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Review

Digitalization in Maritime Transport and Seaports: Bibliometric, Content and Thematic Analysis

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Abstract: In this paper, a bibliometric, content and thematic analysis of digitalization in maritime transport and seaports was performed. The research was primarily motivated by the scarcity of similar works offering a comprehensive and recent literature analysis, the advancements of the maritime digitalization itself, and its influence on all related processes. The initial investigation phase considered 8178 publications, leading through the research steps to the final inclusion of 280 papers, the thematic and content analysis of which were performed using various bibliometric tools. The research encompassed various criteria, ranging through databases, keywords, topics, research areas and others. The resulting concept map emphasized the main concepts that digitalization in maritime transport relies on, or strives towards. The aim of the study was to address the fundamental research questions, with the tendency to define the main key points in the current maritime transport and seaport digitalization process. It can be concluded that an increasing number of authors recognize the importance of new digital technologies in maritime transport and seaports. However, with new digital technologies come specific risks such as spoofing or data manipulation that need to be further analyzed.

Keywords: digitalization; maritime transport; seaports; bibliometric analysis; content analysis; thematic analysis

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1. Introduction

The maritime transport sector represents a backbone of the globalized economy [1], and its digitalization is moving at different dynamics in different domains [2]. Digitalization in the maritime transport sector refers to the implementation of a variety of digital technologies [3], which may provide the enhanced productivity, efficiency, sustainability of business processes [4], as well as transparency [5]. It may also provide a competitive advantage by connecting all of the involved stakeholders in the value chain [6]. Ships, seaports, and offshore facilities have become increasingly dependent on information and communication technologies [7]. Despite opportunities, the digitalization and digital transformation in the maritime transport sector and seaports is slower compared to other transport sectors [8].

After the analysis of the previous research on the topic of digitalization in maritime transport, it is possible to notice several directions. An analysis of digitalization in maritime transport was conducted by Sanchez-Gonzalez et al. (2019) [2], in which the authors elaborated upon shipbuilding and ship design, in addition to maritime transport. Most authors have analyzed the impacts of a single technology/solution in maritime transport and seaports, such as the impact of Blockchain [9–11], a Port Community System [12], or the Internet of Things [13]. For example, Aloini et al. [14] analyzed the role of process coordination dynamics and information exchanges in maritime logistics, for which a case study in a mid-sized port supported by a Port Community System was developed. One of the issues regarding maritime transport digitalization is the vulnerability to cyber attacks, which can lead to the loss of vessels' control or the loss of sensitive data [15]. In this respect, digitalization brings along challenges that need to be addressed [16]. In certain instances [7,15,17–19], the security challenges of individual technologies or groups of technologies have been analyzed, such as phishing, malware, and data theft. Although these publications represent an important contribution to the current body of knowledge, there is a lack of a comprehensive overview of digitalization in maritime transport, with emphasis on the implementation of different ICT (Information and Communications Technology) solutions in various fields such as port operation planning, berth allocation, human resource planning, decision making, routing optimization, and information exchange.

In order to shape (plan) future research, it is important to first understand the current body of knowledge. The aims of this study were to provide a thorough overview of the current body of knowledge related to digitalization in maritime transport and seaports, considering the aforementioned fields, in order to address and provide answers to the main research questions arising from the digitalization process:

- What are the key research areas dealing with digitalization in maritime transport and seaports?
- What types of papers are most represented?
- What type of research methodology is most used?
- How many papers are published per year?
- Which countries have actively participated in the research?
- Which papers and authors are most cited?
- Which research categories are most analyzed?
- What are the keywords dealing with digitalization in maritime transport and seaports?

For this purpose, the bibliometric, content and thematic analysis of digitalization in maritime transport and seaports was conducted. In this way, it was possible to discover the research progress, the key themes of digitalization, and research gaps in maritime transport and seaports. Thus, this paper can assist scholars and practitioners in obtaining a comprehensive understanding of the status quo and further tendencies of digitalization in maritime transport and seaports.

The paper is structured as follows. Section 2 deals with related work and the most relevant literature referring to previous research in the field, in order to place the proposed study in the contribution context. Section 3 represents a systematic explanation of research analyses, and steps of particular phases. In Sections 4 and 5, the final results are discussed through bibliometric, content ant thematic analyses, based on which the main findings are presented. The latter refer to answers to the addressed questions, expected future outcomes, and perspectives on digitalization in maritime transport.

2. Background

This section provides an overview of the existing papers in which literature review or bibliometric analysis were used as research methods. This step is important in order to further delineate the scientific gap(s) which is addressed in this study.

Through a systematic literature review, Sanchez-Gonzalez et al. (2019) [2] have claimed that maritime transport has been accepting digitalization according to different dynamics in the different fields. They have analyzed state-of-the-art of maritime transport industry digitalization, giving an overview for ship design/shipbuilding, shipping and seaports, and defining eight domains to which the digitalization is currently applicable: "autonomous vehicles and robotics; artificial intelligence (AI); Big Data; virtual reality, augmented and mixed reality; Internet of Things; the cloud and edge computing; digital security; 3D printing and additive engineering". Their research has demonstrated that domains exist in which almost no formal research has been conducted so far, concluding that several major areas require attention, e.g., the integration of the studies on AI in the industry, and the use of robotics in maritime transport [2]. Although their focus has been on digitalization in maritime transport, they have also included, in their research, papers dealing with shipbuilding and ship design, which will not be analyzed in our paper. This paper focuses exclusively on the digitalization and implementation of various digital technologies in maritime transport and seaports. Given that digital technologies are rapidly evolving, the authors expect to identify new research directions in the field of digitalization.

Fruth and Teuteberg (2017) [20] provided a systematic literature review of the current state of digitalization in maritime logistics, and discussed existing problematic areas (e.g., the lack of theoretical studies regarding the future behavior of stakeholders in the maritime logistics chain). Furthermore, they presented potentials for improvement, e.g., by expanding their research into several areas where Big Data technology has already been implemented. Their research scope covered not only maritime transport, but also the logistics sector.

Bălan (2020) [21] conducted a literature review and focused on future advanced ICT in cargo maritime transport: Big Data, the Internet of Things, cloud computing, and autonomous vessels (including unmanned ships/vessels) [21]. The author claimed that advanced ICT will have a disruptive impact on maritime transport and supply chains in the future.

Gil et al. (2020) [22] used bibliometric methods to depict the domain of onboard Decision Support Systems (DSS) for operations focused on safety insurance and accident prevention. Despite valuable results, their research focused solely on DSS. The authors noted that maritime transport faces new challenges related to safety due to increasing traffic and ship size, respectively. They concluded that new concepts related to DSS which support safe shipping operations in the presence of reduced ship manning are rapidly growing, both in academia and in industry.

Tijan et al. (2021a) [23] performed a literature review of the drivers, success factors and barriers to digital transformation in the maritime transport sector. Due to a lack of research and scientific papers dealing with digital transformation in the maritime transport sector, the authors focused on publications which were not only related to digital transformation in the maritime transport sector but also to transport and digital transformation in general.

Yang et al. (2019) [24] conducted a literature review regarding features of an Automatic Identification System (AIS), dividing it into three development stages: basic, extended, and advanced applications. They suggest potential digitalization fostering using the system when it is combined with supplementary databases.

The above presented studies offer an important, but not comprehensive, overview of current research achievements and future research directions related to digitalization in the field of maritime transport and seaports.

3. Research Design

Bibliometric, content and thematic analysis methods can be applied to various research areas [25–27]. Bibliometric analysis can be defined as a quantitative analysis of books, articles, or other publications [26] to provide an overview of the current state on the particular topic. Content and thematic analysis helps to identify and visualize key research themes [27]. In order to provide a comprehensive overview of the current body of knowledge related to the digitalization in maritime transport and seaports, the authors established the methodological approach presented in Figure 1.

In the research design setup, the definition of the scope of the study was set together with aims, objectives and research questions (Section 1). The data collection and processing consisted of several consequent steps, including preliminary investigations, filtering based on inclusion and exclusion criteria, and reverse search analysis. The results were then obtained through the final inclusion of papers. Bibliometric, content and thematic analysis were conducted. In this respect, the authors analyzed the authors and their affiliations (by countries) actively participating in research, the most cited papers and authors, research categories and keywords, as well as key research themes. In the end, the authors provide conclusions and further considerations.

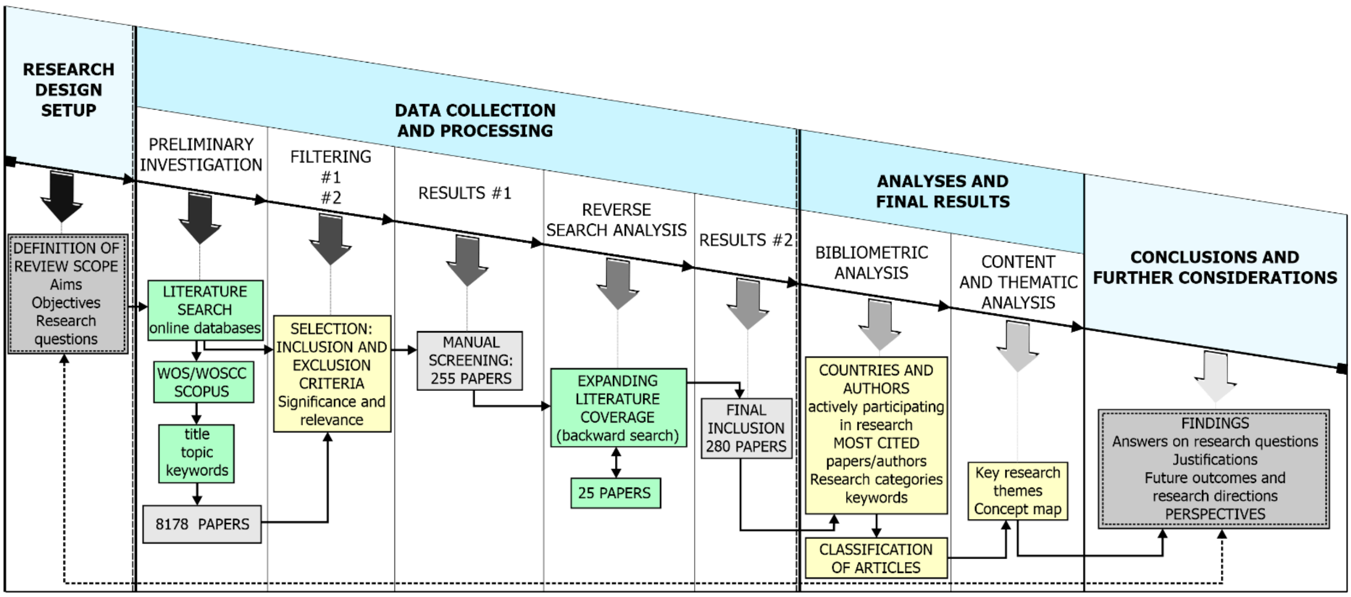

Figure 1. Research steps.

3.1. Selection of Papers

The research was conducted using Web of Science (WOS) and Scopus databases. The authors focused on 75 search strings (Appendix A), which were identified through preliminary research and a literature review. Furthermore, backward analysis was used to extend the set of relevant primary studies [28].

The inclusion and exclusion criteria that are shown in the Table 1 had to be determined in order to identify the most relevant articles.

Table 1. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Topic or Title in WOS; Article title, Abstract, and Keywords in Scopus	Papers in which digitalization is both mentioned to a small extent, and is not a main focus
Fields: ICT and other solutions/systems for port operation planning, berth allocation, human resources planning, decision making, routing optimization, information exchange, e-navigation and cybersecurity	Papers on shipbuilding industry and ship design
Categories for general keywords: "Transportation" and "Transport Science Technology", "Decision Sciences" and "Business, Management and Accounting"	Papers that explicitly referred to surveillance
No limitation to high-ranking periodical publications	Non-English language
Type of papers: journals, conference papers, and book chapters	

As shown in Table 1, the authors focused on Topic or Title in WOS, and on the Article title, Abstract, and Keywords in Scopus. Furthermore, the following related fields were considered: ICT and other solutions/systems for port operation planning, berth allocation, human resources planning, decision making, routing optimization, and information exchange in the maritime transport sector and seaports. Publications referring to e-navigation and cybersecurity were considered as well. For general keywords such as "port", which can be used both in the computing and transport, the authors limited the search to the following categories: "Transportation", "Transport Science Technology", "Decision Sciences", and "Business, Management and Accounting". Furthermore, in line with [25], the search was not limited to high-ranking periodical publications. Beside journals, the authors also considered conference papers and book chapters.

The exclusion criteria were applied to papers in which digitalization is both mentioned to a small extent and is not a main focus, such as [29,30]. Furthermore, papers on shipbuilding industry and ship design, and papers that explicitly referred to surveillance were not considered further. Non-English-language sources were excluded as well, in order to avoid the tentative regional overrepresentation of research [25]. After the described filtration, a total number of 280 papers was analyzed further.

3.2. Analysis

Two tools were used for the analyses of suitable papers. Recognising its features and abilities to facilitate the understanding of network and historical patterns, CiteSpace software was used to generate visual knowledge maps, including countries, research categories and keywords [26]. Among the features used, the authors considered the identification of the rapid-growth topical areas, the identification of geospatial collaboration patterns, and international collaboration [31].

Automated content (text) analysis was conducted using Leximancer software, which provided "concept maps" for the visualization of the results of the analyzed text. With embedded Bayesian learning algorithm' relations between concepts were visualized and aggregated with related meanings into themes [27]. According to the methodology of Vidmar et al. (2021), all of the PDF files were first converted into text files, and then text which was not related to the content (e.g., authors and their affiliation, journal names, etc.) were deleted. Standard English "stopwords" (a list of common words excluded from analysis) were added. The function "merge word variants" was also used, which combines concepts that have the same stems into one concept (e.g., singular and plural words such as port and ports are treated as one concept).

4. Results

4.1. Number of Papers per Year, and Countries

An analysis on an annual basis (Figure 2) showed that the maximum number of selected papers was published in 2020 (60 papers), followed by 2019 (40 papers), 2017 (27 papers), and 2016 (23 papers). In 2021, only 26 papers were published, as the analysis covered papers published before October 2021.

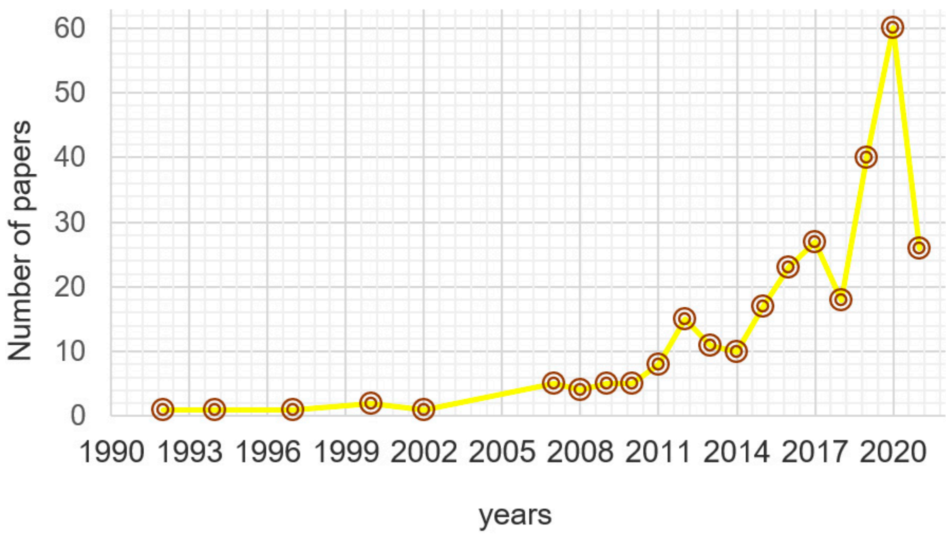

Figure 2. Paper publications per year.

The "country cooperation network" is presented in Figure 3. Within the figure, the size of the letters indicates the representation of authors with affiliations from a particular country, while the larger purple circles indicating higher centrality.

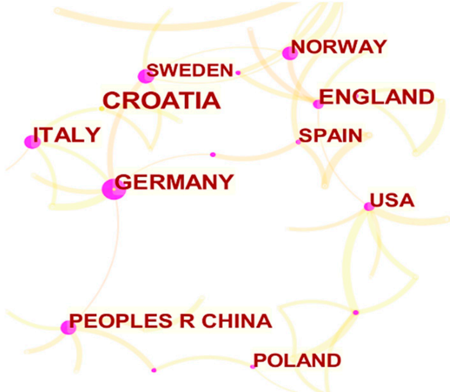

Figure 3. The visualization of the "country cooperation network".

As shown in Table 2, the authors with Croatian affiliation published the largest number of selected academic papers (40 papers in total), followed by the authors with German and English affiliations. High centrality implied the importance of the nodes. The centrality of authors with German affiliation reached 0.77, indicating that they kept a wide range of cooperation with authors affiliated with various countries such as Italy, Sweden, Colombia, and the People's Republic of China, etc. On the other hand, although authors with Croatian affiliation produced the largest output of academic papers, their poor collaboration with authors affiliated with other countries is visible, with the centrality of 0.07.

Table 2. Top 10 countries based on publications.

No.	Count	Centrality	Country
1	40	0.07	Croatia
2	25	0.77	Germany
3	23	0.37	England
4	23	0.57	Italy
5	22	0.42	People's Republic of China
6	17	0.30	USA
7	16	0.45	Norway
8	15	0.15	Spain
9	15	0.14	Poland
10	14	0.43	Sweden

After this step, further analysis was performed.

4.2. Analysis by Paper Type

The largest number of publications were journal papers (176), followed by conference papers (94) and book chapters (10), as presented in Table 3.

Table 3. Types of papers.

No.	Type of Paper	Count	%
1	Journal	176	62.86%
2	Conference	94	33.57%
3	Book chapter	10	3.57%

Most of the conference papers were presented at conferences held in Poland (11 papers), followed by Croatia (8 papers), and Russia (6 papers), as shown in Table 4.

Table 4. Top countries by the number of conference papers.

No.	Count	Country	%
1	11	Poland	11.70%
2	8	Croatia	8.51%
3	6	Russia	6.38%
4	6	Greece	6.38%
5	5	USA	5.32%
6	5	Italy	5.32%

Considering journal papers and countries, most of the papers were published in journals from England (62 in total), followed by Croatia (21) and and Netherlands (20), as shown in Table 5.

Table 5. Top five countries according to their number of journal papers.

No.	Count	Country	%
1	62	England	35.23%
2	21	Croatia	11.93%
3	20	Netherlands	11.36%
4	18	USA	10.23%
5	17	Poland	9.66%

In order to recognize the core field journals, the number of articles per journal was calculated (Table 6). TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation (Poland), with 14 published papers (accounting for 7.95%), is closely followed by the Scientific Journal of Maritime Research (Croatia) with 13 papers (accounting for 7.39%).

Table 6. Top five journals according to the number of published papers.

No.	Journal	Impact Factor (2020)		Country	Count	% Of Papers
		JCR	SJR			
1	TransNav: International Journal on Marine Navigation and Safety of Sea Transportation	-	0.25	Poland	14	7.95%
2	Scientific Journal of Maritime Research	-	0.197	Croatia	13	7.39%
3	Maritime Policy & Management	3.778	1.046	United Kingdom	10	5.68%
4	Sustainability	3.251	0.612	Switzerland	7	3.98%
5	WMU Journal of Maritime Affairs	-	0.585	Germany	5	2.84%

The classification (Figure 4) shows that 73 publications were theoretical, 76 were qualitative, and 43 were quantitative, while 88 publications included mixed methods. The classification was made according to [27].

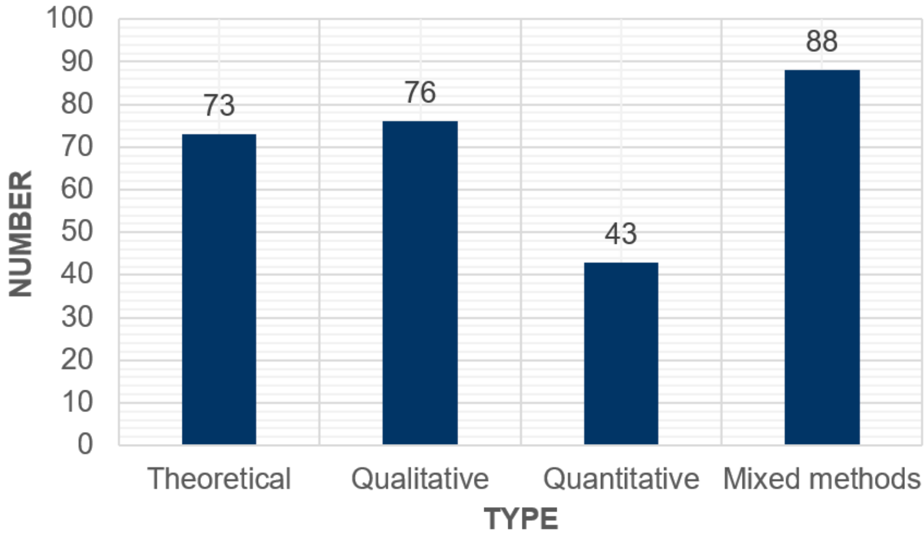

Figure 4. Distribution of the articles by their classification.

The theoretical publications mainly included frameworks based on literature and practice reviews, and the analysis of key research fields. Qualitative research mostly referred to case studies and empirically-based simulations. Regarding quantitative publications, they mainly included surveys or manipulated pre-existing statistical data using various statistical methods.

4.3. Analysis of the Most Cited Papers and Authors

As per the WOS and Scopus databases, the authors had to analyze separately the most cited papers and contributors due to several reasons. Certain papers which were included in Scopus were not indexed in WOS, and vice versa. In addition, in all cases, for the same paper, the citation numbers between the two databases differed.

In WOS, the most cited paper is "A fuzzy logic method for collision avoidance in Vessel Traffic Service" [32], with 95 citations, followed by "Maritime shipping digitalization: Blockchain-based technology applications, future improvements, and intention to use" [33], with 66 citations (Table 7).

Table 7. Most cited papers and authors according to the WOS database (9 February 2022).

No.	Paper	Authors	Total Citations
1	A fuzzy logic method for collision avoidance in Vessel Traffic Service	S.-L. Kao, K.-T. Lee, K.-Y. Chang, and M.-D. Ko	95
2	Maritime shipping digitalization: Blockchain-based technology applications, future improvements, and intention to use	C. S. Yang	66
3	How big data enriches maritime research—a critical review of Automatic Identification System (AIS) data applications	D. Yang, L. Wu, S. Wang, H. Jia, and K. X. Li	55
4	How port community systems can contribute to port competitiveness: Developing a cost-benefit framework	V. Carlan, C. Sys, and T. Vanelslander	52
5	Internet of Things and Business Processes Redesign in Seaports: The case of Hamburg	M. Ferretti and F. Schiavone	47

In Scopus, the most cited paper was the same as it was previously, with 101 citations, followed by the paper "The importance of information technology in port terminal operations" [34], with 80 citations (Table 8).

Table 8. Most cited papers and authors according to the Scopus database (9 February 2022).

No.	Paper	Authors	Total Citations
1	A fuzzy logic method for collision avoidance in Vessel Traffic Service	S.-L. Kao, K.-T. Lee, K.-Y. Chang, and M.-D. Ko	101
2	The importance of information technology in port terminal operation	M. Kia, E. Shayan, and F. Ghotb	80
3	Maritime shipping digitalization: Blockchain-based technology applications, future improvements, and intention to use	C. S. Yang	72
4	How port community systems can contribute to port competitiveness: Developing a cost-benefit framework	V. Carlan, C. Sys, and T. Vanelslander	63
5	Internet of Things and Business Processes Redesign in Seaports: The case of Hamburg	M. Ferretti and F. Schiavone	62

4.4. Analysis of the Categories

Categories can reflect the development level of research on a specific subject during a given period [26]. The related literature in both databases was comprised of approximately 75 subject categories, the most frequent of which are shown in Figure 5.

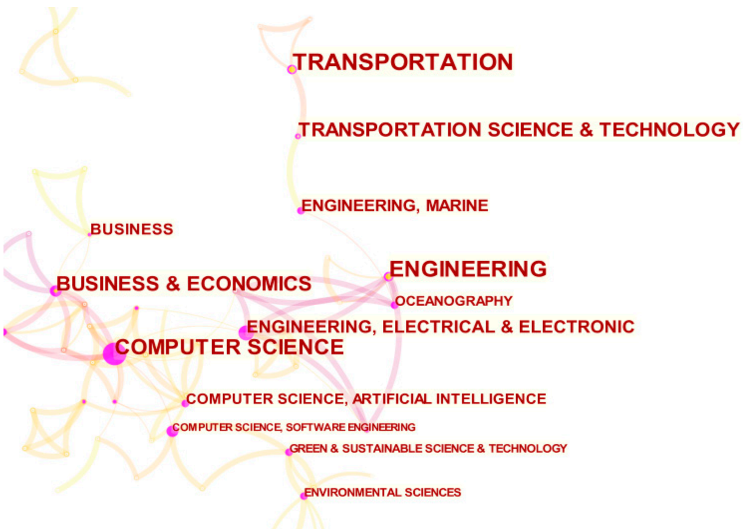

Figure 5. Categories based on the publications.

The top five subject categories (Table 9) include Transportation, Engineering, Computer Science, Business and Economics, and Transportation Science and Technology. The distribution of the categories suggests that issues in transportation, engineering, computer science, business and economics were highly prioritized in research.

Table 9. Top five categories based on publications.

No.	Subject Category	Count
1	Transportation	84
2	Engineering	73
3	Computer Science	52
4	Business and Economics	43
5	Transportation Science & Technology	39

4.5. Analysis of the Keywords

In the analysis, the authors included Author Keywords and Keywords Plus in the Term Source field. Once the synonyms for each term were merged (e.g., "Port Community System" and "PCS"), the keywords emerged as shown in Table 10.

Table 10. Top 10 keywords by frequency (Author Keywords and Keywords Plus).

No.	Keywords	Count	No.	Keywords	Count
1	Port (Seaport, Harbour)	41	6	Internet of Things	19
2	Port Community System (PCS)	27	7	Model	18
3	Big Data	26	8	Management	17
4	Information System	22	9	Information technology; System; Blockchain	16
5	Supply chain; Digitalization	21	10	Ship; Logistics; Technology; Smart port; Artificial Intelligence	15

The most prominent keyword in the field of digitalization in maritime transport and seaports was the term "Port", with the highest frequency (41). It was followed by the terms "Port Community System" (27), and "Big Data" (26). In terms of technologies, the keyword "Port Community System" appeared the most times, and it was the term used in one of the 75 search strings the authors used for this topic. However, "Big Data" was not one of the chosen keywords. Nevertheless, it was at the very top according to frequency. In this respect, modern technologies such as the Internet of Things, Big Data, and Blockchain, etc., are also playing an increasing role in the digital transformation in the maritime transport sector and seaports.

4.6. Content and Thematic Analysis

During the content and thematic analysis, 15 themes were identified (as shown in Figure 6); the order descends according to the number of matches from the analyzed text.

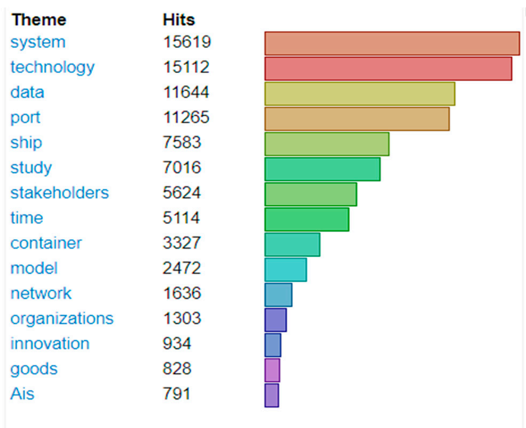

Figure 6. Identified themes and their distribution in the analyzed publications.

The themes are the following: “system”, “technology”, “data”, “port”, “ship”, “study”, “stakeholders”, “time”, “container”, “model”, “network”, “organizations”, “innovation”, “goods”, and “AIS”.

The “concept map” is shown in Figure 7.

The concept map consists of themes (colored circles) and the concepts that form each theme (the black text within the themes). The importance of the themes is shown as a “heat map” (the brighter the theme, the more often it was found in the analyzed text) and size (the larger the theme, the more concepts were combined in it) [27].

The concept map also shows the overlapping of the themes, e.g., “technology” and “innovation”, and which concepts are shared between two themes. Equally, the concept “digital” lies in the overlap of the themes “technology” and “innovation”, along with which relationships between the concepts maintain relationships between the themes, e.g., “process”, “digital”, “adoption” and “innovation”.

As the themes “technology” and “system” have the highest number of occurrences, and for the sake of clarity, the results were discussed first from a technology and then from a system perspective.

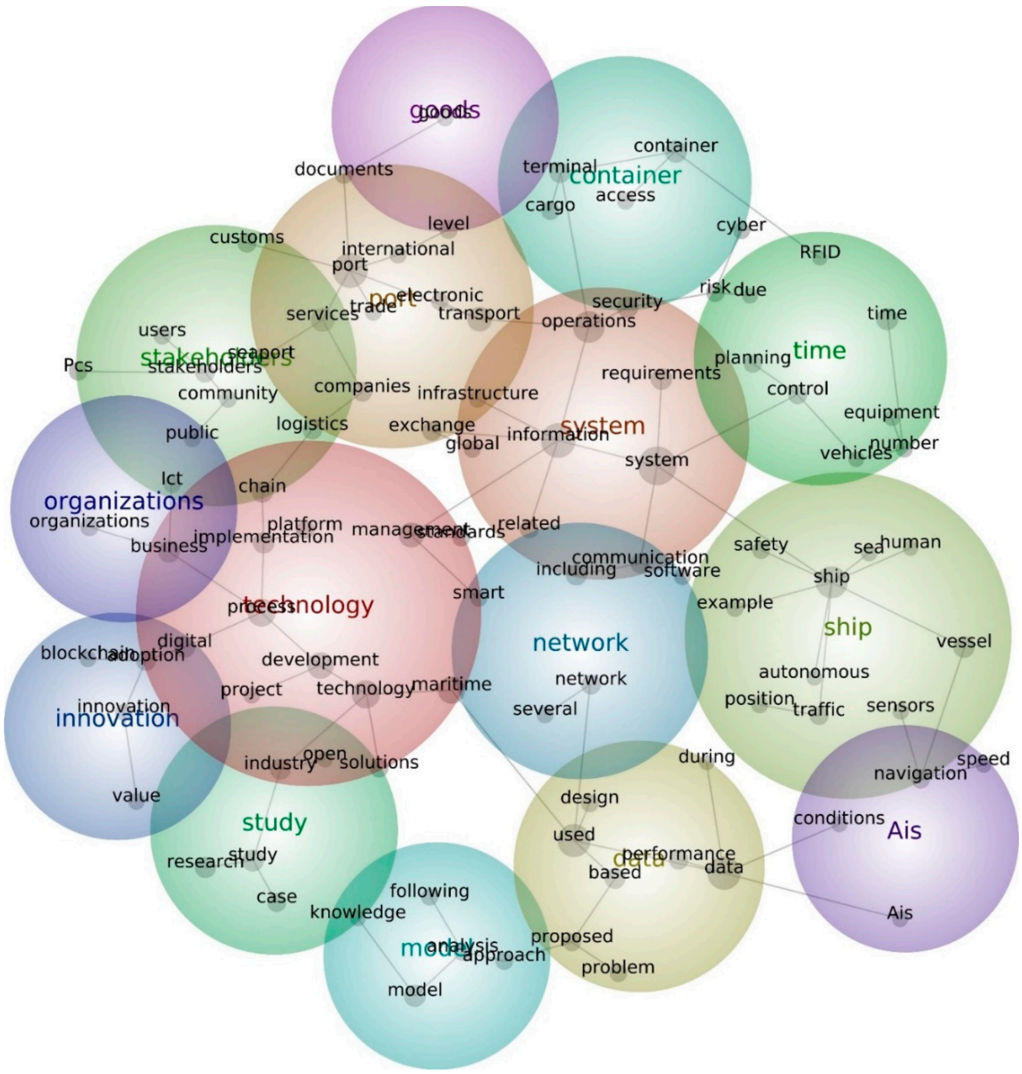

Figure 7. Leximancer concept map.

4.6.1. The “Technology” Perspective

The concept map shows that the theme “technology” overlaps with the following themes:

- "Study": Three concepts are shared between the themes "technology" and "study", namely, "open", "industry", and "solutions". Two paths connect the themes "technology" and "study". The first path which connects the themes "technology" and "study" leads through the concepts "maritime", "technology", "industry", "study" and "research" or "case", and confirms that the research regarding the influence of technologies on maritime industry already exists. In addition, a larger number of studies are case studies, such as [35–40]. A similar explanation is related to the second path, which links the themes "technology" and "study" through the concepts of "technology" and "solutions".
- "Innovation": The concepts "digital" and "adoption" were shared between the themes "technology" and "innovation", with two paths connecting "technology" and "innovation". The first path leads through the concepts of "process", "digital", "adoption", "innovation", and "value". Several authors connect digital technology with added value. For example, [41] claims that digital technology implementation results in a higher overall customer perceived value. According to [42], technology innovation works as a tool to integrate sustainability into the business model, creating long-term value. The second path leads through the concepts of "process", "digital", "adoption", and "blockchain". According to [43], intraorganizational factors such as company size, top management support and organizational structure affect the adoption of technological innovations. According to [41], trust is important for the adoption of new technology and open innovation. Furthermore, digitalization has been investigated increasingly, as the maritime industry is at the transition phase to a smarter and more digital environment surrounded by different digital innovations, including Blockchain adoption [41]. This statement is proven by the fact that several authors have recently researched the impact of Blockchain technology in the maritime transport sector, such as: [10,11,33,44–51].
- "Organizations": The concept of "business" is shared between the themes "technology" and "organizations". Two paths connect the themes "technology" and "organizations". The first path leads through the concepts "technology", "business" and "organizations". The second path leads through the concepts "technology", "business" and "ICT". The authors of [52] claim that ICT enables organizations to achieve a competitive advantage. According to [4], organizations are supported by innovative methods, technologies and tools that offer increasing flexibility and performance at lower prices. The authors of [23] claim that the integration of ICT systems may improve data exchange, management and business planning.
- "Stakeholders" and "Port": The term "chain" as a concept is shared between the "technology" and "stakeholders" themes. However, one path connects three themes: "technology", "stakeholders" and "port". It leads through the concepts of "implementation", "chain", logistics", "companies", and "services", and continues its path toward "port" in one direction, and "seaport" stakeholders" and "community" in another. According to [42], the use of digitalization and new technologies improve the processes management, positively affecting the shipping companies' long-term profits and generating a reputational advantage for stakeholders. According to [4], electronic data interchange has a strong impact on the overall logistics chain's efficiency, as it speeds up business processes. However, huge investments in an appropriate IT "network" are required at the port level. The authors of [53] claim that supply chains are becoming more integrated, making hinterland operations more pronounced. In this respect, port authorities can facilitate the technology's application, enabling better insights into traffic flows. Consequently, companies will be able to optimize their supply chains. The authors of [54] claim that the sea–land supply chain represents a promising field for researching the effects of digital technologies on operation management.
- "Network" and "Data": Two concepts are shared between themes "technology" and "network", namely "maritime" and "smart". However, two paths connect three themes: "technology", "network" and "data", which leads to the concepts: "technology",

"maritime", "used", and "data" in one direction, and "management" and "smart" in another. The authors of [55] claim that the wide implementation of novel technologies (e.g., Cyber–Physical Systems, the Internet of Things, and the Internet of Services) was included in Shipping 4.0, offering smarter embedded computers for onboard equipment, and providing a variety of new information and data, along with a range of shore facilities.

4.6.2. The "System" Perspective

The resulting overlapping of the "system" theme with others, as presented in Figure 7, is elaborated in the continuation.

- "Port": "Infrastructure" as a concept is shared between both the themes of "system" and "port". In this respect, several studies analysed the following: [53] quoted the authors Hlali and Hammami, according to whom the seaport may be defined as a multidimensional system combining between an economical function, an infrastructure system, a geographical space and trade. John et al. (2018) [56] claim that seaport facilities may be considered as critical infrastructure systems which are vulnerable to various risks due to their complex structures. Thus, it is necessary to protect them from threats by using robust and sophisticated security systems, and measures for early detection. Regarding the themes "port" and "system", several authors refer to the Port Community System, which improves data exchange between stakeholders, for example [12,19,36,57,58].
- "Container": The theme "container" overlaps with "port" and "system". The authors of [59] analysed processes including the Port Community System, containers, and involved stakeholders. The authors of [60] mentioned the truck appointment system that enables truck drivers who want to deliver or collect containers at the terminal to provide, in advance, their administrative details to the terminal operator's e-portal.
- "Time": One path connects themes "time" and "system", which leads to the concepts "system", "control" and "planning", or "system", "control", and "vehicles". For example, [61] claim that automated transfer vehicles are one of the most obvious examples of the importance of information and communication technologies in container terminals, as they allow a higher flow of containers and significantly reduce the time needed for serving ships.

Although the theme "system" does not overlap with the themes "ship" and "AIS", the aforementioned themes are closely connected. For example, [62] analysed the system that controls and operates the ship, and which—among others—enables the monitoring of autonomous ships from onshore control centres. Furthermore, [63] analyzed 5G-based ship AIS intelligent control systems. The system can, among other features, process the information of vessels in the navigational area in a systematic manner, and can automatically arrange the vessel information in real time, providing feedback.

5. Discussion and Future Research Perspectives

In order to understand the frequency of publication, an analysis of published papers per year was conducted. The maximum number of selected papers was published in 2020. The development of new technologies is accelerating, and an increasing number of researchers are focusing on digitalization and the impact of digital technologies in maritime transport and seaports.

The authors with Croatian affiliation published the largest number of selected academic papers, followed by authors with German and English affiliations. The authors with German affiliation maintained extensive cooperation with authors affiliated with other countries, including Italy, Sweden, Colombia, the People's Republic of China, and others. On the other hand, despite the fact that the authors with Croatian affiliation published the most papers, there was a lack of engagement with authors affiliated with other countries.

Regarding the conference papers and countries, most conference papers were presented at conferences held in Poland, followed by Croatia and Russia. In order to recognize core field journals, the number of articles per journal was calculated. According to the results, journals focused on maritime transport had the most published papers. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation (Poland), was the journal with the largest number of published papers relating to this research.

Comparing the Web of Science and the Scopus citations, a different number of citations for the same publications is visible. There are several reasons for this, such as the citations being affected by the size of the databases, and different citation practices between publication types existing, etc. Despite this, in both databases, the most cited paper was "A fuzzy logic method for collision avoidance in Vessel Traffic Service" [32]. The top five subject categories are Transportation, Engineering, Computer Science, Business and Economics, and Transportation Science and Technology.

It is necessary to compare the results from the Leximancer tool, which was used to analyse key concepts and themes, and the CiteSpace tool, which was used to analyse categories. Several differences can be noted. Firstly, full access to a paper is a precondition for the detailed analysis. The results from Leximancer are not terms consisting of several words. In this respect, it is necessary to compose a term from the obtained results (words i.e., concepts or themes). For example, in CiteSpace, one of the top 10 keywords is "Information System". In Leximancer, "system" is a theme, and "information" is a concept which is part of the aforementioned theme. The words that are most often repeated in both tools are: Port, Community, System, Data, Information, Chain, Model, Management, Technology, Blockchain, Ship, Logistics, and Smart. However, in Leximancer, "Internet of Things", "Big Data" and "Artificial Intelligence" are missing. For comparison, in CiteSpace, the keyword "Big Data" is in third place in terms of frequency. On the other hand, two of the concepts are "ship" and "autonomous" in the Leximancer tool. In CiteSpace, the keyword "autonomous ships" is not among the 17 most frequently mentioned keywords. In this respect, for a successful analysis, it was necessary to approach the topic from several perspectives.

Through the analysis of keywords, categories and themes, the most and least researched areas were identified. Based on this, topics that are not explored well enough (as they have the lowest number of hits) and should be more researched at the level of the maritime transport sector will be explained below.

5.1. Future Research Directions Based on the Results Obtained by CiteSpace and Leximancer

As was already mentioned, the Leximancer results differ from the CiteSpace results. In other words, using Leximancer, the most frequently mentioned terms are isolated, i.e., they formed the so-called groups; however, in order to understand the meaning of these terms, it was necessary to manually review the papers and derive a conclusion (which may be considered as one of the limitations). For example, the term "goods" is not the main focus" in numerous papers, but this term is mentioned when introducing a particular issue. Therefore, it was necessary to analyse the publications that contain the term "goods" in order to be able to derive future research directions.

On the other hand, regarding the CiteSpace results, the term can contain more words. In this case, for future research directions, the authors also used the terms with the lowest number of hits based on keywords; however, some keywords were not included, such as: "efficient", "usage", and "marine transport", etc., because it was not possible to derive meaningful conclusions (which may represent a limitation of the CiteSpace tool). Our suggested future research directions were also based on future research directions suggested by authors in their papers.

Table 11 shows the terms that had the lowest number of hits in Leximancer and CiteSpace. In addition, Table 11 shows what has been researched in the papers and what is missing in the papers, on the basis of which future research directions have been presented.

Table 11. Future research directions.

Term	Already Analyzed Topics	Future Research Directions
AIS (Automatic Identification System)	A data-driven method for detecting delays of vessels, considering stages, using historical shipping data and real-time S-AIS vessel tracking data [2,64]	Inclusion of other various types of data such as weather and social data [64]
AIS (Automatic Identification System)	Developed concept of using AIS data in a disaster relief operation [65]	AIS for planning and supporting humanitarian relief operations [65]
AIS (Automatic Identification System)	The proposition of AIS-based maritime route extraction method for realization of vessels' traffic routes extraction [66]	Consideration of vessels' type influence in function of improvement of the proposed method, along with usual parameters (water depth, distance from coastline, and number of vessel navigation characteristic area and points, e.g. stop- and waypoint areas, ship stop points, etc.) [66]
AIS (Automatic Identification System)	AIS analyses which could be the use cases and services of a smart port [67]	Possible use of AIS data for computing CO2 emissions of vessels, proposing berth allocation problems, and improving prediction and modeling of vessel trajectories [67]
goods	The impact of PCS in terms of managing goods in sea-land supply chain or port supply chain [54,68], the advantages of Smart contracts (the automatic change of ownership of goods) [45]; The role of Blockchain regarding goods transportation records [46]	The application of new digital technologies for the processing of goods in ports and sea-land supply chain [54,69]
innovation	Innovation strategy for Turkish port for successful development of a port community system, using SWOT analysis [70]	Guideline for policy makers regarding innovations in maritime transport and seaports
innovation	Digital innovation in the port (barriers and facilitators) [60]	How to improve the cooperation among stakeholders in order to support the successful adoption of innovation [60,71]
innovation	Not applicable because no direct link has been found between the terms "innovation" and "PCS" from which a conclusion could be drawn	A lack of research studies regarding PCS innovations, which risks relegating PCS research to irrelevance [72]
innovation	Not applicable because no direct link has been found between the terms "innovation" and "cyber risks" from which a conclusion could be drawn	Methods for mitigating cyber risks which are increasing with the development of new digital technologies (innovations) [73]

Table 11. *Cont.*

Term	Already Analyzed Topics	Future Research Directions
innovation	Investigation of how the adoption of emerging digital technologies (innovations) can provide valuable business opportunities for logistics centres in maritime supply chains [74]	Innovations such as IoT, Blockchain, Mobile devices are still insufficiently researched or neglected [74]
innovation	Analyzed projects introduced in the ports of the North Sea and Baltic Sea which are successively implementing the concept of a Smart Port [75]	Which technologies to choose, how to implement them remains a challenge; in the context of smart ports [75]
innovation	Discussed conceptual evolution from Human-Automation Interaction to Human Autonomy Teaming and presented the risks of high levels of automation and the importance of teamwork in safety critical systems [76]	Recent technological advances (innovations) in the field of Artificial intelligence which can increasingly affect maritime transport sector [76]
innovation	Introduced a three-dimensional (3D) GIS applied to maritime navigation [77]	The range of innovations required to reach real-time 3D monitoring of marine navigation [77]
Innovation and organizations	Not applicable because no direct link has been found between the terms "innovation" and "organizations" from which a conclusion could be drawn	What is necessary to mitigate diversity of attitudes towards adoption of innovations by people (it has sometimes been argued to be the outcome of some cultural resistance to new products and technologies—a factor that may hinder widespread adoption) [78]
Organizations	Drivers, success factors and barriers of digital transformation in organizations [23]	Further studies necessary to gain deeper insights into how to design successful digital transformation [23,78]
surveillance	The importance of maritime surveillance for safety and security of sea traffic, using different technologies (e.g., satellite technology) [8,79]; the information systems and the corresponding traffic or sensor data collected for ship tracking, monitoring and maritime traffic surveillance [80], e.g., AIS [65,66,81], coastal radar etc.	What kind of IT-infrastructure is necessary to enable shore-based traffic monitoring as complement to current surveillance and monitoring services, such as VTS [82]; for the purpose of more qualitative and comprehensive maritime traffic surveillance [79]
surveillance	The importance of surveillance cameras in seaports [17]	The possibilities of smart video surveillance systems [83]

Table 11. *Cont.*

Term	Already Analyzed Topics	Future Research Directions
E-booking systems	Explored the use of e-booking systems in the maritime supply chain and, in particular, the factors influencing the adoption of such systems at the organizational level (multi-case study of eight firms across multiple tiers of the maritime supply chain) [43]	For more detail research, ownership structure and firm size, which might affect the adoption of information system can be included in the research [43]
Ship route planning	Proposed method specialized in generating optimal ship planning routes for a timely maritime emergency search and rescue, reducing the execution time for maritime search and rescue services in practical applications [84]	Further investigation of possibilities of suggested method, that may provide a tremendous amount of information for maritime emergency search and rescue without the assistance of the widely-used electronic chart [84]

It can be noticed that—in some publications—the terms are overlapping, as in the case of “innovation” and “organization”. Organizations are most often mentioned in the context of “cooperation between organizations”, “specifics of individual organizations”, and “competitiveness between organizations”, etc., but as introductory sentences to a particular issue.

5.2. Future Research Directions Related to Advanced Digital Technologies in Maritime Transport

Despite the numerous benefits that Leximancer and CiteSpace provide, it was necessary to read the publications manually in order to ensure that all of the important publications were included. What was missing were, for example, the keywords that mention “5G”, which is a promising research direction. In this regard, the authors have singled out some topics that could be analysed. These topics refer to advanced digital technologies which represent the main drivers of digitalization and digital transformation [23]. The importance of advanced technologies has been recognized by the European Commission as well. In this respect, certain strategies have been developed, such as the AI strategy, which aims to streamline research and policy options for AI regulation [85].

As was demonstrated by the keyword analysis, Artificial intelligence is gaining increasing attention from a number of researchers. AI is usually mentioned in combination with other digital technologies. The combination of AI and “unnamed vessels” refers to vessels that can learn from situations, and can consequently plan and implement a journey. However, AI implemented in procedures related to unmanned vessels can be dangerous. It is important to explore what cybersecurity measures need to be implemented in order to avoid negative consequences separately for various system types (e.g., storyless systems). In addition, one of the research directions is the definition of digital technologies’ combinations which is required in order to minimize or eliminate the negative consequences, such as data breaching, spoofing, or data manipulation. Furthermore, with the combination of AI and Big Data, it is possible to improve the usage of all of the available information. However, possible policy guidelines need to be explored further in order to reap the full benefits of such technologies without compromising data security and privacy.

The lack of research was noticed in the field of AI and optimized port operations. One of the AI applications in seaport operations was analysed by [3]. According to their research, AI can be used determine which container to stack or unload first.

Regarding Artificial Intelligence and machine learning, this combination led to the creation of smart AI-enabled automation systems that can process large amounts of data, evaluate alternatives, and execute decisions [76]. However, machine learning is sensitive to errors, which can go undetected for a long time. Therefore, future research should focus on safety related to machine learning in combination with artificial intelligence. Artificial intelligence and sensors can also be combined. This combination may enable improved decision making, optimized business processes, and reduced harmful environmental impacts.

According to [86], AIS data combined with various artificial intelligence techniques will play an important role in shipping analysis services. It will be easier to approach strategic and operational information on any vessel or fleet of vessels at the global level. However, despite the numerous system opportunities, AIS has numerous vulnerabilities and pitfalls, as it is an open system transmitting on dedicated VHF frequencies. Further research is needed in order to ensure that data can be used without negative consequences (such as AIS spoofing).

The applications and benefits of the Internet of Things in the maritime transport sector are widely analysed, and their shortcomings should also be considered. For instance, the combination of the Internet of Things and sensors may provide data on cargo status in a timely manner, which consequently improves decision making. On the other hand, there appears to be an increased risk of security breaches and potential data manipulation.

Another research direction may be focused on smart ports and automation. The combination of various digital technologies and automation may improve monitoring, control, and planning of business processes in the maritime transport sector and seaports. However, it is necessary to bear in mind that "the more complex the system, the greater the probability of errors and disturbances in the system" [87].

A promising research direction is 5G network application in maritime transport. The authors of [63] analyzed a 5G communication ship traffic intelligent analysis platform, which can fundamentally strengthen the performance related to information collection. If 5G and AI are combined, the AI vulnerabilities may be exploited in cyber-attacks, while the "deployment of 5G network infrastructure will expand the attack surface area" [7].

Although PCSs have already been implemented in numerous ports, with the advent of new digital technologies it is possible to expand the PCSs' functionalities. For example, Blockchain technology may foster business processes and cost reductions. On the other hand, and especially if there are weak network security measures, PCSs are prone to intentional attacks. In this context, it is important to analyse what combination of digital technologies and security measures are required in order to minimize various types of negative consequences.

Several limitations exist in the paper. First of all, the tools recognized only the most frequent keywords, relations between them, and conceptualizations of themes. The research is based on a literature review and, considering the nature and evolution trends of the elaborated topic, the presented state-of-the art could soon fall into the previous research category, as was found for numerous related pieces of research. Nevertheless, the proposed research reflects the current digitalization progress in the field, and it can serve as a sound basis for consequent, similar studies. Furthermore, only two (although leading) databases were used—Web of Science and Scopus—and articles that were not written in the English language were excluded. On the other hand, bibliometric, content and thematic analysis provided a comprehensive overview of the current body of knowledge, and facilitated the identification of the research gaps.

The authors applied a methodological approach for the processing of publications dealing with digitalization in maritime transport and seaports. Furthermore, the aim was to answer fundamental research questions while also defining the main key points in the current maritime and seaport digitalization processes.

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Appendix A

Table A1. Search process in WoS and Scopus databases.

Search Strings	Articles after Applying Formal Criteria		Articles after Screening Manually		Criteria	
	Web of Science	Scopus	Web of Science	Scopus	Web of Science	Scopus
digitalization AND maritime transport	13	12	10	2		
digitalization AND maritime transportation	5	6	0	1		
digitalization AND maritime industry	16	23	3	3		
digitalization AND shipping	48	54	7	7		
digitalization AND seaport	13	19	4	4		
digitalization AND port	30	61	1	3		
digitalisation AND maritime transport	0	12	0	0		
digitalisation AND maritime transportation	0	6	0	0		
digitalisation AND maritime industry	3	23	0	0		
digitalisation AND shipping	7	54	0	0		
digitalisation AND seaport	1	19	0	0		
digitalisation AND port	3	61	0	0		
ICT AND maritime transport	27	14	1	0		
ICT AND maritime transportation	10	18	0	0		
ICT AND maritime industry	11	10	0	0		
ICT AND shipping	70	74	0	0		
ICT AND seaport	20	24	0	0		
ICT AND port	278	179	0	9		
Information technologies AND maritime transport	99	23	18	3		
Information technologies AND maritime transportation	54	26	7	3		
Information technologies AND maritime industry	179	34	18	1		
Information technologies AND shipping	357	253	9	1	Transportation	
Information technologies AND seaport	51	42	9	5		
Information technologies AND port	251	105	10	2	Transportation	Decision sciences, Business, Management and Accounting
Information system AND maritime transport	214	49	11	1		
Information system AND maritime transportation	176	60	7	1		

Table A1. *Cont.*

Search Strings	Articles after Applying Formal Criteria		Articles after Screening Manually		Criteria	
	Web of Science	Scopus	Web of Science	Scopus	Web of Science	Scopus
Information system AND maritime industry	177	36	6	1		
Information system AND shipping	277	74	0	1	Transportation science technology, transportation	Decision sciences, Business, Management and Accounting
Information system AND seaport	198	79	3	2		
Information system AND port	223	126	6	1		Decision sciences, Business, Management and Accounting
Port community system	48	74	22	4		
Information support system AND maritime transport	60	0	0	0		
Information support system AND maritime transportation	49	0	0	0		
Information support system AND maritime industry	50	0	0	0		
Information support system AND shipping	64	0	0	0	Transportation science technology, transportation	
Information support system AND seaport	38	0	1	0		
Information support system AND port	41	3	1	0	Transportation	
Decision support system AND maritime transport	81	35	5	0		
Decision support system AND maritime transportation	99	61	0	2		
Decision support system AND maritime industry	51	24	2	0		
Decision support system AND shipping	126	79	0	2	Transportation	Decision sciences, Business, Management and Accounting
Decision support system AND seaport	69	46	0	0		
Decision support system AND port	83	105	0	1	Transportation science technology, transportation	Decision sciences, Business, Management and Accounting
Integrated system(s) AND maritime transport	172	3	0	0		
Integrated system(s) AND maritime transportation	128	7	1	0		
Integrated system AND maritime industry	138	8	0	0		
Integrated system AND shipping	194	66	1	0		
Integrated system(s) AND seaport	14	8	0	0		
Integrated system(s) AND port	163	207	1	0		
Digital technologies AND maritime transport	23	4	1	0		

Table A1. *Cont.*

Search Strings	Articles after Applying Formal Criteria		Articles after Screening Manually		Criteria	
	Web of Science	Scopus	Web of Science	Scopus	Web of Science	Scopus
Digital technologies AND maritime transportation	7	2	0	0		
Digital technologies AND maritime industry	36	4	0	0		
Digital technologies AND shipping	214	21	1	0		
Digital technologies AND seaport	14	6	0	2		
Digital technologies AND port	401	44	0	0		
Digital data sharing AND maritime transport	6	0	2	0		
Digital data sharing AND maritime transportation	1	0	1	0		
Digital data sharing AND maritime industry	6	0	4	0		
Digital data sharing AND shipping	21	0	0	0		
Digital data sharing AND seaport	1	0	0	0		
Digital data sharing AND port	34	0	0	0		
Digital Maritime Traffic	28	0	0	0		
Integrated Maritime Digital Information System	15	0	1	0		
Maritime Single Window	54	11	3	0		
Maritime National Single Window	13	3	6	1		
National Maritime Single Window	14	4	0	0		
Modern seaports	81	12	1	0		
Seaport Integration	122	5	0	0		
Seaport Modernization	18	1	0	0		
Digital transformation AND maritime transport	3	4	1	1		
Digital transformation AND maritime transportation	2	4	1	1		
Digital transformation AND maritime industry	11	10	0	0		
Digital transformation AND shipping	27	22	1	1		
Digital transformation AND seaport	8	8	0	0		
Digital transformation AND port	48	24	1	1		
TOTAL	8178	255	188	67		

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