International Journal of Marine Engineering Innovation and Research, Vol. 9(3), Sept. 2024. 442-450
(pISSN: 2541-5972, eISSN: 2548-1479)

Smart Port Management in Digital Transformation: A Review for Future Research

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(Received: 09 August 2024 / Revised: 15 August 2024 /Accepted: 22 August 2024)

***Abstract*— Ports are basic center points in worldwide transportation, affecting supply chains and national economies. With the rise of Industry 4.0, joining computerised change such as IoT, huge information, cloud computing, and AI into harbour operations has ended up progressively vital. This study provides a systematic evaluation of 41 selected articles focusing on three critical aspects of smart port development: developments in digital transformation, assessment of smart port implementation, and related challenges and limitations. Utilizing indicators such as technology relevance, operational efficiency, user experience, regulatory barriers, and infrastructure readiness, the analysis reveals that a significant number of articles contributed to digital transformation technologies (average score: 7.61), performance evaluation (average score: 6.63), and challenges and barriers (average score: 6.15). Trend graphs and Pareto diagrams highlight fluctuations in contributions and emphasize that a small number of high-scoring articles have a considerable impact. This research underscores the importance of a thorough and systematic approach in assessing digital transformation technologies and offers valuable insights into the current landscape, opportunities, and challenges. The findings are intended to guide stakeholders in developing effective strategies for achieving sustainable digital transformation in smart ports.**

Keywords— Digital Transformation, Literature Review, Management, Smart Port

I. Introduction

Ports serve as crucial hubs in transportation, playing a vital role in the overall maritime transport chain. Ports play a crucial role not only in enabling waterborne transport but also in influencing the entire supply chain and the national economy of every country[1]. With the advent of Industry 4.0 [2], Digital technologies, including the Internet of Things (IoT), big data, cloud computing, and artificial intelligence (AI), are increasingly becoming essential components of every aspect of the supply chain. Challenges encountered by ports, such as operational mistakes, congestion, delays, information gaps, and environmental and energy issues, can impede the deeper integration of Industry 4.0 into associated industries [3]. Consequently, smart ports are designed to address these challenges. Research on port evolution indicates that ports have advanced from first-generation to fifth-generation facilities [4], featuring dynamic, high-tech systems and a broader range of services [5]. The evolutionary trajectory of ports is expected to lead to smart ports with greater technological involvement [5].

Smart Ports seeks to enhance port performance through technology-driven solutions. While the concept of a "Smart Port" is gaining popularity, its exact definition is still somewhat ambiguous. In a time of swift technological progress, ports are essential to global trade and logistics. The idea of "Smart Ports" has surfaced as a significant element of digital transformation (DT) in maritime logistics. These ports incorporate cutting-edge technologies like the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and blockchain to improve operational efficiency, security, and sustainability [6], enhanced tracking and tracing system [5], Technologies such as radio frequency identification (RFID), GPS systems, three-dimensional scanners, and autonomous robots are integral to Smart Ports. However, despite being frequently mentioned by researchers, the definitions and technologies associated with Smart Ports remain fragmented, lacking clear and comprehensive scientific works [7]. Effective management in advancing Smart Ports involves endowing ports with "intelligence," allowing them to "think like humans" to achieve more rational, reliable, efficient, environmentally friendly, and smarter operations. Smart Ports have demonstrated improvements in port efficiency, communication, and crew satisfaction [8].

Recent research has enhanced our understanding of various aspects of the digital transformation (DT) phenomenon. Consistent with earlier findings on IT-driven transformation, studies have revealed that technology alone is only one piece of a complex puzzle that organizations must address to stay competitive in the digital era, Strategy [9][10], along with organizational changes such as adjustments to structure and culture, is essential for developing the capability to create new avenues for value generation. Despite these insights, we still do not have a thorough understanding of this phenomenon and its effects across different levels of analysis [11].

Implementing Smart Port initiatives involves several challenges, such as high costs, Resisting change, and cybersecurity threats, and the necessity for standardization. Furthermore, the maritime industry's traditionally conservative approach can delay the

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adoption of innovative technologies. Understanding the dynamics of Smart Port management in the digital transformation context is crucial for both academic researchers and industry practitioners. To elucidate this topic, it is important to discuss the following inquiries: What kinds of the idea of intelligent port and research clusters? What establishes specific indicators? This research aims to explore the primary topics that define the current concepts of Smart Ports by examining the latest research clusters and identifying comprehensive systematic reviews. This analysis will aid in developing more competitive Smart Port management by emphasizing advancements in digital transformation for future studies.

This study aims to explore future research directions for information systems (IS) in Smart Port management by reviewing existing literature and identifying gaps. confront challenges When implementing, costs can be high, resistance to change, and cybersecurity threats, which hinder the adoption of innovative technologies in the traditionally conservative maritime industry. Despite numerous studies, a comprehensive understanding of the Smart Port concept remains elusive. This research offers a novel, systematic approach by evaluating digital transformation technologies, performance metrics, and challenges, providing a framework for future research and practical insights to enhance Smart Port implementation.

II. METHOD

This study employs a systematic literature review (SLR) methodology, utilizing data from top international journals indexed in Scopus, spanning from 2019 to 2023. The systematic search approach of SLR involves methodically seeking out information, identifying, and synthesizing relevant articles and literature on previous research topics [12]. This involves locating, assessing, and analyzing all pertinent studies to address new questions related to the research topic [13][14].

In this section, the systematic literature review (SLR) is performed using the PRISMA framework, which offers a detailed checklist for evaluating the quality and thoroughness of systematic reviews and meta-analyses [15]. PRISMA is well-regarded and endorsed by major journals and organizations as a means to enhance the quality of these reviews [16].

This study aims to review previous research by synthesizing the relevance of the topic through a thorough analysis and evaluation of various smart port concept clusters and related research areas. The study was carried out in six stages: planning the literature review, selecting databases, establishing inclusion and exclusion criteria, choosing articles, weighting the selected articles, and detailing specific indicators. The literature review process is systematic and transparent, adhering to a structured approach from identifying to interpreting all relevant studies [17] [18].

A. Literature Reviews

In the initial phase of planning a literature review, researchers commence by investigating journals listed in Scopus and adjusting their focus based on the selected research themes. The aim is to gather appropriate and high-caliber sources of the research subject. This procedure commences with identifying literature that fulfills specific criteria. The chosen sources are then meticulously assessed for their quality and pertinence. Detailed and transparent attention is given to the planning of the literature review, ensuring that each stage adheres to a rigorous methodological approach. This structured approach helps in maintaining the integrity and reliability of the review process, providing a robust foundation for the subsequent stages of the research [12][14].

B. Record Selection

During the stage of selecting a database, this research engages with the official portal of Scopus to efficiently access and evaluate relevant literature. Scopus is specifically favored due to its expansive coverage, established credibility, and provision of essential information [19] [20]. An extensive search using terms like "digital transformation," "smart port," and "management" produced a total of 3,029 research studies from around the world. The screening process takes place in multiple stages. Initially, by using specific source codes, the document collection is narrowed down to 824 during the initial screening phase. A more thorough approach is then used in the second screening phase, resulting in the identification of 85 articles. Further refinement occurs in subsequent screening phases to achieve a more nuanced selection. By applying additional filters, 41 documents are identified for detailed weighting and analysis. The next phase involves classifying the research and establishing research indicators for each selected article. This systematic and iterative process ensures a thorough and well-organized review, enhancing the accuracy and relevance of the final selection [19] [20].

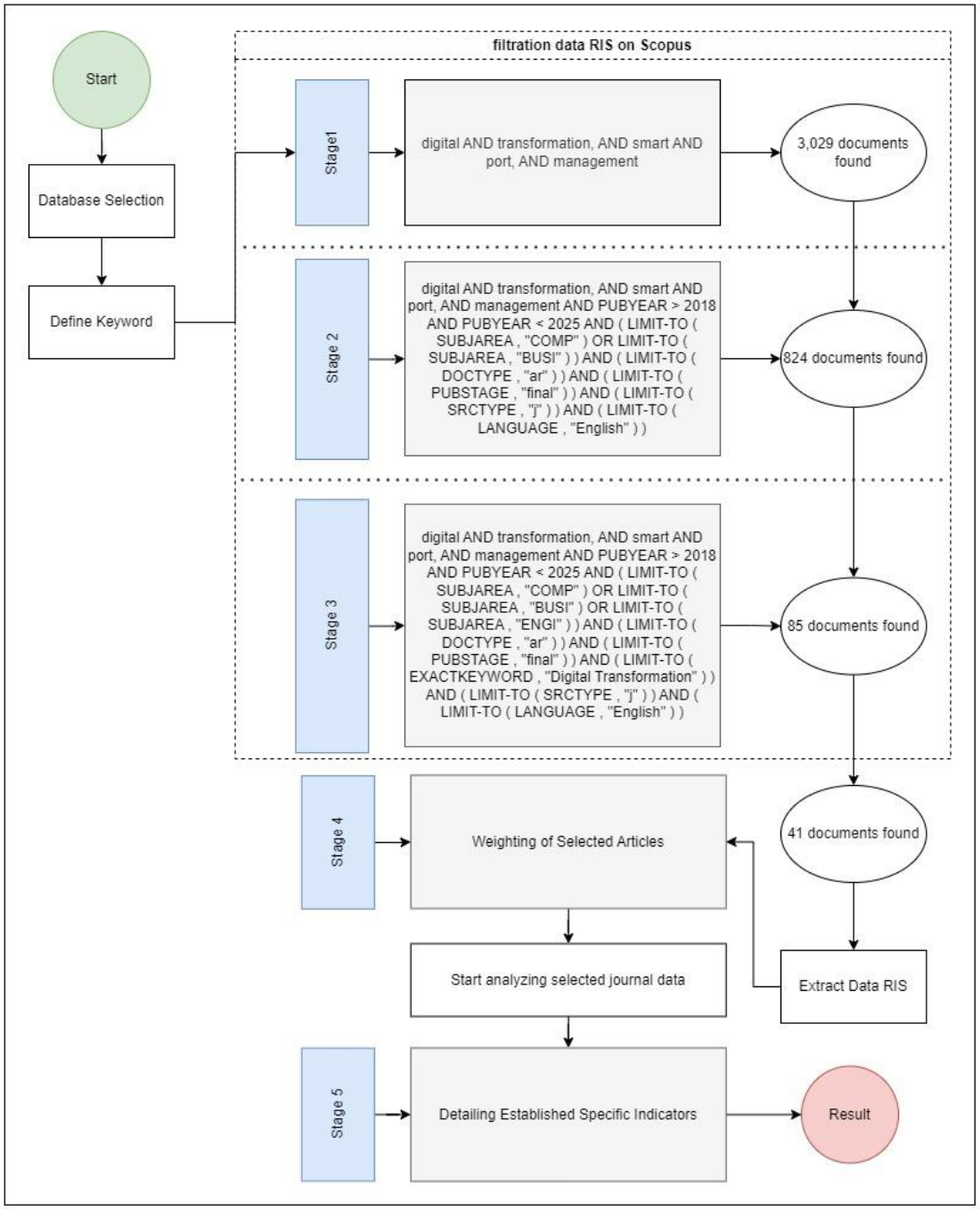
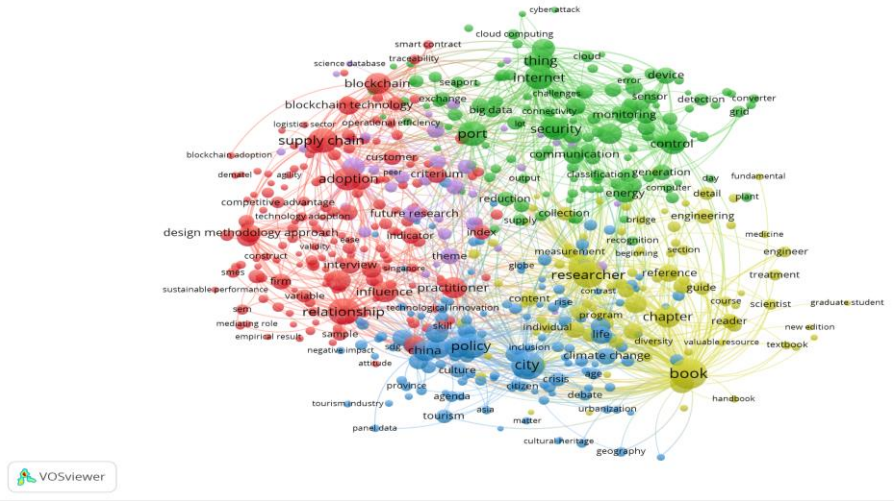


Figure. 1. RIS data filtration stages in Scopus

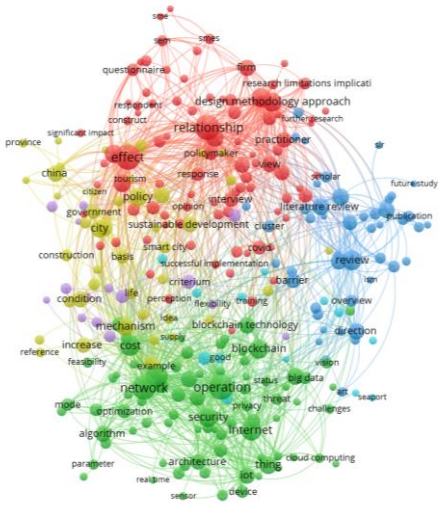
In the data selection stage, the process involves several steps to refine and extract data for visualization in a network visualization research format. The first stage resulted in finding 3,029 documents from the Scopus database. Following the initial retrieval, a filtering process was applied to narrow down the data. In Stage 2, applying specific filtering criteria reduced the dataset to 824 documents, highlighting more relevant and significant findings. Stage 3 involved further refinement using predefined pseudocode, which led to the selection of 85 documents. The final stage of the process, as depicted in Figure 1, showcases the network visualization created using VOSviewer. This visualization effectively represents the filtered data, illustrating the relationships and connections among the selected studies. This structured approach ensures a clear and insightful depiction of the research landscape, facilitating a better understanding of the key themes and connections within the field.

C. Criteria for inclusion and exclusion

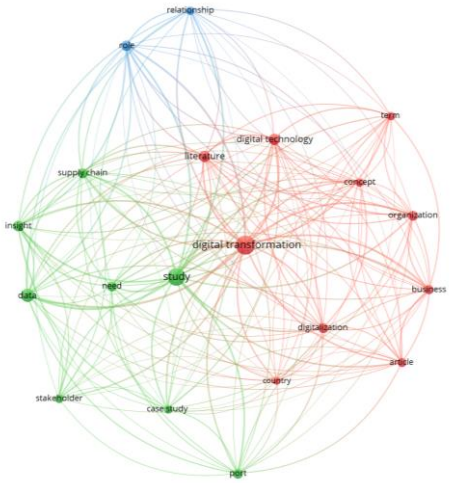
This research set specific criteria for including and excluding literature based on its quality. The search focused on publications between 2019 and 2024, aiming to cover recent research during this period. Only English-language publications were considered to ensure accessibility and broad comprehension, promoting the sharing of knowledge and interdisciplinary collaboration. The provided source code enables a targeted exploration of scientific literature, allowing researchers to access up-



(Figure 2.a)



(Figure 2.b)



(Figure 2.c)

Figure. 2. A visual representation of RIS Data Extract on Network Scientific Landscape

to-date and pertinent information at the intersection of digital transformation, smart ports, and management. This thorough approach emphasizes the significance of keeping up with trends and concepts related to smart ports and contemporary research areas. Ultimately, the source code serves as a valuable tool for researchers looking to engage with and analyze scientific literature, providing deeper insights and knowledge in their respective fields.

D. Paper Selected

The researchers carefully reviewed the chosen journals as part of a systematic literature review. This allowed them to move on to Stage 4, where they evaluated the selected articles. Initially, 85 journals sourced from Scopus were selected for further screening, resulting in 41 selected articles ready for further analysis. This comprehensive set of journals was carefully screened to identify journals that offer valuable insights into the smart port concept and research clusters. Table 1 presents the selected articles and the results of the weighting process in Stage 4. The table emphasizes the significance of the predetermined subjects and emphasizes the crucial role of data and information handling, along with digital skills, in facilitating sustainable decision-making processes in the digital era. Such a comprehensive method guarantees the incorporation of top-notch research and highlights the crucial importance of sophisticated information systems in the continuous digital evolution of port management.

TABLE 1.
DATABASE SELECTION STAGE

Publication year	Article References
2019	[21], [22]
2020	[23], [24]
2021	[25], [26], [27], [28], [29], [30], [31], [32], [33]
2022	[34], [35], [36]
2023	[37], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49]
2024	[50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61]

E. Weighting of Selected Articles

After selecting 41 articles for further analysis, each article was weighted in Stage 4 based on the relevance of its topic. The weighting of the selected articles, classified under "The Concept of Smart Port and Research Clusters," is presented in Table 2. This table showcases the research findings on key factors related to digital transformation in previous studies. The clustering of these findings includes [62]:

1. The Applications and Implications of Digital Transformation Technologies
2. Smart Port Performance Evaluation
3. Challenges and Barriers in Smart Port Development

Additionally, the role of organizations in ensuring the availability of competent resources to manage digital transformation is highlighted as a crucial aspect. Trust is recognized as a crucial factor in establishing a solid base for embracing digital technologies. The thorough method not just groups the research into separate clusters but also highlights the important elements that impact the achievement of digital transformation in port management. Through a comprehensive analysis of these articles, the research delivers a thorough comprehension of the different aspects of smart port advancement and the crucial elements that contribute to its advancement in the digital era.

TABLE 2.
WEIGHTED OF SELECTED ARTICLES IN THE CLASSIFICATION RESEARCH CLUSTERS

Article References	The concept of smart port and research clusters		
	The applications and implications of digital transformation technologies	Smart port performance evaluation	Challenges and barriers studies of smart port development
[21]	9,00	8,00	7,00
[22]	9,00	8,00	7,00
[23]	9,00	8,00	7,00
[24]	8,00	7,00	8,00
[25]	8,00	7,00	8,00
[26]	8,00	7,00	8,00
[27]	8,00	7,00	8,00
[28]	7,00	6,00	7,00
[29]	8,00	7,00	8,00
[30]	7,00	6,00	8,00
[31]	8,00	7,00	8,00
[32]	9,00	7,00	8,00
[33]	8,00	6,00	7,00
[34]	8,00	7,00	7,00
[35]	6,00	5,00	6,00
[36]	8,00	7,00	8,00
[37]	9,00	8,00	8,00
[38]	9,00	7,00	8,00
[39]	8,00	5,00	7,00
[40]	6,00	2,00	4,00
[41]	7,00	2,00	3,00
[42]	8,00	4,00	5,00
[43]	8,00	3,00	4,00
[44]	8,00	4,00	5,00
[45]	9,00	4,00	6,00
[46]	8,00	3,00	5,00
[47]	9,00	4,00	5,00
[48]	8,00	3,00	4,00

Article References	The concept of smart port and research clusters		
	The applications and implications of digital transformation technologies	Smart port performance evaluation	Challenges and barriers studies of smart port development
[49]	9,00	8,00	6,00
[50]	7,00	9,00	6,00
[51]	8,00	9,00	6,00
[52]	8,00	9,00	6,00
[53]	8,00	9,00	7,00
[54]	7,00	8,00	6,00
[55]	6,00	9,00	5,00
[56]	5,00	9,00	4,00
[57]	6,00	9,00	5,00
[58]	4,00	8,00	3,00
[59]	5,00	8,00	4,00
[60]	4,00	9,00	3,00
[61]	10,00	9,00	7,00

F. Detailing Established Specific Indicators

In the final stage of this research, each of the 41 selected articles was analyzed by establishing more specific indicators for the three clusters identified in the previous stage Exploring and assessing the review of previous research clusters is the focus of this study. The study recommends different methods for systematic literature review (SLR), including conventional SLR, rapid evidence assessment (REA), meta-analysis, scoping reviews, realist reviews, and umbrella reviews [62], [63]. With the absence of regular examination of the detailed advancements in the classification of "smart ports" in the realm of digital transformation management, it is crucial to thoroughly investigate and assess previous research by giving importance to the significance of topics covered in the chosen articles. The findings of the analysis and evaluation, displayed in Table 4, underscore the specific criteria utilized to ensure that the selected articles offer a comprehensive analysis of the importance of digital transformation from diverse standpoints.

III. Results and Discussion

The weighting that has been done on each article systematically evaluates the 41 selected articles, focusing on three main groups: Digital transformation technologies, assessment of smart port performance, and obstacles to smart port development.. Each article is analyzed using specific indicators relevant to this group. The significance of a comprehensive method in evaluating the significance and efficiency of digital transformation in smart ports is highlighted by Figure 3. It provides an in-depth perspective on the most recent advancements, possibilities, and difficulties in attaining a successful digital transformation in the industry.

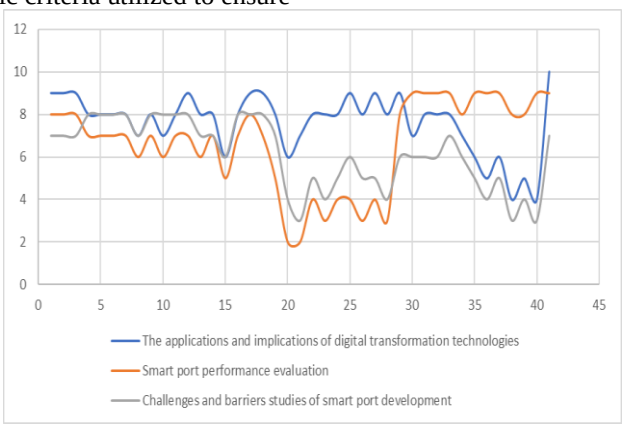


Figure. 3. Trend Analysis of Key Clusters in Smart Port Research Across 41 Selected Articles

The figure 3 above presents a trend analysis of three key clusters in smart port research, based on 41 selected articles. The clusters are the applications and implications of digital transformation technologies (represented by the blue line), smart port performance evaluation (represented by the orange line), and challenges and barriers in smart port development (represented by the gray line). The graph illustrates the variation in the number of articles discussing each cluster over the analyzed period. The trend for digital transformation technologies is relatively stable, with occasional fluctuations, indicating peaks in attention to this topic. Smart port performance evaluation also shows similar fluctuations but generally remains lower in frequency compared to digital technologies. Meanwhile, the challenges and barriers in smart port development are discussed less frequently, with a relatively declining trend over time.

The figure 4 illustrates a Pareto chart displaying the contributions of research articles to smart port development clusters. The chart shows that a small number of articles contribute significantly to the overall research in this area, while a larger number of articles contribute less. The bars represent the frequency of contributions, with the most impactful articles on the left. The cumulative percentage, depicted by the orange line, rises steeply at first, indicating that a few articles account for a large proportion of the total contributions. As the line flattens, it shows that additional articles contribute incrementally to the total. This Pareto distribution suggests that focusing on a small subset of key articles could yield the most significant insights into smart port development.

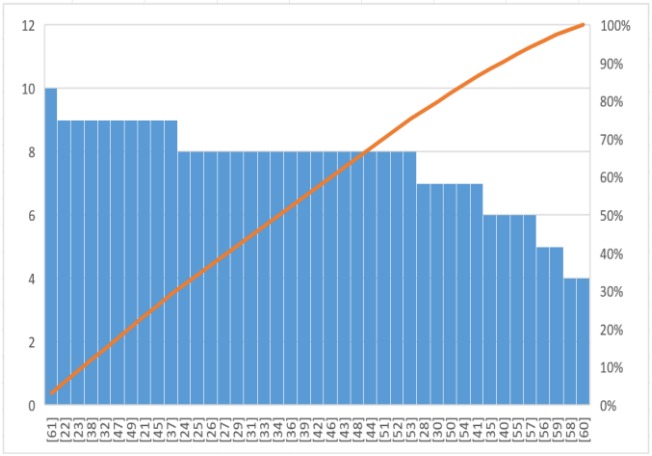


Figure. 4. Pareto Chart of Research Article Contributions to Smart Port Development Clusters

TABLE 3.
DISTRIBUTION OF RESEARCH ARTICLE CONTRIBUTIONS ACROSS SMART PORT MANAGEMENT DEVELOPMENT CLUSTERS

Contribution Level	The applications and implications of digital transformation technologies	Smart port performance evaluation	Challenges and barriers studies of smart port development
Hg (>= 7)	33	27	20
Md (6--5)	6	5	13
Lw (<5)	2	9	8
Average	7,61	6,63	6,15

The table 3 and pie chart on figure 5 presented above illustrate the distribution of research article contributions across three smart port management development clusters: the applications and implications of digital transformation technologies, smart port performance evaluation, and challenges and barriers in smart port development. The table categorizes the contributions by level—high (Hg), medium (Md), and low (Lw)—and provides the average contribution score for each cluster. The pie chart visually represents the proportion of articles in each cluster, showing that 37% of the articles focus on digital transformation technologies, 33% on performance evaluation, and 30% on challenges and barriers. This distribution indicates a relatively balanced research focus across the three clusters, with a slightly higher emphasis on digital transformation technologies.

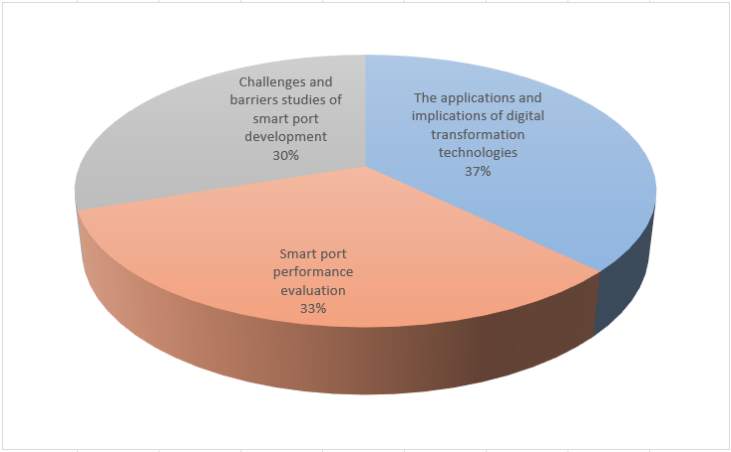


Figure. 5. Research Contributions to Smart Port Development Clusters

In this research development of smart ports, three main areas of focus have been identified. Firstly, approximately 30% of studies concentrate on "Challenges and Barriers to Smart Port Development." Secondly, about 33% of research addresses "Smart Port Performance Evaluation." Lastly, around 37% of studies explore "The Applications and Implications of Digital Transformation Technologies." By gaining a thorough understanding of these three aspects, we can better grasp the challenges and potentials associated with smart port development and optimize the implementation of digital transformation technologies for enhanced outcomes.

IV. CONCLUSION

An extensive assessment of the existing Smart Ports research is presented in this study, with specific emphasis on digital transformation technologies, performance assessment, and related difficulties. Analysis of 41 selected articles reveals that while significant contributions have been made in each area, the impact of research varies. Articles on digital transformation technologies have the highest average score, highlighting their critical role in advancing Smart Ports. Performance evaluation and the challenges and barriers faced by Smart Ports also receive substantial attention, though with somewhat lower impact. Trend graphs and Pareto diagrams demonstrate that a few high-impact articles have a disproportionate influence on the field. The findings emphasize the necessity of a thorough and systematic approach to evaluating digital transformation in Smart Ports. This study provides important observations about the present condition of the industry, recognizes significant prospects for future research, and directs individuals and groups seeking to create successful plans for sustainable digital change and improved port activities.

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