JOURNAL OF MARITIME LOGISTICS
Universiti Malaysia Terengganu

Journal of Maritime Logistics is an international multidisciplinary journal. It collects and publishes scholarly articles on topics related to the maritime industry. It provides the results of the latest research and analysis on foreland, seaports and the hinterland. It also explores substantial topics, including logistics, policies, operations, management and navigation related to three main agenda — ocean activities, seaports and the hinterland.

eISSN: 2805-5195 Journal homepage: https://journal.umt.edu.my/index.php/jml/index

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To cite this article:
DOI: https://doi.org/10.46754/jml.2023.12.005

Journal of Maritime Logistics
https://journal.umt.edu.my/index.php/jml

NON-DIGITAL FACTORS AS A PREREQUISITE FOR THE IMPLEMENTATION OF SEAPORT DIGITALIZATION THROUGH BIBLIOMETRIC ANALYSIS

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ABSTRACT
This research conducts a comprehensive exploration of the prerequisites involved in seaport digitalization through rigorous bibliometric analysis, with a specific focus on non-digital factors. The study reveals critical insights into the landscape of seaport digitalization, emphasizing the foundational role of effective leadership and stakeholder engagement in fostering innovation and alignment with the diverse needs of the maritime community. Strategic planning emerges as pivotal, providing a purposeful digital transformation journey with a clear vision and goals. A robust technology infrastructure encompassing IT systems, cloud computing, and cybersecurity positions seaports for adaptability and technological leverage. Effective data management, workforce training, and compliance with regulations are identified as paramount for digitalization success. Despite these contributions, the study acknowledges limitations in the bibliometric analysis and emphasizes the dynamic nature of technology. Recommendations for future research include in-depth regional studies, longitudinal analyses, comparative studies, exploration of human-centric aspects, and investigations into emerging technologies. While offering valuable insights, this research advocates for continued exploration into specific aspects and regional nuances in the dynamic field of seaport digitalization.

Keyword: Seaport digitalization, factors, Bibliometric analysis.

Introduction

In recent years, seaport digitalization has emerged as a pivotal force reshaping global maritime operations. Traditionally, seaports have been hubs of manual processes and paper-based documentation (Sholihah *et al.,* 2018). However, the advent of digital technologies has ushered in a transformative era, revolutionising the way these ports operate. Automation, data analytics, and connectivity advancements have enabled seaports to enhance efficiency, reduce turnaround times, and streamline logistics processes (Heilig *et al.,* 2017; de la Peña Zarzuelo *et al.,* 2020). From implementing smart container management systems to utilising Internet of Things (IoT) devices for real-time monitoring, seaports worldwide are embracing digital solutions to optimise their operations.

Despite the undeniable benefits, the journey towards comprehensive seaport digitalization is not without its challenges. Ports often grapple with the integration of diverse digital systems, cybersecurity concerns, and the need for substantial infrastructure upgrades (Lehto, 2022). Additionally, the maritime industry faces the challenge of ensuring that all stakeholders, including shipping companies, customs authorities, and port operators, can seamlessly adopt and adapt to digital processes (Tijan *et al.,* 2021; Akpinar & Ozer-Caylan, 2022). These challenges underscore the complexity of the transition but also highlight the urgency and importance of addressing them. In the

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broader context of global trade and logistics, seaport digitalization can be a linchpin for enhancing the overall efficiency of supply chains, reducing delays, and fostering a more interconnected and responsive maritime ecosystem. As the world becomes increasingly reliant on interconnected trade networks, the digitalization of seaports stands at the forefront of ensuring the smooth flow of goods across borders (Pagano *et al.,* 2022).

The central issue motivating this research lies in the need to comprehensively understand and address the multifaceted challenges and prerequisites hindering the seamless implementation of seaport digitalization. Despite the growing emphasis on digital advancements in maritime operations, a noticeable gap exists in our understanding of the non-digital factors that act as prerequisites for successful digitalization in seaports. This research aims to fill this void by conducting a thorough bibliometric analysis to identify critical factors affecting seaport digitalization. The timeliness of this problem is underscored by the urgency for seaports to transition into digital ecosystems, given the dynamic nature of global trade and the increasing demands for efficient and resilient supply chains. Conflicting viewpoints and controversies in existing literature may revolve around varying perspectives on the importance of non-digital factors, with some arguing for a more technocentric approach while others advocate for a holistic consideration of both digital and non-digital elements in the process of seaport digitalization. This research seeks to navigate and contribute to this discourse, providing valuable insights for scholars, practitioners, and policymakers engaged in the maritime industry.

This research paper unfolds in a structured manner to offer a comprehensive exploration of non-digital prerequisites in seaport digitalization. The journey begins with an insightful review of the existing literature on seaport digitalization and potential gaps in understanding. Following this, the methodology section outlines the rigorous bibliometric analysis employed to dissect relevant academic literature. The results section unveils quantitative insights, presenting a detailed picture of the frequency and distribution of non-digital factors. These findings then seamlessly transition into a robust discussion, where the identified factors are critically analysed and their implications for seaport digitalization are explored. The paper concludes with a synthesis of key takeaways and recommendations for stakeholders. This structured approach guides the reader through a nuanced exploration of the topic, offering a roadmap for understanding the complexities of seaport digitalization and the pivotal role played by non-digital prerequisites in shaping its success.

Literature Review

The literature surrounding seaport digitalization forms a dynamic tapestry reflecting the transformative impact of digital technologies on maritime operations. Seminal works, academic papers, and industry reports paint a vivid picture of the current landscape. The exploration commences with an in-depth analysis of technological advancements in seaport operations, ranging from implementing smart container management systems to integrating Internet of Things (IoT) devices (Min, 2022). Automation emerges as a central theme, with discussions revolving around autonomous vehicles, robotic cargo handling, and automated documentation processes (Xiao *et al.,* 2022; Zhou *et al.,* 2022). The review further navigates through the role of data analytics in optimising port performance, showcasing how predictive analytics and real-time data insights contribute to informed decision-making (Durlik *et al.,* 2023; Paternina-Arboleda *et al.,* 2023). Connectivity, both in terms of communication networks and collaborative

platforms, emerges as a critical factor binding these technological facets together (Rizi *et al.,* 2022; Singh *et al.,* 2023). This holistic overview lays the groundwork for understanding the current state of seaport digitalization and reveals the intricacies and interdependencies among various technological elements shaping the maritime domain.

Within this dynamic landscape, the literature review illuminates the challenges and opportunities inherent in the digital transformation of seaports. Challenges include concerns about cybersecurity, interoperability of diverse digital systems, and the need for substantial investments in infrastructure upgrades (Irmak *et al.,* 2023). Simultaneously, the literature highlights opportunities for increased efficiency, reduced turnaround times, and enhanced overall performance (Blakey-Milner *et al.,* 2021; Chen *et al.,* 2022). As seaports strive to stay abreast of these advancements, it emphasise the continuous evolution of digital technologies and the need for adaptive strategies. Ultimately, this not only provides a comprehensive snapshot of the current state of seaport digitalization but also sets the stage for the subsequent exploration of gaps in knowledge and the significance of non-digital factors in the realm of maritime digital transformation.

Amidst the wealth of literature on seaport digitalization, a discerning examination reveals notable gaps and limitations that warrant careful consideration. One such gap lies in the inadequate attention given to specific types of non-digital factors crucial for the success of seaport digitalization. While existing studies extensively explore technological aspects, another factor could significantly influence the implementation and sustainability of digital initiatives in seaports. Additionally, Fraske (2022) pointed out that disparities in regional or sector-specific studies contribute to a fragmented understanding of seaport digitalization, as nuances and challenges unique to certain geographic locations or industry segments may be overlooked. The identification of these gaps underscores the need for a more comprehensive and nuanced exploration of the non-digital dimensions of seaport digitalization, prompting the research to embark on a mission to fill these voids and provide a more holistic understanding of the multifaceted challenges and prerequisites involved.

Methodology

In this section, we detail the rigorous methodology employed to conduct a comprehensive bibliometric analysis aimed at unravelling the intricacies of seaport digitalization research. Bibliometrics offers a quantitative lens through which to explore the landscape of academic literature, providing valuable insights into trends, patterns, and relationships within the field (Gölgeci *et al.,* 2022). This method can be particularly apt for synthesizing the vast and dynamic body of knowledge surrounding seaport digitalization.

This research adopts bibliometric analysis as the primary research design to systematically review and analyse the existing literature on seaport digitalization. Bibliometrics involves the quantitative analysis of publications, citations, and co-citations to uncover patterns, trends, and relationships within a specific field of study (Donthu *et al.,* 2021; Autsadee *et al.,* 2023). In this case, the analysis focuses on academic papers, conference proceedings, and book chapters related to factors for successful digitalization in seaport. The bibliometric approach enables the identification of key authors and thematic clusters, providing a comprehensive understanding of the current state of research in this domain.

The data collection process involves accessing the Scopus database, a

comprehensive repository of academic literature. The inclusion criteria are set to consider only English-language publications, ensuring consistency in language for analysis. Document types such as articles, conference papers, and book chapters are selectively included to capture a diverse range of scholarly contributions. Al Ryalat *et al.* (2019) noted that the Scopus database serves as a reliable source, offering a vast collection of peer-reviewed literature in the field of seaport digitalization. This rigorous selection process ensures the inclusion of high-quality and relevant scholarly works for the bibliometric analysis.

The collected data undergoes a co-word analysis, a bibliometric technique that explores the co-occurrence of keywords within the selected literature. VOSviewer, a powerful visualisation tool, is employed to map and display the relationships between these keywords, revealing clusters and patterns within the literature (McAllister *et al.,* 2022). This technique enables the identification of key themes in the research on seaport digitalization. The visualisation produced by VOSviewer serves as an intuitive representation of the scholarly landscape, allowing for a nuanced exploration of the interconnectedness of ideas and concepts within the field (Afjal *et al.,* 2023). The combination of co-word analysis and visualisation enhances the depth and clarity of insights derived from bibliometric analysis, contributing to a robust understanding of the current state of seaport digitalization research.

Thus, the chosen methodology, anchored in bibliometrics and enhanced by co-word analysis and visualisation using VOSviewer, forms a robust framework for dissecting the complexities of seaport digitalization research. This methodological approach ensures the systematic exploration of the current state of knowledge and positions the research to contribute novel insights and bridge existing gaps in understanding. The subsequent sections of this study build upon the foundation laid by this methodological framework, offering a comprehensive exploration of non-digital prerequisites in the realm of seaport digitalization.

Results

The results section unfolds as a visual narrative, presenting the outcomes of the bibliometric analysis conducted on seaport digitalization literature. Through the lens of co-word analysis, light is shed on crucial facets of implementing seaport digitalization. The analysis elucidates the interconnected landscape of factors, effectively mapping the scholarly discourse into thematic clusters.

The co-word analysis result, presented in Figure 1, depicts the interconnected landscape of factors influencing seaport digitalization. The figure utilises a network graph generated through VOSviewer, where nodes represent key factors, and edges illustrate the strength of co-occurrence relationships between these concepts.

For example, a purple cluster may reveal a strong association between “Leadership” and “Stakeholder Engagement,” suggesting that these two factors often co-occur in the literature, emphasizing their interconnectedness in the context of seaport digitalization. Meanwhile, nodes in the lower-right quadrant in green, such as “Sustainability” and “Digitalization,” might showcase another cohesive cluster, indicating a frequent pairing of these factors in scholarly discussions.

The size and colour intensity of nodes represent their prominence and frequency in the literature, offering a visual hierarchy of the factors. Visualisation aids in identifying thematic clusters and overarching patterns in the research landscape, providing a nuanced understanding of the relationships between various elements crucial for seaport digitalization.

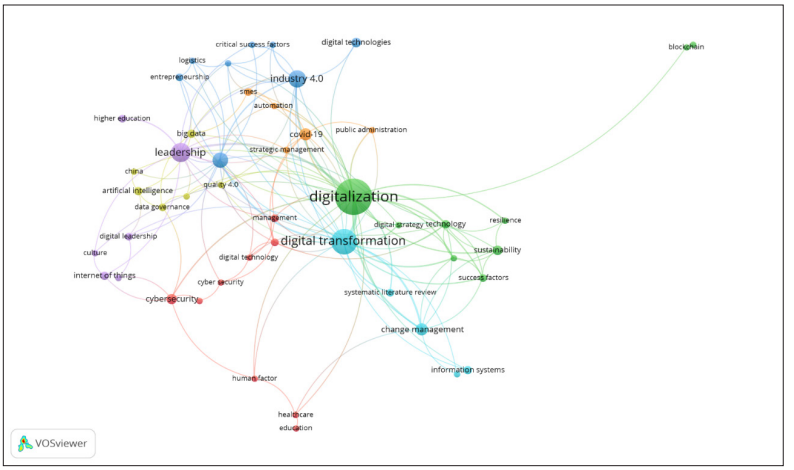

Figure 1: Co-word analysis network of key factors in seaport digitalization
Source: Authors

Table 1 summarises critical elements for the successful implementation of digitalization initiatives in seaports. The table outlines various factors and attributes associated with each factor, along with references to the authors who have contributed to the understanding of these factors. The factors include leadership and stakeholder engagement, strategic planning, technology infrastructure, data management, training and skill development, regulatory compliance, and sustainability considerations. The table serves as a concise reference for stakeholders and decision-makers involved in seaport digitalization, providing insights into the key considerations and the scholarly sources supporting each factor.

Table 1: Key factors for implementing seaport digitalization

Factor	Keyword	Authors
Leadership and stakeholder engagement	Leadership, digital leadership, stakeholder	(Curley & Salmelin, 2017; Tay & Low, 2017; Skinner *et al.,* 2018; Lehto & Limnéll, 2021; Marjamaa *et al.,* 2021; Borodiyenko *et al.,* 2022; Gamage, 2022; Holmgren & Kringelum, 2022; Yalcin, 2022; Khanal *et al.,* 2023; Martínez-Peláez *et al.,* 2023; Memon & Ooi, 2023; Puplampu *et al.,* 2023)
Strategic planning	Strategic management, vision, goals, roadmap	(Kerr & Phaal, 2019; Schumacher *et al.,* 2019; Hajdari *et al.,* 2020; von Solms & Langerman, 2020; Popkova *et al.,* 2021; Claessens *et al.,* 2022; Ghobakhloo *et al.,* 2022; Zheliuk *et al.,* 2023)
Digital technology infrastructure	IT systems, cybersecurity	(Asghar *et al.,* 2019; Deng *et al.,* 2020; D'Amico *et al.,* 2021; Senarak, 2021; Abbas *et al.,* 2022; Kanwal *et al.,* 2022; Aamer *et al.,* 2023; Moudgil *et al.,* 2023)

Data management	Quality and integration, data governance	(Iturrioz *et al.,* 2015; Alhassan *et al.,* 2019; Bradley *et al.,* 2019; Vercammen & Burgman, 2019; Balakrishnan *et al.,* 2020; Janssen *et al.,* 2020; Zeadally *et al.,* 2020; Huber *et al.,* 2021; Mahanti & Mahanti, 2021)
Training and skill development	Workforce training, change management	(Rebele & Pierre, 2019; Bordeleau, 2020; Henke *et al.,* 2020; Petrenko *et al.,* 2020; Surianarayanan & Menkhoff, 2020; Van Laar, 2020; Errida & Lotfi, 2021, Jain *et al.,* 2022; Pacolli, 2022; Molin & Norrman Brandt, 2023)
Regulatory compliance	Regulations, customs and trade compliance	(Vairetti *et al.,* 2019; Kim & Kim, 2020; Agarwala *et al.,* 2021; Ahmad *et al.,* 2021; D'Amico *et al.,* 2021; Kassou *et al.,* 2021; Ponomareva *et al.,* 2021; Zeng *et al.,* 2021; Wen *et al.,* 2022; Wang *et al.,* 2023)
Sustainability considerations	Resilience, green technologies, sustainability	(Bjerkan & Seter, 2019; Natsir *et al.,* 2021; Jugović *et al.,* 2022; Tardo *et al.,* 2022; Belmoukari *et al.,* 2023; Wang *et al.,* 2023)

Source: Authors

Discussion

In the pursuit of seaport digitalization, effective leadership and robust stakeholder engagement emerge as pivotal factors influencing the success of such transformative initiatives. Leadership plays a central role in steering the digitalization process, necessitating a clear understanding of associated benefits, risks, and challenges (Memon & Ooi, 2023). A proactive and visionary leadership approach not only propels the adoption of new technologies but also fosters a culture of innovation and adaptability within the port ecosystem (Curley & Salmelin, 2017; Yalcin, 2022; Skinner *et al.,* 2018). Moreover, the engagement of key stakeholders are paramount for aligning digitalization efforts with diverse needs of stakeholders (Marjamaa *et al.,* 2021; Gamage, 2022; Martínez-Peláez *et al.,* 2023). Port authorities, shipping companies, and other relevant entities would be the key stakeholders in the maritime sectors for implementing seaport digitalization. This collaborative approach ensures that the digitalization strategy is not only technologically sound but also addresses the broader concerns and expectations of the maritime community. Therefore, effective leadership and stakeholder engagement become foundational elements in orchestrating a cohesive and inclusive digital transformation within the seaport environments.

The role of strategic planning in seaport digitalization cannot be overstated. A clear vision and well-defined goals form the bedrock of a successful digital transformation journey (Hajdari *et al.,* 2020; von Solms & Langerman, 2020). Establishing specific, measurable, achievable, relevant, and time-bound (SMART) objectives ensure that the seaport's digitalization efforts can be purposeful and aligned with overarching organisational objectives. Furthermore, the development of a comprehensive roadmap provides a structured and phased approach to implementation, guiding stakeholders

through key milestones (Kerr & Phaal, 2019; Claessens *et al.,* 2022). Strategic planning can facilitate the efficient deployment of technological solutions and enable seaports to navigate potential challenges and allocate resources judiciously. By integrating the insights from strategic planning, seaports can position themselves strategically in the rapidly evolving maritime landscape, fostering adaptability and resilience in the face of technological advancements and industry dynamics.

A robust technology infrastructure can form the backbone of successful seaport digitalization endeavours. Moudgil *et al.* (2023) emphasises the significance of investing in reliable and scalable IT systems to support the complex requirements of modern operations. This includes the integration of cloud computing, data analytics, and advanced communication networks. Concurrently, cybersecurity measures play a critical role in safeguarding sensitive information and ensuring the integrity of digital systems (Asghar *et al.,* 2019; Aamer *et al.,* 2023). A secure and agile technology foundation not only enhances operational efficiency but also positions seaports to leverage emerging technologies and adapt to the dynamic industry landscapes (D'Amico *et al.,* 2021). As seaports increasingly become hubs of digital connectivity, a resilient technology infrastructure emerges as an indispensable enabler of innovation and competitiveness within the maritime domain.

Effective data management can be paramount for the success of seaport digitalization initiatives. Huber *et al.* (2021) and Zeadally *et al.* (2020) underscore the importance of maintaining high-quality data and integrating information from various systems to ensure a seamless flow of data across ecosystems. This involves the technical aspects of data integration and the establishment of clear data governance policies (Alhassan *et al.,* 2019; Mahanti & Mahanti, 2021). Defining roles and responsibilities for data management and implementing robust governance frameworks are essential for preserving data integrity and security (Balakrishnan *et al.,* 2020; Janssen *et al.,* 2020). A well-managed data environment not only enhances decision-making processes but also facilitates innovation and collaboration among stakeholders (Iturrioz *et al.,* 2015; Bradley *et al.,* 2019; Vercammen & Burgman, 2019). In the era of digital transformation, seaports must recognise data as a strategic asset and prioritize its effective management to unlock the full potential of technological advancements.

In the realm of seaport digitalization, the significance of workforce training and skill development cannot be overstated. Rebele and Pierre (2019) and Van Laar *et al.* (2020) emphasise the need for comprehensive training programs to equip employees with the skills to navigate and utilize new technologies. This approach ensures that the workforce remains adept in handling digital tools and processes. Additionally, Errida and Lotfi (2021) underscore the importance of change management strategies to address resistance and facilitate a smooth transition to digital processes. By prioritizing ongoing training initiatives and fostering a culture of adaptability, seaports can empower their workforce to embrace and drive digital transformation. Investing in human capital can become integral to realizing the full potential of digital technologies within the maritime industry.

Navigating the intricacies of regulatory compliance is another critical aspect of seaport digitalization. Agarwala *et al.* (2021) emphasise the importance of adhering to local and international regulations governing operations. Compliance with regulations not only ensures legal adherence but also establishes a foundation of trust and reliability in the maritime industry. Moreover, Ahmad *et al.* (2021) and Kim

and Kim (2020) highlight the significance of implementing digital solutions to facilitate customs processes and ensure compliance with trade regulations. By integrating regulatory considerations into the digitalization strategy, seaports can streamline operations, reduce bureaucratic hurdles, and enhance overall efficiency. Proactive engagement with regulatory frameworks becomes an essential element in shaping the digital landscape of seaports while fostering a secure and compliant environment.

In the era of seaport digitalization, integrating sustainability considerations is also highlighted and emerged as a strategic imperative. Belmoukari *et al.* (2023) emphasise the adoption of green technologies within the digitalization strategy, aligning seaport operations with environmentally sustainable practices. By incorporating eco-friendly solutions, such as energy-efficient technologies and emission-reducing measures, seaports can contribute to the broader goal of environmental conservation (Bjerkan & Seter, 2019). Sustainability considerations extend beyond operational efficiency to encompass the ecological impact of maritime activities. As seaports evolve into digitally connected hubs, prioritizing green technologies have become not only a responsible choice but also a competitive advantage, positioning these ports as leaders in environmentally conscious and future-ready maritime operations.

Conclusion

In conclusion, this research has undertaken a comprehensive examination of the multifaceted challenges and prerequisites integral to the implementation of seaport digitalization. Employing a rigorous bibliometric analysis, the study focused on non-digital factors, shedding light on crucial insights into the seaport digitalization landscape. The key findings underscore the foundational role of effective leadership and robust stakeholder engagement, emphasizing the importance of visionary leadership in fostering innovation and collaborative engagement to align digitalization efforts with the diverse needs of the maritime community.

Strategic planning emerges as a pivotal factor, with a clear vision, well-defined goals, and SMART objectives providing the foundation for a purposeful digital transformation journey. The study emphasises the significance of a robust technology infrastructure, encompassing reliable IT systems, cloud computing, data analytics, and cybersecurity measures, positioning seaports to adapt to dynamic industry landscapes and leverage emerging technologies.

Furthermore, effective data management is identified as paramount for digitalization success, emphasizing the importance of high-quality data, clear governance policies, and well-defined roles. Workforce training and skill development are deemed integral to seaport digitalization, with comprehensive programs and change management strategies empowering employees to navigate new technologies and ensure a smooth transition to digital processes.

Navigating regulatory compliance and integrating sustainability considerations are recognised as critical aspects of seaport digitalisation. Adherence to regulations and the adoption of green technologies contribute not only for legal compliance but also for trust-building and environmental conservation.

However, the study acknowledges certain limitations, including potential gaps in the bibliometric analysis due to the vast and evolving nature of the field, language bias resulting from a focus on English-language publications, and the dynamic nature of technology, which may render some findings quickly outdated. Additionally, recognising the importance of regional nuances, the study suggests a more in-depth regional analysis

for a better understanding of seaport digitalization challenges.

Looking forward, the study offers recommendations for future research in seaport digitalization, encouraging in-depth regional studies, longitudinal analyses to track the evolution of digitalization, comparative studies across seaports, exploration of human-centric aspects, and investigations into the integration of emerging technologies. In summary, while providing valuable insights, this research highlights the need for continued exploration into specific aspects, regional variations, and emerging trends in the dynamic field of seaport digitalization.

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