees are selected using purposive sampling, considering the experienced, well-educated, and professional employees.

Table 3.2: Definitions of Variables

Variables	Definition
Automation	Automation eliminates the requirement for physically be in the area in order to run the machinery. Anyone can work from a remote office while virtually remaining close to the port and terminal, expanding this beyond the terminal just needs internet access (Tran, 2022)
Connectivity	Relationships between stakeholders: port authorities, ministries, harbormaster's offices, freight forwarders, agents, and terminal operators can be enhanced by adapting technology (Jovic et al., 2022).
ICT	Integration of communication protocols and information and document sharing amongst decision-makers enable cooperation (Mussolino & Russo, 2021).
Safety and security	Ports are facing vulnerabilities in safety and security matters. Digitalization can solve these problems, ensure productivity, address environmental aspects, and use energy efficiently (Othman et al., 2022).
Environment management	It is important to maximize the use of natural resources, space, time, and finance to create energy and operational efficiency and establish environmental sustainability. Hence, the inclusive performance of the port can be increased by the smart port. Automation and connectivity mainly help reduce environmental pollution (Othman, Gazzar, & Knez, 2022; Sankla & Muangpan, 2022).
Port competitiveness	Competitiveness can be identified as a comparison between two or more factors that are engaged in maritime economics, port management, and maritime logistics (Rozar et al., 2022).
Sustainability initiatives	Sustainable initiatives are defined clearly by the American Association of Port Authorities (AAPA) as strategies, policies, and actions that meet the needs of present and future stakeholders of the port while ensuring the protection and sustainability of natural and human resources (Degens, 2008).

Source: Developed by author

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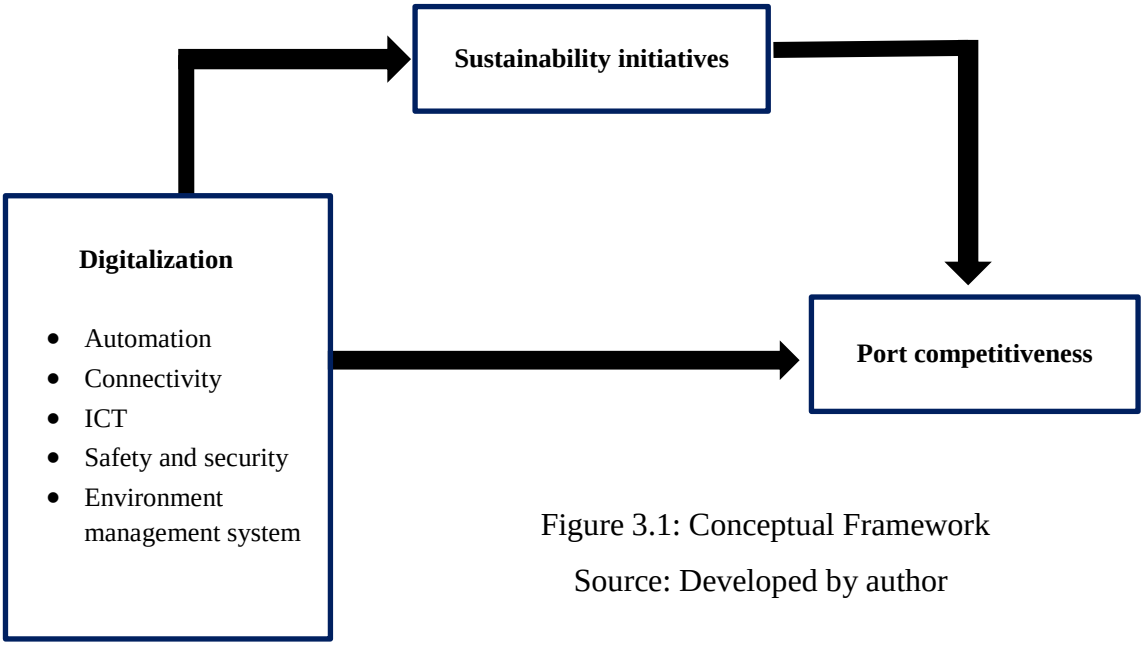

Figure 3.1: Conceptual Framework

Source: Developed by author

3.2 Development of Hypothesis (H)

Table 3.1: Research Hypothesis

	Hypothesis	Sources
H_1	There is a significant impact of digitalization on port competitiveness	Kuo, Chen, & Yang, 2022; Mthembu & Chasomeris, 2022; Gleser, Elbert, & Wu, 2023; Mudronja, Deaaksentijević, & Jugović, 2022; Farah , et al., 2022; Hong, et al., 2023
H_2	There is a significant impact of digitalization on sustainable initiatives	Farah , et al., 2022; Tsvetkova & Hellström, 2022; Han, et al., 2022; Jugovi´c, et al., 2022; Clott & Hartman, 2022; Kuang, Zhu, & Bai, 2023
H_3	There is a significant impact of sustainable initiatives on port competitiveness	Huang, et al., 2022; Li, Jiang, Liu, & Su, 2022; Tsantis, Mangan, & Roberto Palacin, 2022; Shi, Chen, Xu, DiI, & Qu, 2022; Gracia , González-Ramírez, Ascencio, & Mar-Ortiz, 2022; Wagner, Kotowska, & Pluci ´ nski, 2022; Sankla & Muangpan, 2022

Developed By Author

3.4 Data collection and Data Analysis Techniques

Data collection method of this study is questionnaire (Appendix 1). Based on the research questionnaire pertaining to digitalization, the mediating effect of sustainability initiatives on port competitiveness is going to be analyzed. For that, researchers use a five-point Likert scale to gather and analyze the data. A questionnaire was created using Google Forms and distributed among the respondents using LinkedIn among the purposively selected respondents. Those have professional knowledge and the required experience about the port operation in Colombo. Further, questions are based on the generally knowing and relevant concepts which are using pat the port operation. Meanwhile, this research aim to identify the influence of digitalization and sustainability practices on the port competitiveness and not a comparison between cross functional activities. Therefore, same questions for the all respondents can influence for better findings about the Colombo port. Altogether, 192 responses were collected, for a response rate of 76%. All the data were summarized in MS Excel for analysis. The research has used Statistical Package for the Social

Sciences (SPSS) version 25 to analyze the data. The main objectives of the research will be achieved through Regression and Hayes Process Macro analysis. It shows the relationship among digitalization, port competitiveness and sustainability initiatives.

4. Research findings

4.1 Reliability and Validity Analysis

Reliability and validity analyses show the consistency of the variables for the study and to what degree variables are expressed as they are supposed to. It can be stated using the Cronbeach alpha value of each variable, as indicated in Table 4.1.

Table 4.1: Cronbach's Alpha for Major Variables

Cronbach's Alpha	No.of Items
0.854	42

Source: Developed by author

This study used Cronbach's alpha to identify the correctness and internal consistency of the directions of digitalization, sustainability initiatives, and port competitiveness. Consequently, table 4.1 illustrates the good scale of reliability and internal consistency of the directions of digitalization, sustainabilityinitiatives, and port competitiveness with a value of 0.854.

4.2 Relationship between Digitalization, Sustainability Initiatives and Port Competitiveness

4.2.1 Regression Analysis

Regression analysis was used to examine the three kinds of associations: digitalization and port competitiveness, digitalization and sustainability initiatives, and the relationship between sustainability initiatives and port competitiveness.

According to Table 4.2, the digitalization—automation, connectivity, ICT, safety and security, and environment management—show a statistically significant impact on port competitiveness at a 5% confidence level. Automation, connectivity, ICT, safety and security, and environment management are recorded at 0.182, 0.151, 0.413, 0.412, and 0.277, respectively, which means that keeping all other variables constant, it is expected that for every unit rise in this variable, it will increase port competitiveness by 0.182, 0.151, 0.413, 0.412, and 0.277 units, respectively. Therefore, results support H_{1a}, H_{1b}, H_{1c}, H_{1d}, and H_{1e}.

Table 4.2: Impact of Digitalization on Competitiveness

Variables	Standardrized Beta	Sig.
Automation	0.182	0.011
Connectivity	0.151	0.037
ICT	0.413	0.000
Safety	0.412	0.000
Environment	0.277	0.000

Source: Developed by author

Table 4.3 illustrates the results of the relationship between digitalization and sustainability initiatives. According to that, digitalization is statistically significant at a 5% confidence level. The values of automation, connectivity, ICT, safety and security, and environment management were recorded at 0.285, 0.174, 0.475, 0.439, and 0.378, respectively, which means that keeping all other variables constant, it is expected that for every unit rise in this variable impact, sustainability initiatives will increase by 0.285, 0.174, 0.475, 0.439, and 0.378 units, respectively. Hence, results support to the H_{2a}, H_{2b}, H_{2c}, H_{2d} and H_{2e}.

In accordance with Table 4.4, sustainability initiatives are statistically significant at a 5% confidence level. The coefficient value of sustainability initiatives is 0.491, which means that keeping all other variables constant, it is expected that for every unit rise in this variable impact, port competitiveness will increase by 0.491 units. Therefore, results supports for H_{3a}.

4.2.2 Process Macro Analysis

SPSS Process Macro assess the mediating role of sustainability initiatives on the relationship between digitalization (automation, connectivity, ICT, security and safety, environment management) and port competitiveness by calculating direct, indirect, and total effects.

The results revealed an indirect effect of automation on port competitiveness (b = 0.0772 (0.1412*0.5469)). That means automation influences port competitiveness through sustainability initiatives. Therefore, researcher could identify that sustainability initiatives have fully mediated the relationship between automation and port competitiveness. Also, this is a complementary mediation due to the same sign of the impact of automation on sustainability initiatives (b = 0.1412) and sustainability initiatives on port competitiveness (b = 0.5469). Table 4.5 presents the summary of the mediation effect.

Table 4.6 illustrates the indirect effect of connectivity on port competitiveness (b = 0.0641 (0.1169*0.5485)). That means connectivity influences port competitiveness through sustainability initiatives. Hence, sustainability initiatives have fully mediated the relationship between connectivity and port competitiveness. Also, this is a complementary mediation due to the same sign of the impact of connectivity on sustainability initiatives (b = 0.1169) and sustainability initiatives on port competitiveness (b = 0.5485).

As per the results of Table 4.7, an indirect effect of ICT on port competitiveness (b = 0:1077 (0:2473 *0.4355)) can be identified. That means ICT influences port competitiveness through sustainability initiatives. Further, direct effect of ICT on port competitiveness in the presence of sustainability initiatives is also found to be significant (b = 0.1384, p < 0.05). Therefore, it is concluded that sustainability initiatives partially mediate the relationship between ICT and port competitiveness. Further, this is complementary mediation due to the same sign of the impact of ICT on sustainability initiatives (b = 0.2473) and sustainability initiatives on port competitiveness (b = 0.4355).

According to the results of Table 4.8, the indirect effect of safety and security on port competitiveness is 0.0875 (0.1990*0.4397). That means safety and security influence port competitiveness through sustainability initiatives. Also, direct effect of safety and security on port competitiveness in the presence of sustainability initiatives was also found to be significant (b = 0.1259, p < 0.05). Therefore, it is concluded that sustainability initiatives partially mediate the relationship between safety and security and port competitiveness. Meanwhile, this is complementary mediation due to the same sign of the impact of safety and security on sustainability initiatives (b = 0.1990) and sustainability initiatives on port competitiveness (b = 0.4397).

In view of Table 4.9, the study identified the only indirect effect of the environment management system on port competitiveness (b = - 0.0661 (0.1281*0.5158)). That means the environment management system influences port competitiveness through sustainability initiatives. But the results do not show the direct effect of the environment management system on port competitiveness in the presence of the mediator sustainability initiatives (b = 0.0414, p > 0.05). Therefore, research can identify that sustainability

Table 4.3: Impact of Digitalization on Sustainability Initiatives

Variables	Standardrized Beta	Sig.
Automation	0.285	0.000
Connectivity	0.174	0.016
ICT	0.475	0.000
Safety	0.439	0.000
Environment	0.378	0.000

Source: Developed by author

Table 4.4: Association of Sustainability Initiatives and Port Competitiveness

Variables	Standardrized Beta	Sig.
Sustainability	0.491	0.000

Source: Developed by author

Table 4.5: Mediation impact of Sustainability Initiatives between Automation and Port Competitiveness

Relationship	Total effect	Direct effect	Indirect effect	Confidence level		Conclusion
				Lower Bound	*Upper Bound*	
Automation -> Sustainability initiatives -> Port competitiveness	0.1033 (0.0115)	0.0261 (0.4870)	0.0772	0.0319	0.1272	Full mediation

Source: Developed by author

Table 4.6: Mediation Impact of Sustainability Initiatives between Connectivity and Port Competitiveness

Relationship	Total effect	Direct effect	Indirect effect	Confidence level		Conclusion
				Lower Bound	*Upper Bound*	
Connectivity -> Sustainability initiatives -> Port competitiveness	0.1156 (0.0371)	0.0515 (0.2973)	0.0641	0.0119	0.1283	Full mediation

Source: Developed by author

Table 4.7: Mediation Impact of Sustainability Initiatives between ICT and Port Competitiveness

Relationship	Total effect	Direct effect	Indirect effect	Confidence level		Conclusion
				Lower Bound	*Upper Bound*	
ICT -> Sustainability initiatives -> Port competitiveness	0.2461 (0.000)	0.1384 (0.0011)	0.1077	0.0496	0.1785	Partial mediation

Source: Developed by author

Table 4.8: Mediation Impact of Sustainability Initiatives between Safety and Security and Port Competitiveness

Relationship	Total effect	Direct effect	Indirect effect	Confidence level		Conclusion
				Lower Bound	*Upper Bound*	
Safety and security -> Sustainability initiatives -> Port competitiveness	0.2134 (0.000)	0.1259 (0.0005)	0.0875	0.0393	0.1491	Partial mediation

Source: Developed by author

Table 4.9: Mediation Impact of Sustainability Initiatives between Environment Management System and Port Competitiveness

Relationship	Total effect	Direct effect	Indirect effect	Confidence level		Conclusion
				Lower Bound	*Upper Bound*	
EMS -> Sustainability initiatives -> Port competitiveness	0.1075 (0.0001)	0.0414 (0.1183)	0.0661	0.0307	0.1144	Full mediation

Source: Developed by author

initiatives fully mediate the relationship between environmental management systems and port competitiveness. Also, this is a complementary mediation due to the same sign of the impact of EMS on sustainability initiatives (b = 0.1281) and sustainability initiatives on port competitiveness (b = 0.5158).

Therefore, the results of the mediating analysis support the hypothesis that sustainability initiatives mediate the relationship between all the directions of digitalization and port competitiveness.

The summary of the hypothesis testing of this study is illustrated in the table 4.10.

4.2 Discussion

4.2.1 Impact of Digitalization on Port Competiveness

ICT and safety and security have influenced competitiveness by 41%, with the highest influence factor being the document management system at their office. They have their own computerized document management system, which is the most important direction in ICT. According to Mthembu & Chasomeris (2022), digital platforms exchange and share real-time information among the port community. Mudronja et al. (2022) have stated that a single-window system creates a shorter waiting time through the speed of the loading and unloading processes and reduces the cost of the entire process by removing the delay. And also Digitalization facilitated efficient supervision of the port area and better identification of the persons, equipment, and treats, which can be further analyzed through ICT (Rodeigue & Notteboom, 2022).

Further findings show the impact of environmental management on port competitiveness at 27%. Especially smart ports ensure lower emissions, pollution, and consumption of energy (Othman et al., 2022). Sankla & Muangpan (2022) also agreed with smart and sustainable port operations, which give many benefits such as improving business sustainability in the port, renewable energy usage. Those indicators provide benefits for all the stakeholders in maritime logistics by achieving environmental objectives and enhance the green competitiveness (Kuang, et al., 2023; Othman et al., 2022). However, Colombo Port is not practicing a considerable digital base waste management system or noise monitoring. But some extend the monitoring and measuring of air quality.

Before implementation of automation, it requires more return on scale, which is expected by terminal operators (Knatz et al., 2022). Amarathunga (2022) has declared through his study of the Colombo port that developing

nations are facing a few challenges for automation. According to the results of the study, only 15% influence the competitiveness of the Colombo port. It revealed that semi- or fully automated yard and quay operations influence port competitiveness.

As per the results, approaches and practices of digital connectivity have been influencing competitiveness at a considerable level. Ambrosino & Xie (2022) have mentioned that TOS (Terminal Operating System) can manage the real-time storage and flow of cargo between the transport nodes. Through better connectivity, PCS can determine competitiveness (Mthembu & Chasomeris, 2022). Relationship between stakeholders (Jovic et al. 2022), integration (Lin & Chang 2022) and hinterland connectivity (Gleser et al., 2023) can enhance the maritime trading resilience through efficent service.

4.2.2 Impact of Sustainable Initiatives on Port Competitiveness

The impact of sustainability initiatives on port competitiveness has been shown to be considerable level according to findings. Economic, social, and environmental impacts have a high degree of implications for the competitiveness of the Colombo port. Lim et al. (2019) mention efficiency of the port operation, productivity for value creation, better business services and quality, foreign investments, engagement of the stakeholders and their benefits, funding of port development, infrastructure development of the port, volume, gross domestic production, cost of operating, revenue, and efficiency of the cost as major economic factors of the port. Port operation concerns the geopolitical and economic system as a foundation organization, and he connects with all countries with these activities (Cavalli et al., 2021). Such as trading partnerships, trade facilitation, logistics services, economic developments, and digitalization programs. Also, strong relationships among countries influence port competitiveness (Tsantis et al., 2022). New facilities and infrastructure (Jun et al., 2018; Wagner et al., 2022) and multi-terminal collaboration (Jiang et al., 2022) can reduce the cost and enhance port competitiveness (Ambrosino & Xie, 2022).

Sankla & Muangpan (2022) mention community, the safety of workers, and port security as the social aspects of the smart port. It has an impact on boosting the activities of the port, which ensure best practices and create recognition through the implanting of digitalization tools. According to Othman et al. (2022), Low and related regulations with duties and responsibilities play an important role in ensuring the ship's safety and security and cargo movement within the port. Currently, security issues have taken on another dimension with the rise of piracy activities, criminal activities within the borders of global terrorism, and digitalization.

4.2.3 Impact of Digitalization and Sustainability Initiatives

Research revealed a significant impact of automation, connectivity, ICT, safety and security, and environmental management on the sustainability of the port of Colombo. In this sense, ICT and safety and security influence are greater than the other directions (47% and 43%, respectively). Automation and environmental management are associated with the sustainability of the port by 28% and 37%, respectively. This association can be identified in the global context. Applications of ICT help for connectivity, collaboration, environment-friendly transportation, and energy-efficient transportation in the freight movement (Jiang et al., 2022). According to Mudronja et al. (2022), it enhances communication and the transfer of information among stakeholders, manages traffic, improves transparency and safety, and reduces business costs. Othman et al. (2022) have declared that digitalization has become a threat to port operations. Such as stolen goods, illegal activities, cyber-attacks, etc. Under this situation, technology has connected the social dimension of the port operation (Heikkilä et al., 2022).

Research revealed a 17% association between connectivity and sustainability. Meanwhile, globally, many studies show this relationship as the meticulous direction in maritime trading. Wahyuni et al. (2019) have mentioned the importance of government intervention through digitization. Government involvement is necessary to make the port sustainable towards digitalization, addressing the gaps between legislation and implementation (Kuo et al., 2022). Also, Clott & Hartman (2022) have mentioned that global institutions, shipping professional organizations, and associations have supported this transformation by providing consultation and funding, and a social network has been initiated for the promotion of sustainability (Vitellaro et al., 2022).

4.2.4 Impact of Digitalization on Port Competitiveness via Mediating Role of Sustainability Initiatives

As the results of Process Macro, sustainability initiatives mediate the link between the digitalization and port competitiveness. The impact of *automation, connectivity, and environmental management on port competitiveness is fully mediated* by sustainability initiatives as an indirect relationship. That means digitalization impact port competitiveness through sustainability initiatives. Also, the impact of *ICT and safety and security on port competitiveness is partially mediated* by sustainability initiatives. Those have direct and indirect relationships with each other. The positive impact of both approaches on port competitiveness has been controlled and governed by the presence of sustainability initiatives.

Table 4.10: Summary of Hypothesis Testing Results

	Hypothesis	**Decision**
H_{1a}	There is a significant impact of automation on competitiveness of the port of Colombo	Accepted
H_{1b}	There is a significant impact of connectivity on competitiveness of the port of Colombo	Accepted
H_{1c}	There is a significant impact of ICT on competitiveness of the port of Colombo	Accepted
H_{1d}	There is a significant impact of safety and security on competitiveness of the port of Colombo	Accepted
H_{1e}	There is a significant impact of environment management on competitiveness of the port of Colombo	Accepted
Conclusion: *H_1 - There is a significant impact of digitalization on port competitiveness*		
H_{2a}	There is a significant impact of automation on sustainability initiatives of the port of Colombo	Accepted
H_{2b}	There is a significant impact of connectivity on sustainability initiatives of the port of Colombo	Accepted
H_{2c}	There is a significant impact of ICT on sustainability initiatives of the port of Colombo	Accepted
H_{2d}	There is a significant impact of safety and security on sustainability initiatives of the port of Colombo	Accepted
H_{2e}	There is a significant impact of environment management on sustainability initiatives of the port of Colombo	Accepted
Conclusion: *H_2 - There is a significant impact of digitalization on sustainable initiatives of the port*		
H_{3a}	There is a significant impact of sustainability initiatives on competitiveness of the port of Colombo	Accepted
Conclusion: *H_3 - There is a significant impact of sustainable initiatives on port competitiveness*		
H_{4a}	Sustainability initiatives significantly mediate the link between automation and competitiveness of port of Colombo	Accepted
H_{4b}	Sustainability initiatives significantly mediate the link between connectivity and competitiveness of the port of Colombo	Accepted
H_{4c}	Sustainability initiatives significantly mediate the link between ICT and competitiveness of the port of Colombo	Accepted
H_{4d}	Sustainability initiatives significantly mediate the link between safety and security and competitiveness in the port of Colombo	Accepted
H_{4e}	Sustainability initiatives significantly mediate the link between EMS and competitiveness of the port of Colombo	Accepted
Conclusion: *H_4 - Sustainability initiatives significantly mediate the link between digitalization and port competitiveness*		

Economic, social, and environmental sustainability link the digitalization and port competitiveness. Moreover, indirect effects of economic, social, and environmental initiatives can be identified using several studies in the international context. However, a lack of studies has been concerning about the mediating effect of sustainability initiatives on the digitalization and competitiveness of the port of Colombo. Cavalli et al. (2021) have mentioned that most industries in the world have been facing novel and unprecedented challenges. Their operational decisions become more responsible and consider sustainable initiatives. Also Sustainable initiatives are required for the maritime business as an emerging trend in the shipping industry (Jugovic et al., 2022).

Increasing trade flows require port development, which drives economic growth. Port authorities need to increase port expansion and infrastructure development while meeting economic, social, and environmental objectives and goals (ESCAP, 2021). That means while reducing environmental negative impact and improving social welfare, ports need to operate with higher economic performance (Sankla & Muangpan, 2022). Sankla & Muangpan (2022) mentioned that the best operation planning gives many benefits, such as improving the business sustainability in the port, the usage of renewable energy, improving the health and safety of the population, managing the environment in the port, reducing emissions, improving the air quality, minimizing greenhouse gases, minimizing water consumption, waste management, electricity consumption, and monitoring and managing the green concepts.

5.conclusion and recommendations

5.1 Conclusion

With the deep literature survey, the researcher found many scholarly articles related to the concepts of digitalization, port competitiveness, and sustainability that have been researched considering the individual concepts. But there were no studies available to study the impact of digitalization on port competitiveness with the mediating effect of sustainability strategy. This gap has been filled by this study. Considering the conceptual framework and its operationalization, the researcher has developed mainly four hypotheses (H1, H2, H3, and H4), and based on those, 16 hypotheses were developed by the researcher. Accordingly, a questionnaire was developed and collected data from the educated, professional, and experienced employees of shipping lines, SLPA, SL Custom, and terminal operators. Considering the requirement and validity of the information, data was collected using convenience sampling. Those were analyzed using multiple regression, and Hayes process macro which were used to test the hypothesis of the study.

The study consisted of five objectives (RO1, RO2, RO3, RO4, and RO5) aligned with the five questions (RQ1, RQ2, RQ3, RQ4, and RQ5). The first objective (RO1) was achieved through the comprehensive literature review. RO2, RO3, RO4, and RO5 were achieved through the development of the hypothesis and tested through the findings. For that, regression analysis was used to achieve RO2, RO3, RO4, and the Hayes Process macro was used to achieve RO5.

5.2 Recommendations and Implications

Infrastructure development is a pivotal investment for future gains in trading. Firstly, Research show the lack of adaptation automation to the port operation. Also previous studies show the positive impact of automated terminals, yard operations, quayside operations, equipment, and gate systems. Specially automation, as the super-infrastructure requires a huge scale of investment, and it became a challenge due to its low impact on competitiveness. Such as transportation, yard automation, quayside areas, automated guided vehicles (AGV) and automated rail-mounted gantry cranes (ARMG), unmanned automated tractors, runners, cranes ship-to-shore, and equipment. Because only CICT is running with RTG Auto Gantry – Automated Rubber Tired Gantry. Secondly, Research identified lack of consideration for the connectivity through digitization. Therefore, stakeholders in the Colombo port require more attention to enhance digital connectivity among the stakeholders due to their lower influence. Currently, competition among ports has been enhanced by this direction. The study shows the high degree of the internal factors of connectivity: TOS, DGPS integration of stakeholders, container tracking system, and collaboration of maritime institutions. Therefore, it is required to adapt world-developed digital technology to enhance connectivity: tracking facilities, barcodes, global positioning systems, etc. Also, coordination with UNCTAD, IMO, ADB, ESCAP, and other trade-related organizations is required to enhance the smooth functioning of port operations.

Thirdly, management of the information and the establishment of an integrated system for traffic handling for inner and seaside traffic is essential considering the results of the study. One of the latest technologies for that digital twin system It shares all the live pictures and videos of all the port activities. Better monitoring and visualization of the port. Specially it secures port operations from any threats: accidents, activities, vessels, and human-involved risks. It requires safety and security regulations and obligations. Further port can use drone and digital dolphin technology for traffic and threat management, and IoT sensors, AI, and augmented intelligence give weather data. Those build reputations for the port operation and build trust among the stakeholders and investors. Fourth, it requires 5G coverage than the 4G for the total port area for better information sharing and connectivity among trading partners such as telecommunications, software development companies, etc. WiFi, CCTV and Ethernet become outdated considering the facilitation of 5G. This coverage facilitates the usage of computer applications and many software and technologies. Such as block chain, which improves the efficient storage system and freight document and data transfer efficiently, and IoT, which provides facilities for storage and monitoring of the data. Finaly, The study shows that the requirement of training facilities about digital practices, including cyber security, can enhance human capital in the supply chain. Therefore, stakeholders in the port of Colombo have to be concerned about capacity building through social development activities and training programs for staff to ensure sustainability.

5.3 Limitations and Future Research Directions

This research compiles the few limitations. There are a few models to identify the mediating effect. Such as Amos, Sobel test, regression test, etc. Therefore, the results of the data show different meanings due to the fact that all systems give sensitive information and output. Further data was collected from mainly four groups in the supply chain. However there are many stakeholders are engaging and joining with the maritime logistics. Such as freight forwarders, exporters and importers, end-users etc…port compittiveness is never ending topic under the volatile market condition. New conditions and directions come as trends for influencing the competitiveness. Therefore future research requires identifying the influence of current technological advancement towards the competitiveness. Further, comparisons of the terminals or regional ports also need to consider due to different outcomes and performances given through their operation. Therefore it is require to compare the operation of the terminals or regional ports in the context of digitalization.. Further research is required to identify the impact of the recommendations and the implications of this research. Such as return on investment from automation and infrastructure developments, etc.

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APPENDIX – QUESTIONNAIRE

PART 1 - PERSONAL INFORMATION

Please put the tick **(√)**

1. Gender
   Male Female

2. Your Position in your Company? (choose one)
   Non-Executive Grade
   Executive Grade
   Assistant Manager or Manager Grade
   Senior Manager Grade or above
   Other

3. What is your level of education? (choose one)
   Diploma
   Bachelor's Degree
   Post-graduate Diploma
   Master's Degree
   Other

4. How many years of the experience in the field? (choose one)
   1-5 years
   5-10 years
   10-15 years
   15-20 years
   20 and more

5. What is your role in port industry?
   Port Authority
   Terminal operation
   Shipping line
   Port user

PART 2 – D1GITILIZATION, SUSTAINABILITY INITIATIVES AND PORT COMPETITIVENESS

Please put the tick **(√)** in the relevant box considering followings.

Strongly Agree	**-**	**SAG**	**Agree**	**-**	**AG**
Neutral	**-**	**N**	**Disagree**	**-**	**DA**
Strongly Disagree	**-**	**SDA**			

Sr. no.	Statement	SAG	AG	N	DA	SDA
6.	There are semi-automatic or fully-automatic cranes in the terminal area.					
7.	There are semi-automatic or fully-automatic straddle carriers.					
8.	There are semi-automatic or fully-automatic entrance and exit gates in the port area.					
9.	There is semi-automatic or fully-automatic loading and unloading equipment in the container yard area.					
10.	There are semi-automatic or fully-automatic security systems for fire, accidents, disasters, etc.					
11.	All the activities of terminal operations can be identified and tracked using a computer or mobile application.					
12.	Container movement can be identified using a computer- or mobile-based application.					
13.	Ship movements can be identified through an integrated positioning system.					
14.	Local and global institutions support the use of digitalization to improve.					
15.	There is a computerized document management system for day-to-day port activities.					
16.	There is a facility to exchange information among all the parties using a single computer system.					
17.	There is a high-speed wireless network for activities.					
18.	There is an integrated system to handle vessels traffic.					
19.	Individuals and objectives in the port area can be identified from the office.					
20.	There is a computer-based system to identify and analyze the threats in the port area (climate change, accidents, etc.).					
21.	There is an alarming system for the vehicles, ships, and other accidents in the port area.					
22.	There is a cyber-security system to protect computers and systems from unauthorized access.					
23.	There is a computer-based system for the safe storage of containers.					
24.	Workers have been given the required training about the use of digitization approaches.					
25.	There are efficient port activities.					

26. Port has better geographical connectivity with other ports and producers.
27. There is high security at the port.
28. There is effective trade facilitation.
29. The port of Colombo has a good reputation around the world.
30. There are fair port charges.
31. Ports are more preferable to handle large volumes of containers.
32. There are developed infrastructure facilities (Warehouse, road, and telecommunication).
33. There is hinterland connectivity.
34. There is a trading partnership with other countries and institutions.
35. There is quality and timely cargo handling.
36. Colombo Port is operating as a profit-making business.
37. The Port of Colombo handles a considerable number of containers compared to other ports.
38. There is protection of the land environment.
39. They are using alternative energy (hybrid, EV, solar, etc.).
40. All the waste is collected, stored, and removed according to environmental standards.
41. They are protecting water quality from the waste and drainage of ships and other auxiliaries.
42. There are rules and regulations to adhere to for safety and security.
43. There is a safety management system.
44. There is a disaster management and contingency plan.
45. Workers have a reputation due to their occupation.
46. Workers have training facilities.