Stakeholder digital transformation model in the maritime transport sector

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SVEUČILIŠTE U RIJECI

POMORSKI FAKULTET

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MODEL DIGITALNE TRANSFORMACIJE DIONIKA U SEKTORU POMORSKOG TRANSPORTA

DOKTORSKA DISERTACIJA

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Abstract

In this dissertation, a universally applicable model of digital transformation of stakeholders in the maritime transport sector was created and validated. The model will help stakeholders shape more successful digital transformation strategies. First, bibliometric, content and thematic analyses of digitalization and digital transformation in maritime transport and seaports were performed using the CiteSpace and Leximancer tools. The research included various criteria, for example analysis by keywords, topics and research areas. The goal was to address fundamental research questions in order to define the key points in the current process of digitalization and digital transformation of maritime transport and seaports.

The success factors that influence the digital transformation of stakeholders operating in the maritime transport sector, as well as drivers of digital transformation and barriers to its implementation, were then identified and analyzed. Drivers, success factors and barriers were grouped according to the Technology-Organization-Environment (TOE) framework, i.e., in three aspects: the technological aspect referring to the acceptance and implementation of modern technologies and innovations, their security and interoperability; the organizational aspect referring to organizational resources, organizational structure, communication among employees within the organization, and the aspect pertaining to the external environment which affects activities of the organization and its growth.

Given the notable lack of literature on the topic of digital transformation in maritime transport and seaports, additional literature review and analysis were required before the research model could be created. For this reason, the digital transformation was analyzed from the perspective of three digital technologies and information systems: Maritime National Single Window, Blockchain and Port Community System. In addition, digital information services as drivers of digital transformation were analyzed. Then, qualitative methods were used to investigate the relevance of the factors, based on information obtained from experts in the maritime transport sector, who possess substantial experience in the field of digital transformation.

In the last phase, the model was validated. For this purpose, the partial least squares structural equation modeling (PLS-SEM) approach was used. The research has shown that organizational, technological, and environmental factors affect the digitalization of the organizations in the maritime transport sector. As a result of digitalization, changes in business models are visible:

organizations in maritime transport sector generate additional revenue from new sources, provide new services, and introduce new sales channels.

The contribution of this dissertation is manifold. First, the results of the dissertation can provide a basis for further research on digital transformation in the maritime transport sector. Second, the developed and validated universal digital transformation model may help stakeholders in the maritime transport sector to focus their resources more effectively and to shape more successful digital transformation strategies. The results can also help legislators in drafting more modern laws that will incorporate technological advances, resulting in better cooperation between stakeholders, simplification of business processes, better use of infrastructure and resources and sustainable business of stakeholders operating in the maritime transport sector.

Keywords: digital transformation, maritime transport, digitalization, digital transformation model, TOE framework

Prošireni sažetak

U ovoj je doktorskoj disertaciji izrađen i validiran univerzalno primjenjiv model digitalne transformacije dionika u sektoru pomorskog transporta, a koji će pomoći dionicima u oblikovanju uspješnijih strategija digitalne transformacije. Najprije je provedena bibliometrijska, sadržajna i tematska analiza digitalizacije i digitalne transformacije u pomorskom transportu i morskim lukama pomoću računalnih alata CiteSpace i Leximancer. Istraživanje je obuhvatilo različite kriterije, primjerice analizu prema ključnim riječima, temama i područjima istraživanja. Cilj je bio pozabaviti se temeljnim istraživačkim pitanjima, s tendencijom definiranja glavnih ključnih točaka u aktualnom procesu digitalizacije i digitalne transformacije pomorskog transporta i morskih luka.

Potom su istraženi i analizirani čimbenici uspjeha koji utječu na digitalnu transformaciju dionika koji posluju u sektoru pomorskog transporta, kao i pokretači digitalne transformacije te prepreke pri njezinoj provedbi. Pokretači, čimbenici i prepreke su grupirani sukladno teorijskom okviru TOE, tj. prema tri aspekta ili konteksta: tehnološkom aspektu koji se odnosi na prihvaćanje i primjenu modernih tehnologija i inovacija, njihovu sigurnost i interoperabilnost, organizacijskom aspektu koji se odnosi na resurse u organizaciji, strukturu organizacije, komunikaciju među zaposlenicima unutar organizacije te aspektu vanjskog okruženja koje utječe na aktivnosti organizacije i njezin rast.

S obzirom na nedostatak literature o digitalnoj transformaciji u pomorskom transportu i lukama, a s ciljem izrade istraživačkog modela, javila se potreba za dodatnom analizom literature. Iz tog razloga, digitalna transformacija analizirana je iz perspektive triju digitalnih tehnologija i informacijskih sustava: jedinstvenog sučelja za formalnosti u pomorskom prometu (Maritime National Single Window), Blockchaina i informacijskog sustava lučke zajednice (Port Community System-a). Osim toga, analizirane su digitalne informacijske usluge kao pokretači digitalne transformacije. Potom je, putem kvalitativnih metoda, istražena mjerodavnost čimbenika temeljem informacija dobivenih od strane stručnjaka pomorskog transporta, koji imaju iskustva u području digitalne transformacije.

U posljednjoj fazi je validiran model. U tu svrhu je korištena PLS-SEM statistička analiza. Istraživanje je pokazalo da organizacijski i tehnološki čimbenici te čimbenici vanjskog okruženja utječu na digitalizaciju organizacija u sektoru pomorskog prometa. Kao rezultat digitalizacije vidljive su promjene u poslovnim modelima: organizacije u sektoru pomorskog

prometa ostvaruju dodatne prihode iz novih izvora, pružaju nove usluge i uvode nove prodajne kanale.

Rezultati disertacije poslužit će znanstvenicima kao temelj za daljnja istraživanja digitalne transformacije u sektoru pomorskog transporta, kao i stručnjacima u oblikovanju odgovarajućih strategija digitalne transformacije, te zakonodavcima u formiranju suvremenije zakonske regulative koja će uključiti tehnološka dostignuća, što bi u konačnici moglo rezultirati boljom suradnjom među dionicima, pojednostavljenjem poslovnih procesa, boljim korištenjem infrastrukture i resursa te održivim poslovanjem dionika koji posluju u sektoru pomorskog transporta.

Ključne riječi: digitalna transformacija, pomorski transport, digitalizacija, model digitalne transformacije, TOE okvir

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Part I Critical review and research results

1. Introduction

Maritime transport is crucial for today's global trade and involves numerous stakeholders and complex business processes. Stakeholders in the maritime transport sector operate in an unstable environment due to the difficulty of predicting market conditions, growing demands from service users, complex changes in regulatory framework, technological progress, etc. In line with this, stakeholders need to develop appropriate business improvement strategies in order to achieve and maintain a competitive market position and to operate sustainably. Traditional methods of attaining a competitive position are no longer sufficient, and in addition to the pursuit of profit, there is a growing awareness of environmental, social and governance aspects of business.

Setting up a sustainable business is one of the main reasons for implementing digital transformation in many industries, including the maritime transport sector. Digital transformation refers to the use of new digital technologies and information systems in order to achieve a more sustainable business, e.g., through cost reduction, emissions reduction, etc. In addition, digital transformation offers opportunities to develop new business models.

A preliminary review of the available literature identified a lack of research and scientific papers that offer a comprehensive overview of the digital transformation in the maritime transport sector. The same applies to the lack of systematic initiatives on digital transformation in the maritime transport sector. Research mainly focuses on digital transformation in general or on the impact of individual digital technologies and information systems in maritime transport and seaports. To better understand the digital transformation of stakeholders in the maritime transport sector, it was necessary to conduct a comprehensive analysis of published research on digitalization and digital transformation in the maritime transport sector, then identify and evaluate the factors that influence digital transformation of stakeholders.

The research problem covers the following: The movement of cargo and related information in the maritime transport sector can be a complex process, involving numerous and heterogeneous stakeholders who should cooperate to achieve a smooth exchange of information. The existence of heterogeneous and independent information systems and the lack of standards can be a major obstacle to the digital transformation of stakeholder operations in the maritime transport sector. In addition, the necessary technical modifications depend on the state of existing digital technologies and information systems used in the organization and must be adapted to the needs of the organization. This usually requires a major upgrade or replacement of existing digital technologies and information systems, resulting in high investment/implementation costs. In addition, some stakeholders in the maritime transport sector usually have a conservative approach to the use of new digital technologies and information systems due to doubts about data security or insufficient awareness of the positive effects.

The goal was to develop and validate a stakeholder digital transformation model in the maritime transport sector, which would help stakeholders shape more successful digital transformation strategies. In this regard, the results could be used to support decision makers in their digital transformation efforts.

The partial least squares structural equation modeling (PLS-SEM) approach was used to validate the model. First, composite reliability and convergent validity were analyzed, as well as the reliability of measurement model indicators. Then, discriminant validity was assessed and the composite model was evaluated. After completing evaluations of the measurement and the composite model, according to which the measured properties of the research model were considered to be appropriate, it was possible to proceed with the assessment of the structural model (Benitez et al. 2020; Garson 2016). The evaluation of the structural model focused on estimates of model fit, estimates of path coefficients, their importance, effect size (f^2), and coefficient of determination (R^2) (Benitez et al. 2020).

In this dissertation, the research is divided into 5 phases as follows: In the **first phase**, the research problem was defined, the purpose and objectives of the research were determined, and the phases were elaborated.

The **second phase** deals with the literature review and analysis related to previous research in the field of digitalization and digital transformation in the maritime transport sector, through bibliometric, content and thematic analyses. In this phase, the expected future outcomes and perspectives of digitalization and digital transformation in maritime transport were identified. As a result of the second phase, the paper, that can be found in the section Part II Included publications, subsection A of this thesis, was published.

The **third phase** aimed to identify the success factors that affect the digital transformation of stakeholders operating in the maritime transport sector and to analyze drivers of digital transformation, as well as barriers to its implementation. Drivers, factors and barriers were grouped according to the Technology–Organization–Environment (TOE) framework. As a result of the third phase, the paper was published (see section Part II Included publications, subsection B of this thesis).

Due to the pronounced lack of literature addressing digital transformation in the maritime transport sector, it was necessary to investigate the topic further. Therefore, in the **fourth phase**, an analysis of key drivers of digital transformation was conducted: the Maritime National Single Window (MNSW), Blockchain and Port Community System (PCS), most of which represent best practices and initiatives. Furthermore, digital information services (as drivers of digital transformation) were analyzed. As a result of the fourth phase, five papers were published (section Part II Included publications, subsections C, D, E, F, G of this thesis).

In the **fifth phase**, a stakeholder digital transformation model in the maritime transport sector was validated. The partial least squares structural equation modeling (PLS-SEM) approach was used for this purpose. As a result of the fifth phase, the paper, that can be found in the section Part II Included publications, subsection H of this thesis, was published.

In the **sixth phase**, the main contribution and application of the research results as well as future research directions, are provided.

2. Bibliometric, content and thematic analyses of relevant literature

The objective of this phase is to define the key points in the current digitalization process in the maritime transport and seaports (Jović et al. 2022). The following research steps were undertaken: Preliminary research, filtering based on inclusion and exclusion criteria and reverse search analysis. As the last step, bibliometric, content and thematic analyses were conducted. “Analysis of categories of scientific papers”, “Analysis of scientific papers based on keywords” and “Content and thematic analysis”, that were part of this research, were singled out and additionally elaborated, in order to justify the further direction of the dissertation.

2.1. Analysis of the categories of scientific papers

Using the CiteSpace tool (Chen 2021), the categories of scientific papers were analyzed. “Categories can reflect the development level of research on a specific subject during a given period” (Guo et al. 2021). Approximately 75 topic categories were identified of which the most frequent ones are shown in Figure 1 (Jović et al. 2022).

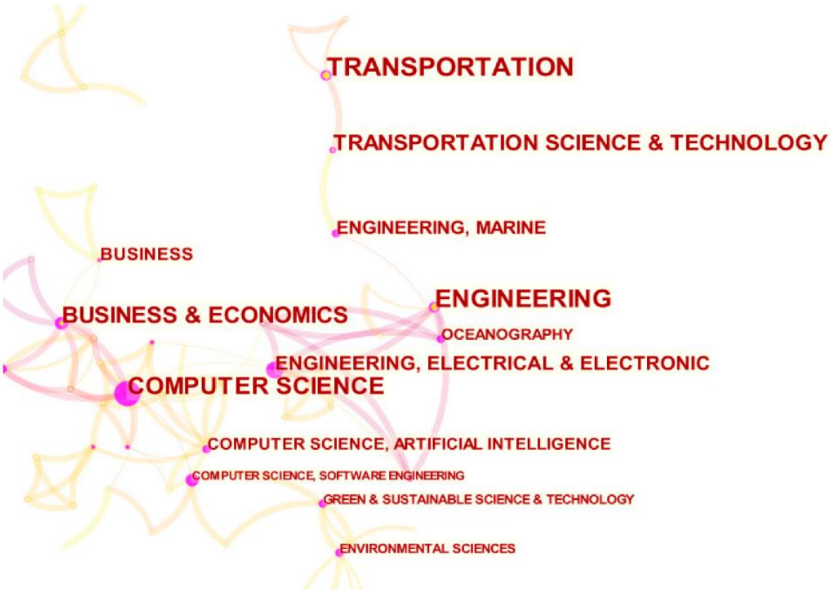

Figure 1. Categories of scientific papers.

The top five subject categories in the context of digitalization were identified: Transportation, Engineering, Computer Science, Business and Economics, and Transportation Science and Technology. In this respect, issues in transportation, engineering, computer science, business and economics were highly prioritized. It can be concluded that more should be devoted to categories such as Environmental Sciences and Green Sustainable Science and Technology, given that governments, research institutions, etc. increasingly recognize the importance of business sustainability. As shown in Figure 1, the economic aspect of digitalization and digital transformation has been most emphasized in previous research. However, in order to achieve sustainable business, it is necessary to consider the economic, environmental and social aspects of sustainability equally.

2.2. Analysis of scientific papers based on keywords

The CiteSpace tool (Chen 2021) was used to analyze the research keywords. The most prominent keyword in the field of digitalization and digital transformation 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) as shown in Table 1 (Jović et al. 2022).

Table 1. 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

In terms of digital technologies and information systems, the research showed that researchers have increasingly recognized the importance of modern technologies such as Blockchain, and the importance of information systems such as the Port Community System (PCS) and Maritime National Single Window. For this reason, further research was conducted on the topics:

Blockchain, Port Community System and Maritime National Single Window in the maritime transport sector, which will be explained in more detail below.

2.3. Content and thematic analysis by clusters

The content and thematic analyses using Leximancer identified 15 themes (Jović et al. 2022): “system”, “technology”, “data”, “port”, “ship”, “study”, “stakeholders”, “time”, “container”, “model”, “network”, “organizations”, “innovation”, “goods” and “AIS”. After comparing the results obtained from both tools (i.e., CiteSpace and Leximancer), the following differences can be found: in CiteSpace, one of the top 10 keywords was “Blockchain”, whereas in Leximancer, “Blockchain” was a concept, which was part of the “Innovation” theme. The words that were frequently repeated in both tools are *Port, Community, System, Data, Information, Chain, Model, Management, Technology, Blockchain, Ship, Logistics and Smart*, which would imply that information systems for data exchange as well as innovations such as Blockchain play an increasing role in simplifying business processes in maritime transport and seaports.

In addition, the analysis revealed a pronounced lack of literature on the topic of digital transformation in maritime transport, which was also observed in the search process (see Table 2).

Table 2. Search process in WoS and Scopus databases.

Search strings	Articles after applying formal criteria		Articles after screening manually	
	Web of Science	Scopus	Web of Science	Scopus
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	104	72	4	4

Only eight papers on the topic of digital transformation were applicable to the current study, which leads to the conclusion that the topic of digital transformation in maritime transport is under-researched.

This research resulted in the publication of the journal paper *Digitalization in Maritime Transport and Seaports: Bibliometric, Content and Thematic Analysis* (Jović, M.; Tijan, E.; Brčić, D.; Pucihar, A.), published in the *Journal of Marine Science and Engineering* (2022), 10, 486, indexed in WoS CC (Q1). The entire paper can be found in *Part II Included publications*, subsection *A* of this thesis.

3. Identification of drivers, success factors and barriers of digital transformation

In this phase, the factors affecting the digital transformation of stakeholders operating in the maritime transport sector, the drivers of digital transformation as well as barriers to digital transformation were analyzed (Tijan, Jović, Aksentijević, et al. 2021). Drivers, success factors and barriers were grouped according to the Technology-Organization-Environment (TOE) framework, i.e., its three aspects: the technological aspect referring to the acceptance and implementation of modern technologies and innovations, their security and interoperability; the organizational aspect referring to organizational resources, organizational structure, communication among employees within the organization and the aspect of the external environment which affects activities of the organization and its growth. Because there is a lack of scientific papers on digital transformation in the maritime transport sector in particular, in this study, both, the papers on digital transformation in general and digital transformation of transport in general were considered. This step was very important, given that a draft model was developed based on the results of this research.

3.1. Drivers of digital transformation

Based on the literature review, three organizational, two technological and five external environmental drivers of digital transformation were identified.

One of the drivers of digital transformation in the maritime transport sector, which has been increasingly recognized by researchers, is **cost reduction**. It refers to reducing cost of exchanging information and carrying out transactions. Another identified driver is **streamlining operations**, which refers to the enhancement of resource planning and information flow. The identified drivers, such as **shorter time delays, processing large amounts of data, improving stakeholder collaboration** and **data transparency,** could be related to the aforementioned driver **streamlining operations**.

More stringent environmental regulations in maritime transport could potentially encourage digital transformation. For example, if ships arriving at a port are provided with information on the availability of berths in real time, their navigation speed could be adjusted and hence the dwell time in port shortened, ultimately resulting in reduced harmful emissions before berthing/while waiting and during voyage. In this way, digital transformation facilitates compliance with **regulatory requirements.**

Other identified drivers are **new and emerging technologies, changing customer behavior and expectations** and **competitive environment**, which are also closely related. The emergence of new digital technologies and information systems can largely affect the competitive landscape and customer expectations. In this respect, reliable, flexible and cost-effective transport services are important to customers, which can encourage organizations to digitally transform their business and thus remain competitive.

3.2. Success factors for digital transformation

Based on the literature review, 13 organizational, six technological and six external environmental success factors for digital transformation in the maritime transport sector were identified.

For example, **the new business model** represents one of the identified success factors. For organizations that continue to rely on the existing business model, without adapting to the environment, there is a risk that they will no longer be able to meet the needs of customers and the market (Venkatesh, Mathew, and Singhal 2019; Mihardjo and Sasmoko 2018). A **clear vision** is also an identified success factor, as recognized by numerous researches, and may be a first step towards digital transformation (Larjovuori, Bordi, and Heikkilä-Tammi 2018). The **engagement of managers and employees** and **investment in employee and manager knowledge** are also important for successful digital transformation. In that vein, incentives should be effectively developed and employees should be encouraged by managers, as these factors may influence the organizational agility (Maymand and Mollaei 2014).

3.3. Barriers to successful digital transformation

Based on literature review, ten organizational, four technological and two external environmental barriers to digital transformation were identified.

Heterogeneous organization structures and **the lack of cultural integration** are identified barriers that are closely related. The lack of an effective organizational culture and inadequate cultural integration within the organization affect the organizational performance and cause productivity loss (Tedla 2016). Furthermore, less digitally mature organizations tend to focus on individual technologies and have a **technology-oriented culture only** (Kane et al. 2015). However, digital transformation is not only the digitalization of business processes, but also includes changes in the business model.

High investment/implementation cost and **high implementation risk and lack of clarity about the pay-off from investment into emerging technologies** are also barriers to digital transformation. To overcome the barriers, an increasing number of organizations in the maritime transport sector offer digital solutions to optimize ship operation or facilitate cooperation and communication between stakeholders. Technical modifications are required based on the state of existing technologies in an organization and must be adapted to the requirements of the organization.

An increasing number of organizations in the maritime transport sector are offering high-technology solutions to optimize ship operations (in regard to the optimum speed and fuel consumption), or to facilitate collaboration and communication between stakeholders (Jović, Tijan, Marx, et al. 2020). This usually implies a major upgrade or replacement of the working tools, applications and underlying infrastructure, which results in increased cost and risk.

After an in-depth analysis, the model of drivers, success factors and barriers affecting digital transformation in the maritime transport sector was developed (see Figure 2).

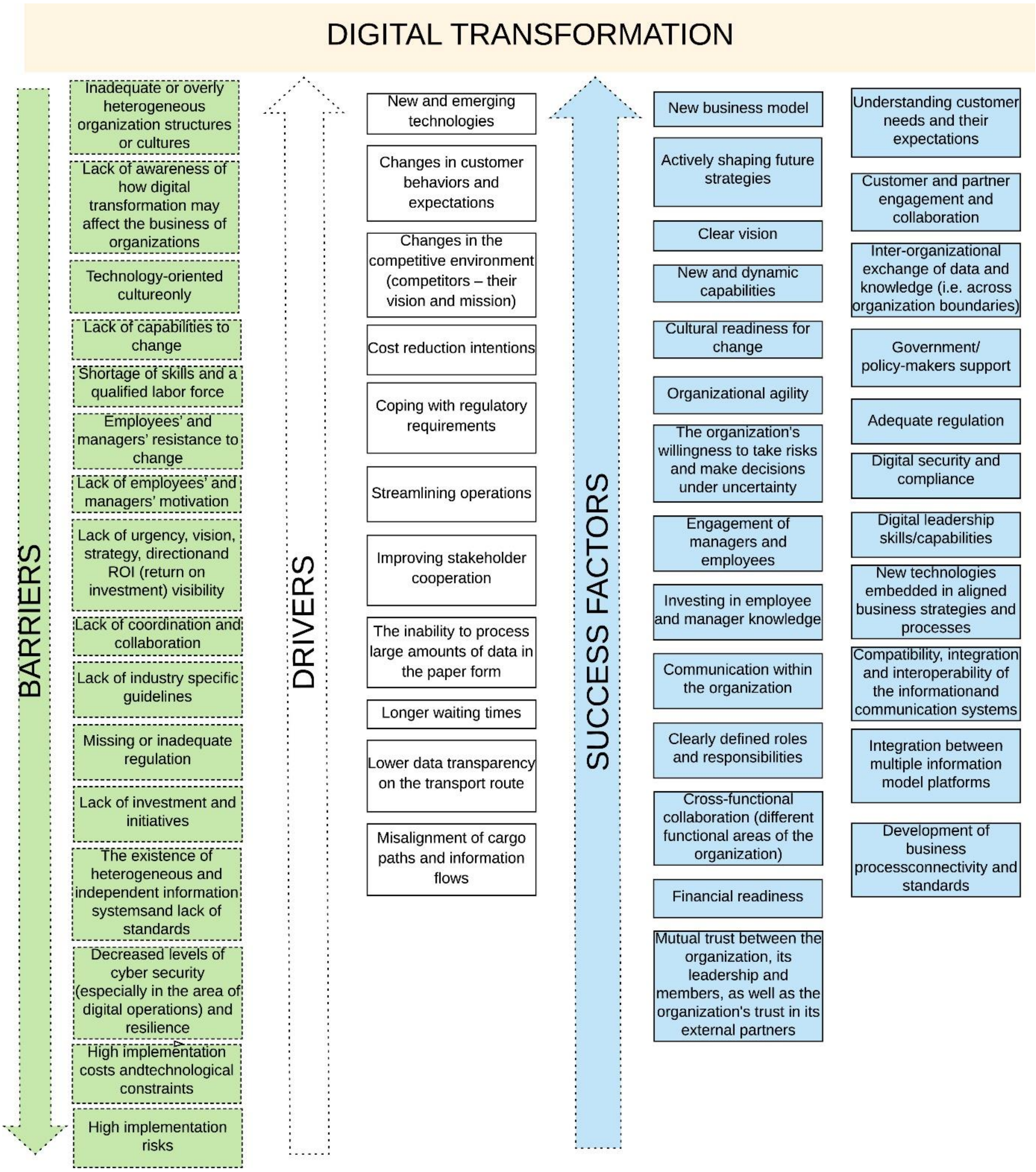

Figure 2. Model of drivers, success factors and barriers affecting digital transformation in the maritime transport sector.

This research resulted in the publication of the journal paper *Digital transformation in the maritime transport sector* (Tijan, E.; Jović, M.; Aksentijević, S.; Pucihar, A.), published in the journal *Technological Forecasting and Social Change* (2021), 170, 120879, indexed in WoS CC (Q1). The entire paper can be found in *Part II Included publications*, subsection *B* of this thesis.

4. Analysis of key drivers of digital transformation

Due to the identified lack of sources on the topic of digital transformation in the maritime transport sector, it was necessary to additionally analyze existing sources, which would contribute to a more profound understanding of digital transformation in the maritime transport sector. The previous step, i.e., identifying drivers, success factors and barriers was very important in order to make the basis for the research model. However, a fully adaptation of the research model to the maritime context was needed.

Furthermore, the growing importance of simplified data exchange among stakeholders in the maritime transport sector through the implementation of information systems and digital technologies was emphasized. In this respect, to deepen the knowledge of digital transformation, the Maritime National Single Window, Blockchain and Port Community Systems were taken as examples. The aforementioned digital technologies and information systems represent drivers of digital transformation in the maritime transport sector. Best practices and initiatives at national and regional levels as well as the positive impacts of digital technologies and information systems and the challenges to successful information exchange were analyzed. This step was important, since the literature review section was followed by interviews with experts in maritime transport sector, in order to complete a research model of factors which influence the digital transformation in the maritime transport sector.

4.1. Maritime National Single Window

The Maritime National Single Window is one of the key drivers of digital transformation in the maritime transport sector. As mentioned earlier, the Maritime National Single Window was analyzed through various examples, in order to ultimately gain a deeper understanding of digital transformation in maritime transport. Given the complexity of seaport businesses, the analysis has led to the conclusion that the implementation of MNSW enhances digital transformation because of a single-entry point for administrative procedures among stakeholders involved in seaport business (e.g., once entered information or document in MNSW is automatically forwarded to relevant authorities and systems which reduces paper documents and yields savings).

Furthermore, additional research was conducted, which followed up on previous MNSW research (Tijan et al. 2019). In this respect, using the example of the Montenegro Case Study, it has been proven that MNSW has an important role in digital transformation (Kapidani et al. 2020). For that purpose, the cost-benefit analysis of the MNSW implementation was conducted. The economic benefits were quantified such as the value of time and labor saved. At the end, it has been proven that MNSW as a driver of digital transformation would imply shorter dwel time for ships and shorter export/import delays in Montenegro.

Although the advantages of digital transformation through the implementation of MNSW were visible, less successful cases were identified. The issues that arose during MNSW implementation were related to the legal restrictions, financial issues and less cooperative stakeholders who operate individual information and communication technology (ICT) (Tijan et al. 2019). The results of this research coincide with the identified barriers to successful digital transformation from the previous phase.

4.2. Blockchain technology

As mentioned earlier, Blockchain is also one of the drivers of digital transformation. The importance of Blockchain has been increasingly recognized by researchers. To better understand digital transformation, the positive impacts as well as challenges of the Blockchain-based information exchange were analyzed (Jović, Tijan, Žgaljić, et al. 2020). For that purpose, a total of 99 sources were included in this research. The following advantages of Blockchain-based information exchange have been identified (see Table 3).

Table 3. The positive impacts of Blockchain-based information exchange

No.	Positive Impacts
1	Cost reduction
2	Improving transparency and visibility and real time information
3	High data availability on the network
4	Reduced need for paper documentation
5	Smoother information exchange, a peer-to-peer network
6	Data and information immutability
7	Establishing trust
8	Improving the security and privacy in distributed networks
9	Enhancing collaboration and cooperation
10	Facilitated determination and setting of rules and governance norms at the transport, logistics, and supply chain levels
11	Ability to trace and track goods or transactions
12	Possibility of integration with the disruptive technologies (Internet of Things, Big Data)
13	Reducing human errors and eliminating the possibility of providing inaccurate or incomplete information; reducing the rework and recall, the possibility of losing documents; enhanced job performance
14	Possibility of increasing the trade contract efficiency and harmonizing conflicting objectives
15	Reduced transaction delays
16	Automated compliance to freight and trade regulations and standards
17	Improved decision making
18	Ensuring human rights and fair working practices
19	The basis for supply chain mapping and the application of low carbon transportation
20	Reduction of energy and fuel consumption, pollution, and environmental degradation

Despite numerous advantages of digital transformation, in comparison to other industries, the maritime industry is considered to be the least technologically advanced due to, for example, the resistance of stakeholders to change, and stakeholders who prefer traditional ways of exchanging documents, despite the inefficiency. In order to facilitate digital transformation, it is necessary to engage the stakeholders and build trust among them. One of the barriers, which hinder the implementation of Blockchain technology as well as the process of digital transformation, is the lack of consensus and standards, because stakeholders can continue to develop their own Blockchain solutions and platforms, potentially leading to interoperability issues. Furthermore, one of the barriers, which also represents one of the disadvantages of digital transformation is the large energy consumption required for processing key algorithms and computations within the Blockchain.

4.3. Port community system (PCS)

Port authorities play an important role in initiating the digital transformation of the port community. Numerous seaports have started digital transformation by implementing PCSs in order to remain competitive. PCS enables all port information to be centralized, which leads to safer and faster data exchange between port stakeholders.

The most common reasons for digital transformation through the implementation of PCS are increased quality of data, reduced paperwork, and improved and facilitated activities throughout the entire transport and logistics chain. In this respect, "By developing and implementing a PCS, port authorities are becoming real digital hubs, where available data is gathered and exchanged between various stakeholders" (Tijan, Jović, Panjako, et al. 2021).

In some cases, different port authorities cooperate in order to achieve enhanced digital transformation. For example, a unified Port Community System "Polski Port Community System" has been created for Poland's main ports of Gdańsk, Gdynia and Szczecin-Świnoujście, through which the following port authorities cooperate: Port of Gdańsk Authority S.A., Szczecin and Świnoujście Seaports Authority S.A., and the Port of Gdynia Authority S.A. The aim of this cooperation through PCS is to optimize the management of transport processes by collecting, combining and processing traffic data and other logistics-related data in one place, and to ultimately enable sustainable business throughout the supply chain (Polski PCS 2021).

To deepen the knowledge of the complexity of digital transformation, the link between PCSs and different types of port authorities was analyzed as shown in the Table 4 (Tijan, Jović, Panjako, et al. 2021).

Table 4. PCS as a driver of digital transformation in various seaports.

Port Authority	Country	PCS Implementation
The Port Authority of Northern Tyrrhenian Sea (Ports of Livorno, Piombino, Capraia, Portoferraio, Rio Marina and Cavo).	Italy	"Tuscan Port Community System" aims to digitalize and simplify complex logistics flows
Port Authority of Jamaica	Jamaica	PCS aims to integrate private-sector companies with public-sector entities, to improve efficiency and effectiveness in trade and logistics-related activities
Port of Gdańsk Authority S.A.; Szczecin and Świnoujście Seaports Authority S.A.; Port of Gdynia Authority S.A.	Poland	Polski Port Community System aims to optimize the management of transport processes; to enable sustainable business throughout the supply chain
Port of Rotterdam	Netherlands	Portbase aims to make supply chains that run through the Netherlands stronger and smarter
Port Authority of Valencia	Spain	ValenciaportPCS aims to facilitate the passage of goods through the ports, adding a clearly perceptible value for customers and port users
Port Authority of Nagoya	Japan	Cooperation and exchange of information between different port community systems
The Port Authority of the Western Ligurian Sea (Port of Genoa, Prà, Savona and Vado Ligure)	Italy	Interoperability between the Railway Circulation Integrated Platform and the Port Community System

Ultimately, it has been proven that the success of digital transformation depends on collaboration between all involved stakeholders, and not on the type of port authority (Tijan, Jović, Panjako, et al. 2021). The results of this research are in line with the identified success factors for digital transformation from the previous phase.

4.4. Digital information services

To facilitate digital transformation and streamline operations, it was necessary to analyze the needs of stakeholders (e.g., what kind of digital information services are needed and should be provided) and adapt digital solutions accordingly. Digital information services that promote efficiency and sustainability of business in the transport sector are considered important elements for improving the attractiveness of transport sectors and thereby reducing greenhouse gas emissions of the transportation sector as a whole.

What is applicable to maritime transport is also applicable to other transport sectors, such as inland waterway transportation. Research on digital transformation of inland waterway transportation (e.g., Specht et al. 2022) focuses on the type of digital information services that are to be provided by port authorities, for example. The research provided an initial insight into the requirements and demands for digital services for sustainable inland waterway transportation, which is also applicable to the maritime transport sector.

According to the results, stakeholders face a number of various planning and decision-making challenges that can be improved by enhanced information flow. As such, it has been confirmed that a lack of available or suitable berths as well as time-consuming preannouncement and reporting obligations are apparently common. Additionally, stakeholders do not have sufficient insight into the extent of information on available services at the berths (e.g., fresh water supply, electricity, waste disposal) as well as a lack of available shore power facilities. Therefore, it can be concluded that for a successful digital transformation, it is not enough to focus on digital technologies and information systems only, but that it is necessary to be aware of the needs of the involved stakeholders. In this respect, the results of this research coincide with the identified barriers to successful digital transformation from the previous phase.

This research resulted in the publication of the following journal papers:

- *Maritime National Single Window—A Prerequisite for Sustainable Seaport Business* (Tijan, E.; Agatić, A.; Jović, M.; Aksentijević, S.), published in the journal *Sustainability* (2019), 11, 4570, indexed in WoS CC (Q2). The entire paper can be found in *Part II Included publications*, subsection *C* of this thesis.
- *National Maritime Single Window – Cost-Benefit Analysis of Montenegro Case Study* (Kapidani, N.; Tijan, E.; Jović, M.; Kočan, E.), published in the journal *Promet* -

Traffic&Transportation (2020), 32, 4, indexed in WoS CC (Q4). The entire paper can be found in *Part II Included publications,* subsection *D* of this thesis.

- *Improving Maritime Transport Sustainability Using Blockchain-Based Information Exchange* (Jović, M.; Tijan, E.; Žgaljić, D.; Aksentijević, S.), published in the journal *Sustainability* (2020), 12, 8866, indexed in WoS CC (Q2). The entire paper can be found in *Part II Included publications,* subsection *E* of this thesis.
- *The Role of Port Authority in Port Governance and Port Community System Implementation* (Tijan, E.; Jović, M.; Panjako, A.; Žgaljić, D.), published in the journal *Sustainability* (2021), 13, 2795, indexed in WoS CC (Q2). The entire paper can be found in *Part II Included publications,* subsection *F* of this thesis.
- *Digital Information Services Needed for a Sustainable Inland Waterway Transportation Business* (Specht, P.; Bamler, J.-N.; Jović, M.; Meyer-Larsen, N.), published in the journal *Sustainability* (2022), 14, 6392, indexed in WoS CC (Q2). The entire paper can be found in *Part II Included publications*, subsection *G* of this thesis.

5. Development and validation of the research model

Before validating the model, additional steps had to be undertaken. After deepening the knowledge about digital transformation in maritime transport in previous phases, the next step was to complete the research model of digital transformation in the maritime transport sector. However, to complete the research model, it was necessary to define (through the literature review), "Changes in business model", i.e., the scope of changes caused by digitalization and digital transformation (see Figure 3).

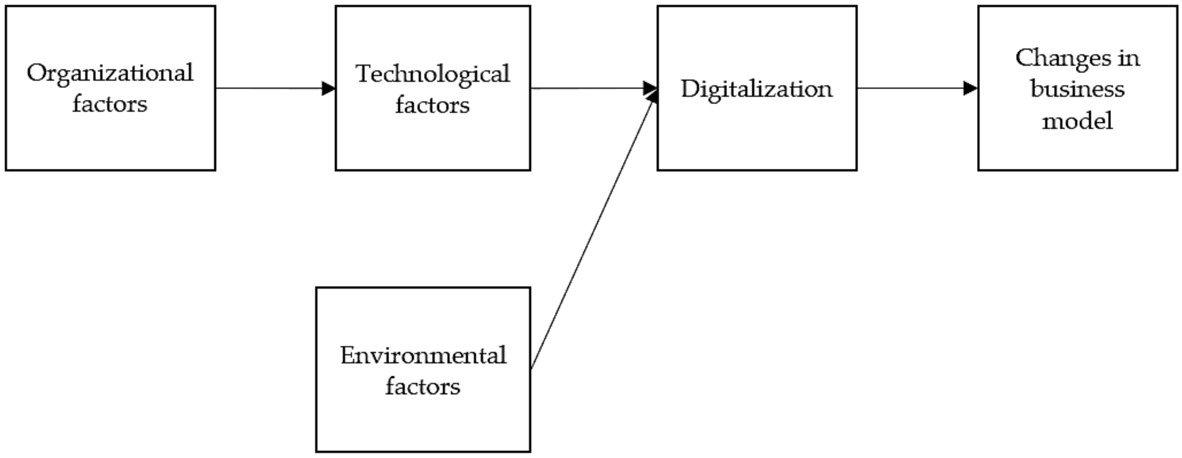

Figure 3. The proposed research model of digital transformation.

Furthermore, to ensure the relevance of identified factors, experts in the maritime transport sector were interviewed. Different types of stakeholders, i.e., administrative and commercial were considered, to yield more relevant results. In this respect, managers of various organizations were taken into account, for example the relevant Ministries, shipping and logistic companies, port authorities and companies that focus on digitalization of stakeholders operating in the maritime transport sector. The questions were structured according to the identified factors. All respondents had the opportunity to add or modify the identified factors.

As the last step, in order to validate the research model, a survey was conducted on a sample of Croatian administrative and commercial stakeholders operating in the maritime transport sector. The complete set of data was collected from 94 organizations in Croatia. The collected data were analyzed using the partial least squares structural equation modeling (PLS-SEM) approach.

5.1. Defining the relevance of factors

In this phase of the research, interviews with experts from different organizations were conducted. The results of the interviews are elaborated below, considering TOE factors, as well as digitalization and changes in the business model.

5.1.1 Technological factors

Technological factors include measures to improve information security, interoperability of ICT systems, standards, funds for the implementation of new digital technologies and information systems including related risks, and the need for new IT experts.

The stakeholders that were interviewed stated that they have sufficient funds available for the implementation of new digital technologies and that they combine their own solutions with open-source solutions.

The importance of information security was recognized by both administrative and commercial stakeholders. In order to improve information security, professional teams in charge of cybersecurity continuously monitor the systems and digital technologies. Systems are protected with strong firewall protection, as well as strong antivirus software, both for servers and for various sites. Within the organization, strict divisions are established concerning data that can be accessed by a particular user at a particular level. Regarding the backup of data, some of the stakeholders have a secondary location.

In addition to the risks associated with cybersecurity, there are other risks associated with digitalization. One of the commercial stakeholders has claimed that their systems cover multiple aspects, which means that each aspect has its own system, but all systems work unison, and depend on each other. This also has negative consequences, given that if one system fails, such as the pricing system, the automatic shipment tracking system will pull the wrong contracts. One of the risks is also an increased dependence on digitalization. In case of a failure of the digitalized system, the employers do not know how to operate manually, which leads to the blockage of the entire business. One of the stakeholders has mentioned the risks related to the quality of project implementation by the contractor; contractors not fulfilling their obligations could lead to failure of the entire project.

All stakeholders stated that internal systems are to some extent connected to external systems, and with the new Port Community System, stakeholders will be able to timely exchange data. Regarding the standards, the EDI and API standards have been mostly used by stakeholders.

All interviewed stakeholders have hired IT experts in order to accelerate digital transformation. One of the stakeholders also emphasized the importance of the role "business process manager". In this regard, when an application is created by a programmer and implemented, then business process managers work on such applications because they are familiar with all business processes.

5.1.2 Organizational factors

Organizational factors include the vision of the organization, motivation of managers and employees, investment in employees´ and managers´ knowledge, new leadership roles, the awareness of how digital transformation may affect the business and sharing of information within the organization.

Regarding the clearly communicated vision, one of the stakeholders recognized the importance of having vision, and continuously working with employees, as all major digital changes should be brought closer to them. In this respect, training sessions are held for employees regularly. Furthermore, when a certain application is deployed, then it enters a testing period within which all stakeholders (both administrative and commercial) who work on it make remarks and participate in the testing process.

Regarding information sharing among employees, one of the commercial stakeholders stated that they actively share information in the following way: first information is shared within the agency, then between agencies at the cluster level. After that, information is shared between clusters at the regional level, and then among regional offices at the global level. As specialized communication tools are used, information exchange is very fast.

The importance of motivation and awareness of how digital transformation may affect the business has also been emphasized. One of the commercial stakeholders has highlighted that their employees are aware that digitalized services are more profitable, easier, faster, more transparent for them and the clients, and therefore it is not difficult for them to become accustomed to working with new technologies. From the administrative stakeholders´ perspective, employees were motivated because they had the opportunity to visit different countries and analyze various systems in different ports. The goal was to understand how certain systems work and apply that knowledge to comparable systems in Croatian ports.

To increase employees´ awareness of the importance of digital transformation, one of the stakeholders recognized the need for departments to deal exclusively with digitalization and improvement within the organizations. This is to ensure that everyone involved is open to change. Another suggestion is to hire new external associates and experts who will be able to influence other employees in adoption of digital technologies and information systems.

5.1.3 Environmental factors

Environmental factors include the pressure of competition and business partners, regulatory requirements, cooperation with research institutions, the compliance with standards and the socially responsible business.

Regarding the pressure of competition, commercial stakeholders in the international market are more developed compared to administrative stakeholders, and some of them do not feel as much pressure of competition. Dissatisfaction arises when some business applications of other stakeholders are not user friendly or if they do not allow easy transfer of data from one database to another and require manual entry of data. In this way, stakeholders may feel the pressure of business partners. Administrative stakeholders have recognized the importance of cooperation with competitors, in order to develop certain digital solutions, especially through various EU co-funded projects.

Both commercial and administrative stakeholders cooperate with research institutions. Commercial stakeholders regularly cooperate with startups in order to maintain a leading position regarding the innovative services. Administrative stakeholders, on the other hand, cooperate with universities and adopt a scientific approach. If the scientific approach is not sufficient for the development of a certain innovation, they bring in experts from well-known research centers from abroad.

Furthermore, stakeholders are strictly regulated by legal regulations and there is a compliance with standards such as ISO. One of the commercial stakeholders claimed that, in Croatia, it is very difficult to run a company that is a leader in digitalization. Some innovative technologies do not even depend on legislation, but rather on local authorities that refuse to use them.

In addition, both administrative and commercial stakeholders have recognized the importance of sustainable business, and are adjusting their services accordingly.

5.1.4 Changes in business models and digitalization

Changes in business models as a result of digital transformation and digitalization are defined as follows: provision of new services and generation of additional revenue as a result of digital transformation, new digital sales channels, new ways of charging for services and entering new markets due to digital transformation.

With regard to the provision of new services due to digitalization and digital transformation, commercial and administrative stakeholders have recognized the connection between digital transformation and the development of new services. From the perspective of commercial stakeholders, this may refer to digital solutions that monitor emissions, solutions that allow customers to have complete oversight and visibility of logistics services and delivery or refer to value added services, such as track-sense devices, that record the position of the container, the temperature inside the container, etc., thus eliminating costs or even generating additional revenue.

Regarding new digital sales channels, one of the interviewed commercial stakeholders claimed that clients are able to log in to the system and access relevant information at any time, which means that clients no longer have to adjust to the agent's working hours. In addition, applications are being developed that will eliminate traditional e-mail communication. Such messages will be focused, standardized, and will have their own history, with the aim to create analytics out of these messages, which is not possible in traditional e-mail communication.

Administrative stakeholders have also introduced several new services that did not exist before, such as complete control of ticket sales, video surveillance of the entire port area, safety of navigation (VTS), radar, etc.

So far it has been established that digital services offer many advatages. However, there are some disadvantages as well. The following example shows the disadvantages of new digitalized services. Users (clients), who have learned to work in the traditional way, express dissatisfaction because of the lack of a human-to-human relationship. Despite the lack of interpersonal relationships, clients still opt for this method since such services are of better quality and more affordable.

As for the new ways of charge for services, various answers have been provided. From the commercial stakeholders´ perspective, the importance of the paperless bill of lading is increasingly recognized due to the following reasons. If a bill of lading is lost in transport, it is necessary to provide a large amount of additional documentation, which ultimately leads to excessive waste of time and high cost. For this reason, paperless bill of lading projects were developed. As far as administrative stakeholders are concerned, one of the examples are cargo terminal entry ticket sales for haulers. Such software was not previously used, and with its implementation, possibilities for additional earnings are opened up and related processes are accelerated, also increasing physical security levels.

In terms of entering new markets, as commercial stakeholders have begun to transform completely as logistics partners (including warehousing, distribution, customs, insurance, etc.), they are entering new markets. In addition, some of them are also entering new markets due to advanced digital solutions. On the other hand, administrative stakeholders are not focused on profit and new markets to a large extent. Their goal is to invest earnings in the seaports and improve the area with appropriate projects.

In addition to changes in the business model, the research model also consists of the "digitalization" factor. Digitalization was defined in terms of internal and external business processes as well as the cooperation with new business partners. The latter is realized through various projects, mostly European, the importance of which is particularly emphasized by administrative stakeholders.

5.2. Data analysis using the partial least squares structural equation modeling approach

In order to validate the model, a survey was conducted on the sample of Croatian administrative stakeholders (such as port authorities, ministry, harbormaster's offices) and commercial stakeholders (e.g., freight forwarders, agents, terminal operators) operating in the maritime transport sector. The complete set of data was collected from 94 organizations in Croatia. The collected data were analyzed using the PLS-SEM approach. In the first part of the PLS-SEM analysis, testing of the measurement model was performed. First, it was necessary to analyze composite reliability and convergent validity, as well as the reliability of measurement model indicators. Then, it was necessary to asses discriminant validity and to evaluate the composite model.

For the assessment of the structural model, the focus was on estimates of model fit, estimates of path coefficients, their importance, effect size (f^2), and coefficient of determination (R^2) (Benitez et al. 2020).

The models before and after the bootstrap-based test differ. Figure 4 shows the model before bootstrapping.

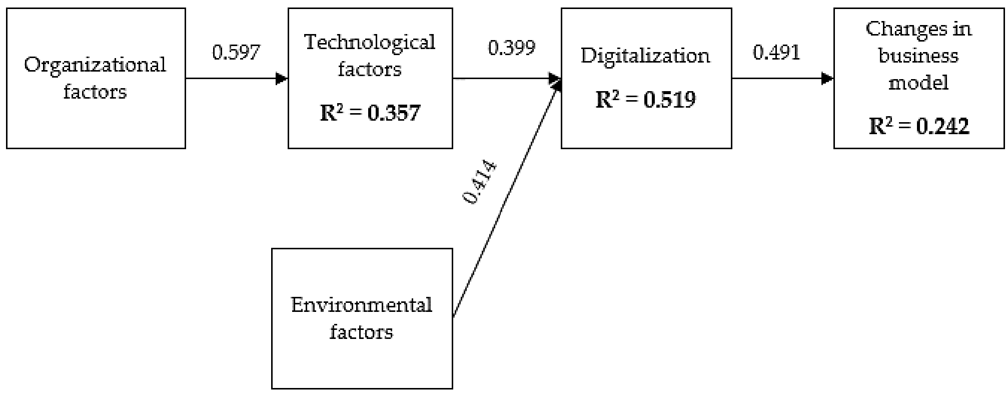

Figure 4. Model before the bootstrap-based test.

To begin with, it is necessary to clarify the difference between the original sample and the sample mean. The original sample is the parameter from estimating the model on the original dataset, which is possible to get from a PLS algorithm estimation (before bootstrap-based test). On the other hand, the sample mean estimate is the average of the estimates from all the subsamples of the dataset drawn during the bootstrapping procedure (Sarstedt et al. 2019). Bootstrap-based test is necessary to test the statistical significance of various PLS-SEM results (e.g., path coefficients, Cronbach's alpha, HTMT, and R^2 values). "Bootstrapping creates subsamples with observations drawn at random from the original dataset" (SmartPLS n.d.). In this respect, the original samples which are shown in Figure 4 (including both R^2 and path coefficient) have not been considered. Figure 5 shows the model after the bootstrap-based test has been applied.

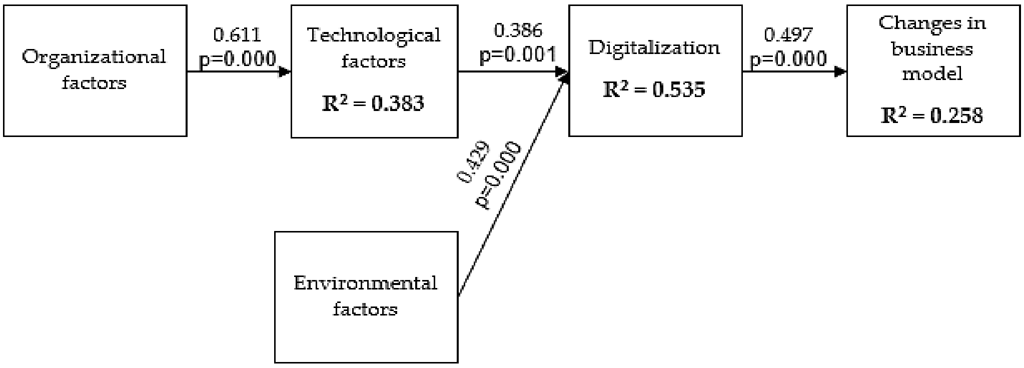

Figure 5. Model after the bootstrap-based test.

As can been seen in Figure 5, the values (R^2 and path coefficient), after bootstrap-based test, differ (compared to the Figure 4), because only the sample mean has been considered. Since all path coefficients turned out to be positive, it can be concluded that the hypotheses have been confirmed. Regarding the R^2, "when the phenomena are already quite well understood, one would expect a high R^2. When the phenomena are not yet well understood, a lower R^2 is acceptable" (Benitez et al. 2020). This may be the first such study, which means that $R^2 = 0.258$ was an acceptable value. Furthermore, p values were also obtained using bootstrap-based test. p values were lower than 0.05, which means that the relationships between the variables were statistically significant.

In Figure 6, factor loadings, path coefficient and R^2 (before bootstrap-based test) are shown.

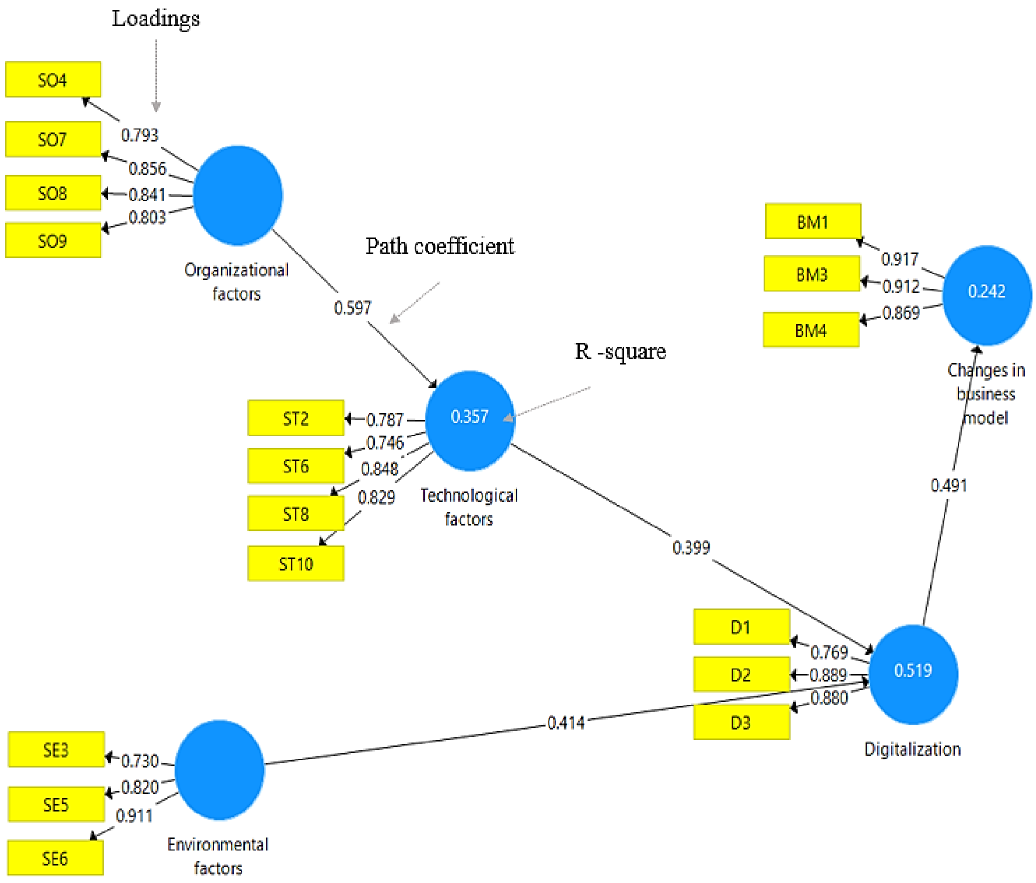

Figure 6. Loadings, path coefficient and R2 (model before bootstrap-based test).

An assessment of the reliability of the indicator can be made based on factor loadings. The value of the loading factor above 0.707 is acceptable. The original measurement model contained 38 indicators that were gradually eliminated. In each iteration, it was necessary to eliminate one factor with the lowest factor loading. This process was continued until only indicators with a factor loading above 0.707 remained.

In can be concluded that the model of influencing factors on digital transformation in the maritime transport sector was validated and the following hypotheses confirmed:

Hypothesis 1: Organizational factors have a positive impact on technological factors.

Hypothesis 2: Technological factors have a positive impact on digitalization.

Hypothesis 3: Environmental factors have a positive impact on digitalization.

Hypothesis 4: Digitalization has a positive impact on changes in a business model.

This research resulted in the publication of the journal paper *Factors of Digital Transformation in the Maritime Transport Sector* (Jović, M.; Tijan, E.; Vidmar, D.; Pucihar, A.), published in the journal *Sustainability* (2022), 14, 9776, indexed in WoS CC (Q2). The entire paper can be found in *Part II Included publications*, subsection *H* of this thesis.

6. Conclusion

In this chapter, the main contribution and application of research results, as well as future research directions, are provided.

6.1. Main contribution and application of research results

Contributions of the dissertation taking into account all phases may be summarized as follows. First, the dissertation contributes to the current body of knowledge in the field of digitalization and digital transformation in the maritime transport, with an emphasis on the implementation of different information and communication technology solutions in various fields, such as port operation planning, berth allocation, human resource planning, decision making, routing optimization, and information exchange.

Furthermore, the overview of the identified drivers, success factors and barriers offer researchers an introduction to the investigated field and may provide a baseline towards the future research design. Secondly, the understanding of drivers that promote digital transformation, the success factors that facilitate and enable digital transformation as well as being aware of barriers to digital transformation can help practitioners in shaping their digital transformation strategies.

The overview of numerous successful and less successful cases of digital transformation through the implementation of Maritime National Single Window, Blockchain and Port Community System may help researches and stakeholders to understand the importance of digital transformation, and the requirements for a successful implementation of digital technologies and information systems. Furthermore, regarding digital services, the survey gives a good indication and summary of perceptions in terms of information needs with regards to digital services for a sustainable business.

The validated model provides a better understanding of the factors (i.e., technological, organizational, and environmental) that affect the digitalization of organizations operating in the maritime transport sector and how these changes bring about changes in business models (i.e., the way an organization operates and conducts business). Secondly, the developed and validated universal digital transformation model with identified influencing factors may help stakeholders in the maritime transport sector to focus their resources more effectively and to shape more successful digital transformation strategies. Organizations must develop a detailed plan, i.e., a digital transformation strategy for the deployment of digital technologies and information systems, while at the same time focusing on the needs of the organizations. Thirdly, the model with identified influencing factors can help practitioners and decision makers in shaping their digital transformation and digitalization strategies.

How the model can help stakeholders in developing digital transformation strategy is further elaborated here. While developing the digital transformation strategy, organizations have to consider technological, organizational and environmental factors. The surveyed organizations which are more focused on digital transformation have successfully incorporated technological factors into their strategies. In this respect, the organizations have confirmed that their ICT systems are interconnected, and that they systematically manage the risk of implementing new digital technologies. In addition, the existing technology enables them to upgrade modern digital technologies. It is important to note that those organizations that are more focused on digital transformation regularly invest in modern technologies in order to develop business and services.

Furthermore, it is necessary to consider organizational factors when developing digital transformation strategies. The organizations that represent leaders in digital transformation, have noticed that there is room for improvement of their digital transformation strategies in terms of organizational factors. For example, although there are enough human resources to introduce new digital technologies, in the future, an additional need for human resources could arise, given the rapid development of new digital technologies. In addition, the organizations have identified the need for improvement in the following organizational factors: investing in employee knowledge, providing continuous training for employees and raising the awareness within the organization of how digital transformation can affect the business of the organizations. In other words, it is necessary to devote even more attention to human resources, their education and familiarization with new digital technologies, in order to accelerate digital transformation.

The direction in which digital transformation strategies will be developed also depends on environmental factors. In this respect, the organizations are often subject to specific regulatory requirements and their business is subject to compliance with standards and conventions. In this respect, the results can also help legislators in drafting more modern legislation that will include technological advances, resulting in better cooperation among stakeholders, simplification of business processes, better use of infrastructure and resources and ultimately sustainable business of stakeholders operating in the maritime transport sector.

In addition, the organizations should include socially responsible business in their strategies. To achieve complete sustainability goals in maritime transport, all three dimensions of sustainability (i.e., economic, environmental and social) should be equally considered. Some of the organizations increasingly use green sources and have implemented various solutions in order to lower the harmful impacts of their business, or have developed research centers focused on the development of zero-carbon technologies and solutions.

Moreover, the organizations should digitalize internal and external business processes and regularly cooperate with new partners in order to develop new digital solutions. The cooperation is possible through various projects, which are of special importance for administrative stakeholders. If the above factors are considered while developing digital transformation strategies, the organizations may notice improvements in various business aspects such as sales, accounting, finance, cost management, procurement, reporting, official procedures of arrivals and departures of ships, customs formalities, human resource management and analytics. As a result, the organizations generate additional revenue from new sources, provide new services and introduce new sales channels as a result of digitalization and digital transformation.

6.2. Future research directions

Future research could focus on investigating the specific nature of maritime transport compared to other industries in terms of acceptance of disruptive digital technologies such as the Blockchain, Internet of Things, etc. The role of administrative authorities may also be further investigated with regard to the acceptance and use of the disruptive technologies in the maritime transport sector, as the rapid technological change poses new challenges for them.

Another research direction may focus on smart ports and automation. The combination of various digital technologies and automation may improve the 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.

Since the research findings obtained in the final phase were based on a sample of 94 organizations in Croatia, the comparison of these findings with findings from other countries (e.g., countries in which digital transformation leaders operate such as the USA, Japan, Korea, the Netherlands, etc.) could provide further insight into digital transformation in the maritime transport sector. Furthermore, as both, commercial and administrative stakeholders were analyzed together, further refined research could include one group of stakeholders at a time.

Finally, to facilitate digital transformation, it is necessary to analyze the needs of stakeholders and adapt digital solutions accordingly, which may represent another research direction. In order to broaden the scope of the research, additional analysis of digital transformation may be conducted, for example at the supply chain level.

7. Summary of papers

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

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.

Jović, M.; Tijan, E.; Brčić, D.; Pucihar, A. Digitalization in Maritime Transport and Seaports: Bibliometric, Content and Thematic Analysis. Journal of Marine Science and Engineering 2022, 10, 486. https://doi.org/10.3390/jmse10040486

B. Digital transformation in the maritime transport sector

In this paper, the authors perform a literature review of the drivers, success factors and barriers to digital transformation in the maritime transport sector. Previous research offering a comprehensive overview of digital transformation in the maritime transport sector is scarce. In order to fill this research gap, the authors have identified a total of 139 sources, mainly related to the drivers, success factors and barriers for digitalization and digital transformation. The analysis of the state of the art was performed, along with the analysis of the impact of digital transformation in the maritime transport sector using a number of cases. The development of innovative technologies (such as Blockchain or autonomous shipping) definitely fosters digital transformation in the maritime transport sector. The barriers which are slowing down digital transformation compared to other industries are highlighted, such as the lack of awareness of how digital transformation may affect the business, and the lack of standards and cooperation among stakeholders. The research findings fill the identified research gap, and can serve practitioners in shaping up proper strategies for successful digital transformation of organizations in the maritime transport sector.

Tijan, E.; Jović, M.; Aksentijević, S.; Pucihar, A. Digital transformation in the maritime transport sector. Technological Forecasting and Social Change 2021, 170, 120879. https://doi.org/10.1016/j.techfore.2021.120879

C. Maritime National Single Window—A Prerequisite for Sustainable Seaport Business

This paper presents a comprehensive review of National Single Window concept and its impact on sustainability in maritime transport and seaports. The theoretical frameworks of sustainability, maritime transport, seaports, the National Single Window and the Maritime National Single Window is provided. The importance of stakeholder connectivity in maritime transport and seaports in improving sustainability is demonstrated, as well as the advantages of smoother data exchange through global analysis of National Single Window examples, the majority of which present national and regional best practices and initiatives. Empirical data has been provided in order to demonstrate the impact of National Single Windows and Maritime National Single Windows on seaport sustainability (economic, environmental, and social).

Tijan, E.; Agatić, A.; Jović, M.; Aksentijević, S. Maritime National Single Window—A Prerequisite for Sustainable Seaport Business. Sustainability 2019, 11, 4570. https://doi.org/10.3390/su11174570

D. National Maritime Single Window – Cost-Benefit Analysis of Montenegro Case Study

In this paper, the costs and benefits of the National Maritime Single Window (NMSW) for coastal countries that have limited human resources and infrastructure related to maritime traffic are researched. A general method for conducting a cost-benefit analysis of NMSW implementation is proposed. Using this method and the input data for Montenegro, as an example of a small-sized coastal country, the authors assess whether such an investment in NMSW implementation can be beneficial to coastal countries with limited resources.

Kapidani, N.; Tijan, E.; Jović, M.; Kočan, E., National Maritime Single Window – Cost-Benefit Analysis of Montenegro Case Study. Promet - Traffic&Transportation 2020, 32, https://doi.org/10.7307/ptt.v32i4.3422

E. Improving Maritime Transport Sustainability Using Blockchain-Based Information Exchange

In this paper, the authors perform a comprehensive literature review of the positive impacts of blockchain-based information exchange in the maritime transport sector, as well as the challenges and barriers for successful blockchain-based information exchange, considering all three aspects of the sustainability (economic, environmental, and social). The papers from relevant databases (Web of Science and Scopus) and selected studies have been used. The literature coverage was expanded by using backward snowball sampling. In total, 20 positive impacts and 20 challenges/barriers were singled out. Despite the identified barriers and challenges (such as the slow acceptance of blockchain technology in the maritime transport sector or the high implementation cost), blockchain technology possesses a definite potential to improve the information exchange between all involved stakeholders (for example, by improving the visibility across transport routes and by reducing the paper-based processes), positively affecting all three aspects of sustainability. The authors contribute to the existing research of the economic aspect of maritime transport sustainability by blockchain-based information exchange by expanding it and by researching the environmental and social aspects of sustainability.

Jović, M.; Tijan, E.; Žgaljić, D.; Aksentijević, S. Improving Maritime Transport Sustainability Using Blockchain-Based Information Exchange. Sustainability 2020, 12, 8866. https://doi.org/10.3390/su12218866

F. The Role of Port Authority in Port Governance and Port Community System Implementation

This paper researches the role of the port authorities in port governance, and the role of the port authorities in Port Community System implementation. The authors provide the theoretical frameworks of seaports, port authorities, port governance, and Port Community Systems. The literature review was carried out using the Web of Science database and additional relevant sources. The authors concluded that although different port governance models exist (regarding the type of port authority), there is no evidence as to which governance model is universally preferable, as it is specific to each seaport. In addition, the research has shown that port authorities play a very important role in the implementation of a Port Community System, increasing the sustainability of seaport operations. Its implementation enables the port authorities to evolve into real digital hubs and neutral data managers, which ultimately leads to the optimization of seaport processes and more efficient use of transport infrastructure.

Tijan, E.; Jović, M.; Panjako, A.; Žgaljić, D. The Role of Port Authority in Port Governance and Port Community System Implementation. Sustainability 2021, 13, 2795. *https://doi.org/10.3390/su13052795*

G. Digital Information Services Needed for a Sustainable Inland Waterway Transportation Business

Inland waterway transportation (IWT) is highly efficient in terms of greenhouse gas emissions but lacks economic competitiveness when compared to other modes of transport. Digital information services that foster efficiency and sustainability of IWT are considered important elements for improving its attractiveness and thereby reducing greenhouse gas emissions of the transportation sector as a whole. Therefore, this paper addresses the question of what kind of digital information services are actually needed and should be provided, e.g., by port and waterway authorities, to stimulate a modal shift in favour of IWT. Though the concept of river information services (RIS) already provides a harmonised approach to information services in the sector, the current political and scientific discourse still lacks insight into what degree the currently available information services actually meet industry needs. Equally, possibilities to provide practical recommendations are limited. Therefore, this contribution fills this knowledge gap by providing data from the field gathered through a combination of qualitative and quantitative research methods. After elaborating on the underlying problem as well as the current state of research and practice, we will lay out observed information-relevant challenges to business actors and their respective needs. Based on this, practical recommendations for improvements of digital services and further avenues for research are derived.

Specht, P.; Bamler, J.-N.; Jović, M.; Meyer-Larsen, N. Digital Information Services Needed for a Sustainable Inland Waterway Transportation Business. Sustainability 2021, 14, 6392. https://doi.org/10.3390/su14116392

H. Factors of Digital Transformation in Maritime Transport Sector

This paper aims to present the model of factors, which influence the digital transformation in maritime transport sector. The preliminary model is based on a literature review and interviews conducted to identify the relevant factors influencing the digital transformation of stakeholders operating in the maritime transport sector. In order to test the model, the survey was conducted on the sample of Croatian administrative (port authorities, ministry, harbormaster's offices, etc.) and commercial stakeholders (freight forwarders, agents, terminal operators, etc.) operating in maritime transport sector. The collected data was analyzed using the partial least squares structural equation modeling (PLS-SEM) approach. The research has shown that organizational, technological, and environmental (TOE) factors affect the digitalization of the organizations in the maritime transport sector. As a result of digitalization, changes in business models are visible: organizations in maritime transport sector generate additional revenue from new sources, provide new services, and introduce new sales channels.

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Curriculum Vitae

Marija Jović was born on September 10, 1992 in Rijeka. She obtained her Bachelor's and Master's degrees in logistics and management in maritime industry and transport at the University of Rijeka, Faculty of Maritime Studies. From January 2019 to September 2021, she was employed at the University of Rijeka, Faculty of Maritime Studies as a researcher on the INTERREG project DigLogs (Digitalization of logistics processes). Since October 2022, she has been employed at the Institute of Shipping Economics and Logistics in Bremen (Germany) as a research associate.

She has co-authored 31 scientific papers, of which 16 journal papers and 15 conference papers. In addition, as a co-author, she published one professional paper and four conference abstracts. In 2019, as a co-author, she received the award for the best peer-reviewed scientific paper "The Transition of Croatian Seaports into Smart Ports" at the 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO).

She participated in the following projects:

1. Information management in seaport clusters (2017-2019): The aim of this project was to rationalize seaport businesses through the reengineering of business processes and the implementation and application of integral electronic information (data and messaging) exchange system;

2. Electronic Transportation Management System e-TMS (2018-2021): The software that enables users to centrally create and supervise the business processes they perform;

3. Maritime EDUcation Standard for Shipping and Ship Management Ability (MEDUSA) (2019-2021): The goal was to provide high-quality, efficient and innovative higher education standards in the maritime transport sector in the long term;

4. ERASMUS (Athletes Friendly Education) (2019-2021): The goal of the project was to find the most effective way to improve the education of athletes through an innovative educational approach;

5. INTERREG V-A Italy-Croatia project Digitalising Logistics processes (DIGLOGS) (2019 – 2021): The aim of this project was to develop the necessary concepts, technological solutions, models and plans, in order to establish advanced digitized

logistics processes in multimodal freight and passenger transport present in the program area (the area covered by the mentioned project);

6. PROMARES (PROmoting MARitime and multimodal freight transport in the Adriatic Sea) (2019-2022): The goal of the project was to remove the challenges that hinder the comprehensive development of maritime and multimodal freight transport;
7. Horizon 2020, Innovation driven Collaborative European Inland Waterways Transport Network (IW-NET) (2020-2023): The goal of the project is to create a European inland waterway transport network driven by innovation.

Part II Included publications

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

Marija Jović, Edvard Tijan, David Brčić, Andreja Pucihar

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

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 [9,10,11], 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 [7,15,17,18,19], 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 Section 4 and Section 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 [25,26,27]. 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.

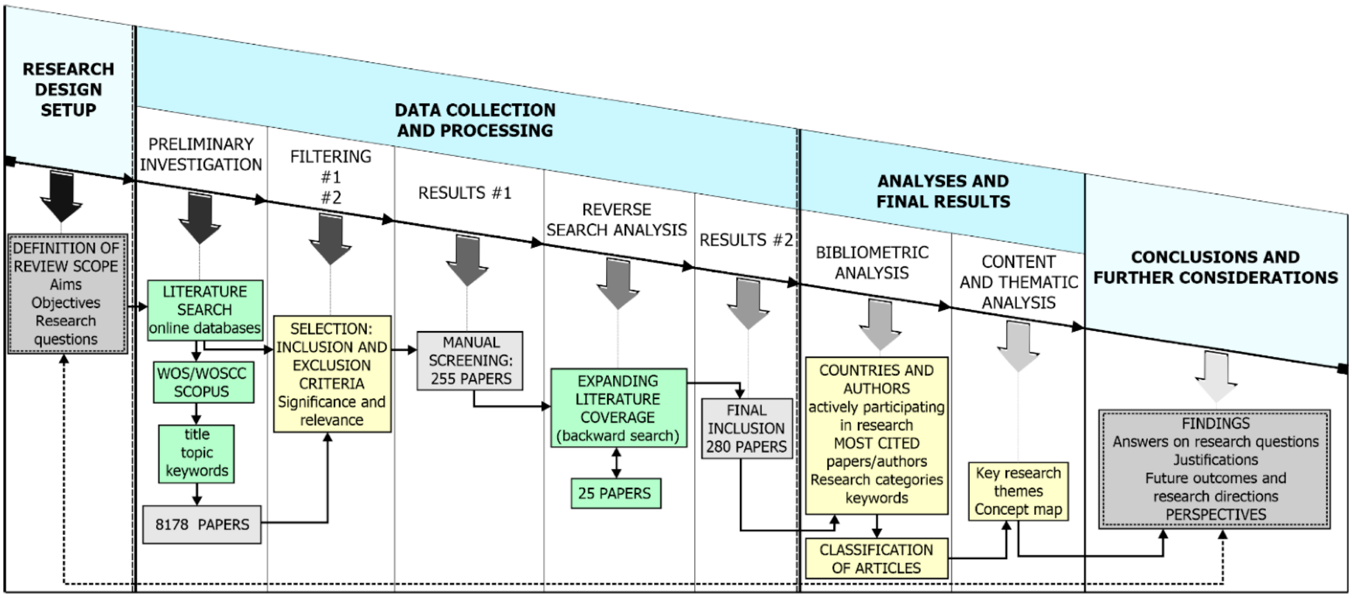

Figure 1. Research steps.

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.

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.

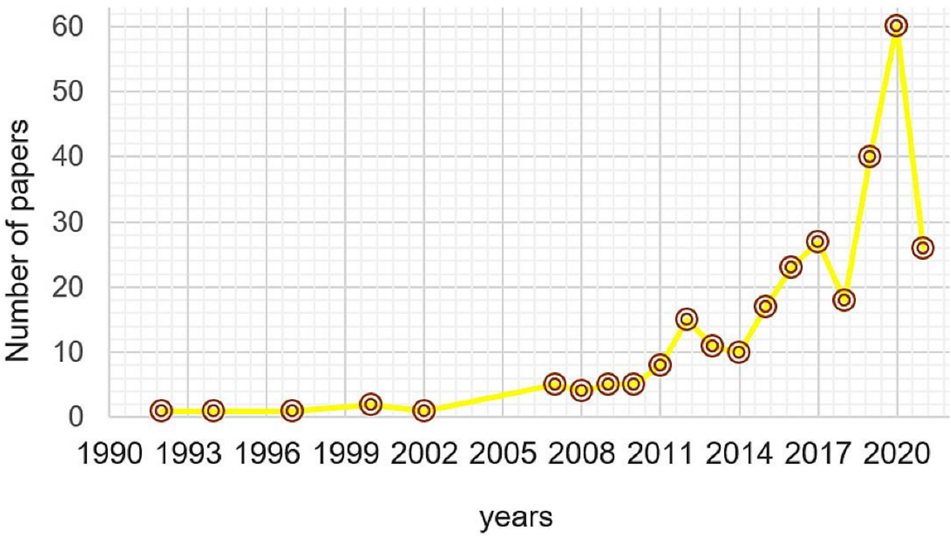

Figure 2. Paper publications per year.

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.

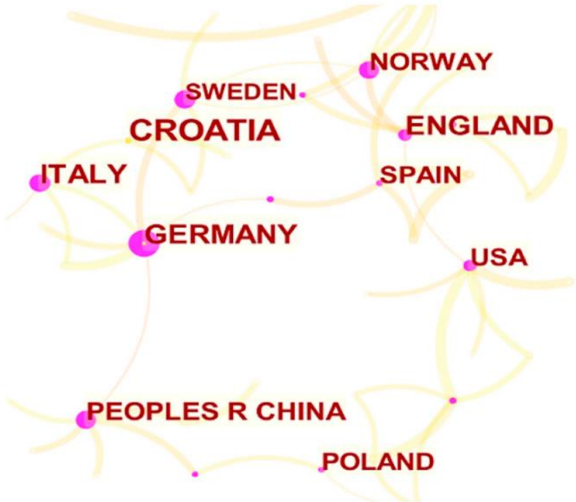

Figure 3. The visualization of the “country cooperation network”.

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 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].

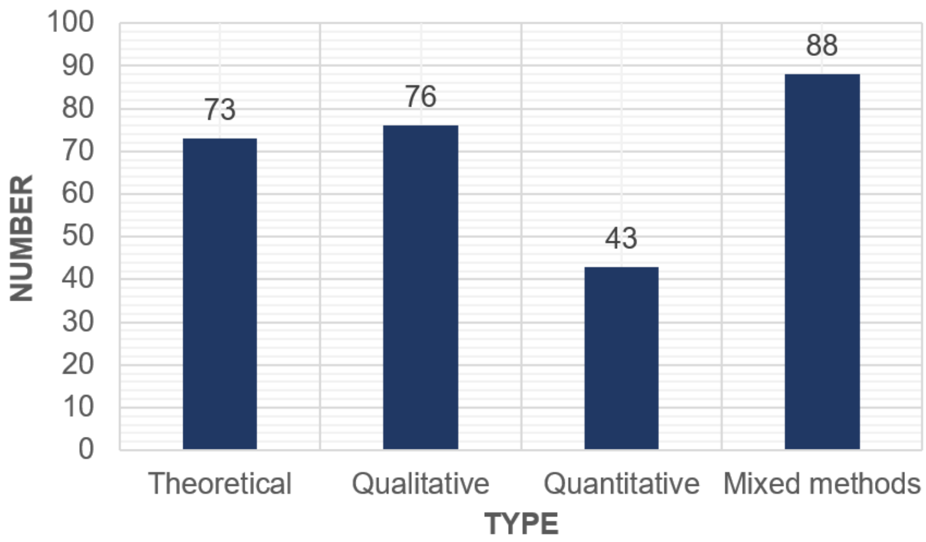

Figure 4. Distribution of the articles by their classification.

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.

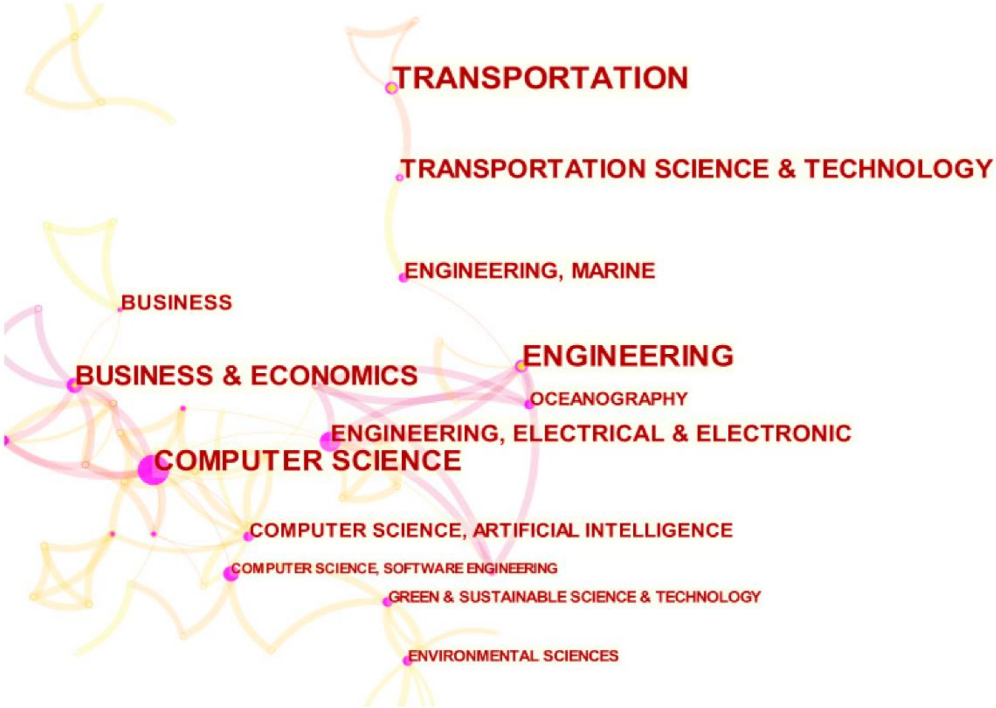

Figure 5. Categories based on the publications.

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.

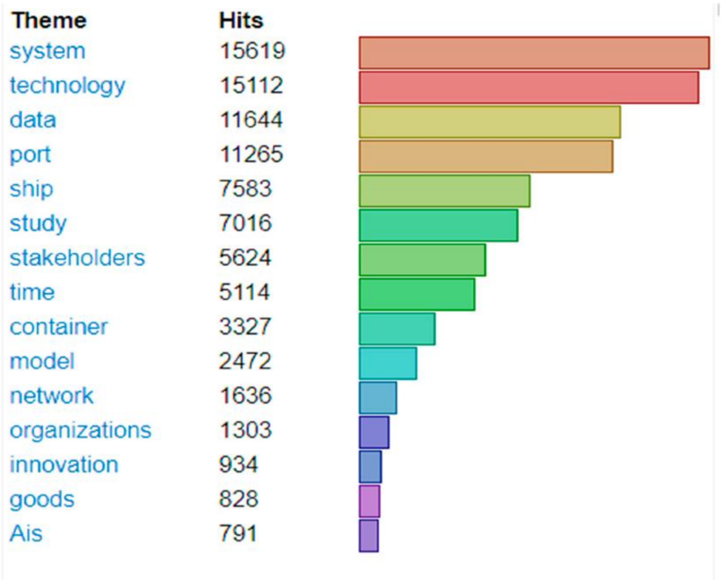

Figure 6. Identified themes and their distribution in the analyzed publications.

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.

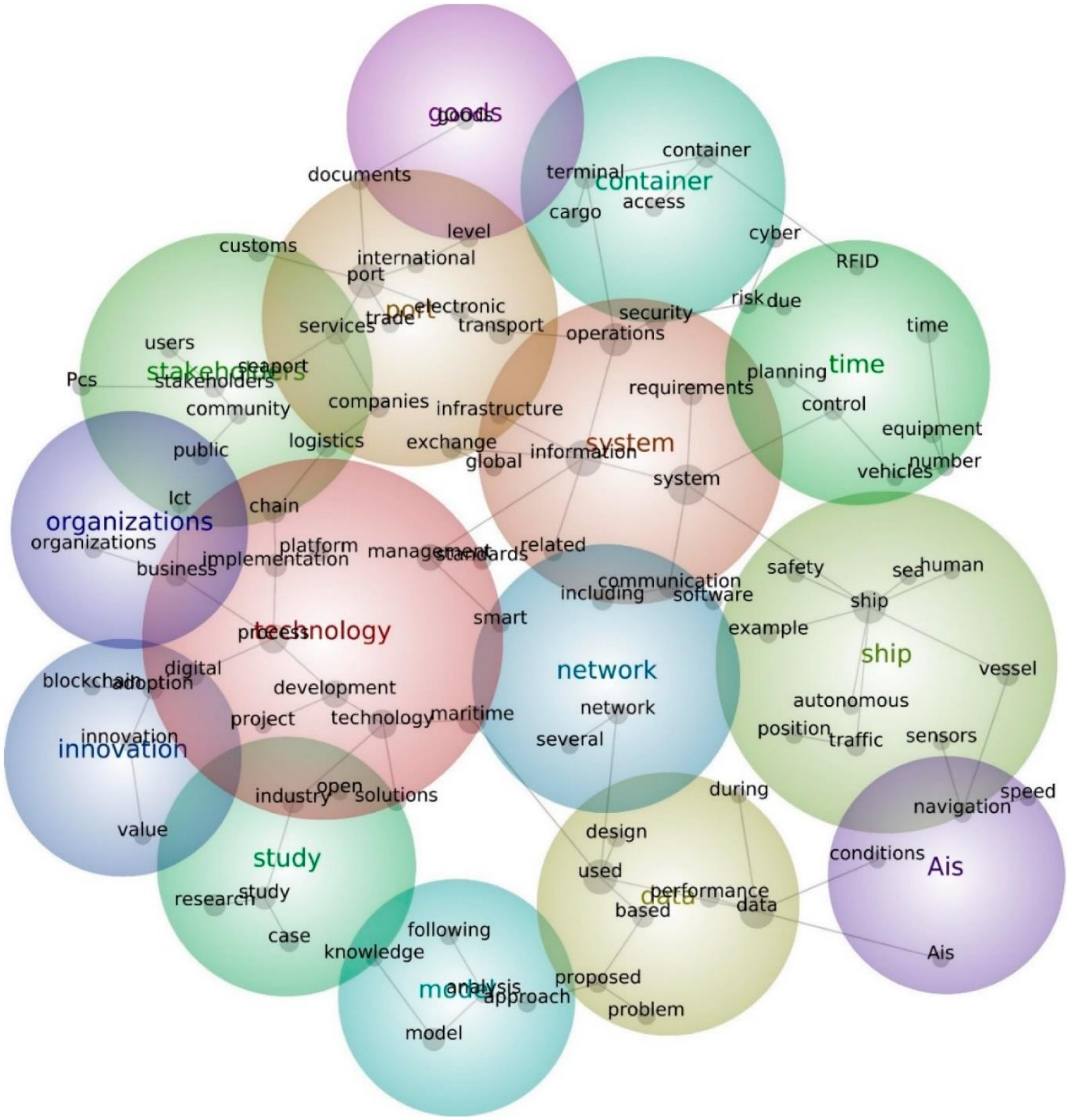

Figure 7. Leximancer concept map.

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.

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 [35,36,37,38,39,40].

  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: [10,11,33,44,45,46,47,48,49,50,51].

- “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]
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]
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.

Author Contributions

Conceptualization, M.J., D.B., E.T. and A.P.; methodology, M.J., A.P. and D.B.; software, M.J. and A.P.; validation, D.B., A.P. and E.T.; formal analysis, M.J., D.B., E.T. and A.P.; investigation, M.J. and A.P.; writing—original draft preparation, M.J.; writing—review and editing, M.J., D.B., E.T. and A.P.; visualization, M.J., A.P. and D.B.; supervision, E.T., A.P. and D.B.; funding acquisition, A.P. and D.B. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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		
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		
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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B. Digital Transformation in the Maritime Transport Sector

Abstract: In this paper, the authors perform a literature review of the drivers, success factors and barriers to digital transformation in the maritime transport sector. Previous research offering a comprehensive overview of digital transformation in the maritime transport sector is scarce. In order to fill this research gap, the authors have identified a total of 139 sources, mainly related to the drivers, success factors and barriers for digitalization and digital transformation. The analysis of the state of the art was performed, along with the analysis of the impact of digital transformation in the maritime transport sector using a number of cases. The development of innovative technologies (such as Blockchain or autonomous shipping) definitely fosters digital transformation in the maritime transport sector. The barriers which are slowing down digital transformation compared to other industries are highlighted, such as the lack of awareness of how digital transformation may affect the business, and the lack of standards and cooperation among stakeholders. The research findings fill the identified research gap, and can serve practitioners in shaping up proper strategies for successful digital transformation of organizations in the maritime transport sector.

Keywords: Digital transformation; Maritime transport; Literature review; Drivers; Success factors; Barriers

1. Introduction

In recent years, firms in almost all industries have conducted a number of initiatives to explore new digital technologies and exploit their benefits (Matt et al., 2015). This frequently involves a transformation of key business operations and affects products, services and processes, as well as organizational structures and management concepts (Matt et al., 2015). Digital transformation (DT) causes fundamental changes in traditional business practices by the implementation and use of digital technology (Dehning et al., 2003). It exceeds changes of business processes and enables the creation of new types of organizations, brings changes in organizational culture, relationships, value creation and customer reach, as well as market position (Lucas et al., 2013). DT refers to organizational changes, caused by digital technologies, which lead to the redefinition of existing business capabilities, processes, and relationships (Dehning et al., 2003). The changes are observable in business models; in the way how organizations create, deliver and capture value (Pucihar, 2020).

DT can be defined as the process of reshaping the business models due to, and through, the adoption and use of digital technologies with the aim of creation of setting (within the organization and its environment) in which new possibilities (digital capabilities) are enabled and value is created (Jeansson & Bredmar, 2019). Integrating and exploiting new digital technologies is one of the biggest challenges that companies currently face (Hess et al., 2016). The maritime transport, an important mode of transport in international trade (Gren et al., 2020) is moving towards digitalization and DT at different speeds in the different domains (Sanchez-Gonzalez et al., 2019). Shipping, as a part of logistics chain, is a volatile industry and is in a turbulent condition due to the energy price fluctuations, technological immaturity and upcoming increases in regulations (Zaman et al., 2017).

Seaport stakeholders and enterprises in the maritime transport sector, as many enterprises in other industries, struggle with the lack of awareness, proper strategies and initiatives for successful DT (Gausdal et al., 2018; KPMG International Cooperative, 2018). The majority of contemporary research is focused either on DT of transport in general, or digitalization trends focused on the maritime transport. A lack of research and scientific papers offering a comprehensive overview of DT in the maritime transport sector is particularly pronounced. To overcome this research gap and to provide a better understanding of DT in the maritime transport sector, authors conducted a comprehensive literature review focusing on the period from 2015 to 2020 to capture recent research in the field of DT in the maritime transport sector, transport in general or digital transformation in general. The aim was to identify drivers, success factors and barriers for successful DT which can be applied to the maritime transport sector context. To achieve this aim, the following research questions were addressed in this study:

- What are the drivers of digital transformation which can be applied to the maritime transport sector?
- What are the success factors for digital transformation which can be applied to the maritime transport sector?
- What are the barriers to successful digital transformation which can be applied to the maritime transport sector?

After analyzing the state of the art of digitalization and DT in the maritime transport sector, the authors have identified the drivers, success factors and barriers for DT, applying them to the maritime transport sector context, and provided several cases of successful DT in the maritime transport sector. At the end, the Discussion with an emphasis of the specifics of the maritime transport sector compared to other industries in terms of DT is provided.

2. State of the art of digitalization and digital transformation in the maritime transport sector

Digitalization focuses mainly on the business process automation, operations automation, as well as on the processing of information. On the other hand, digital transformation (DT) is currently an important trend that penetrates many industrial and societal domains (Gray & Rumpe, 2017) and may be defined as the use of new digital technologies (analytics or embedded devices) to enable business improvements (e.g. improving the customer experience, streamlining processes) (Hausberg et al., 2018; Kovynyov & Mikut, 2018), (Morakanyane et al., 2017), or to innovate the business models (Hausberg et al., 2018; Gerster, 2017; Savić, 2019; Morakanyane et al., 2017) in strategic, tactical and operational terms (Saul & Gebauer 2018).

Only a small number of industry players in the maritime transport sector consider that digitalization has already changed their business significantly, whereas the companies in high-tech and in public transportation have already seen greater changes from the pressure of digitalization (Quitzau et al., 2018)(. (Sanchez-Gonzalez et al., 2019) verified the state-of-the-art of digitalization in the maritime transport and stated that digitalization currently applies to eight digital domains: “autonomous vehicles and robotics; artificial intelligence; Big Data; virtual reality, augmented and mixed reality; Internet of Things; the cloud and edge computing; digital security; 3D printing and additive engineering”. Their work demonstrates that “there are domains on which almost no formal study has been done so far and concludes that there are major areas that require attention in terms of research (e.g. the use of robotics in sea transport services and the integration of the studies done on AI in the industry)”.

(Fruth & Teuteberg, 2017) provided an overview of the current state of digitalization in maritime logistics and discussed the existing problem areas (e.g. lack of theoretical studies that examine in more detail the future behavior of actors in the maritime logistics chain), and showed potentials for improvement, e.g., by expanding the research into areas where information and Big Data projects have already been implemented. Proliferation of digitalization in maritime transport is most pronounced in the navigation systems, for example the concept of e-navigation and the ongoing developments within the navigation in general (Nkuna, 2017).

Shipping companies rate the importance of digitalization for their own industry according to the following: 15% consider radical industry change to be unavoidable, while 69% feel that there will be significant changes but no revolution in the industry, while a sizeable 16% consider the topic to be overrated (Quitzau et al., 2018). According to the PwC Norway survey (PwC Norway, 2017) that included 28 decision-makers active in ocean shipping, "the DT is set to play a key role in shipping and for shipping companies in the future and the maritime industry is now anticipating extensive digitalization processes with a great degree of certainty". Crewless shipping seems still far away, but both Norwegian and Greek shipping companies are becoming open to an idea of ships controlled from land.".

(Gausdal et al., 2018) claim that the main drivers of DT (from the Blockchain perspective only) are the intention to reduce costs, overregulation in the maritime industry, and the large quantity of data that maritime companies process, along with the intention to increase the business effectiveness. Opposed to that, the main barriers to DT are high implementation costs, low quality of offshore Internet connections, aging decision-makers, overly technology-oriented culture, the lack of investment initiatives, the low level of modern digital technology (e.g. Blockchain) diffusion through the supply chain, and risk aversion.

Seaports play a very important role in the maritime logistics and represent important hubs in the international trade. (Heilig et al., 2017a) provided an overview of the development and state-of-the-art of DT in modern seaports in order to identify current DT potentials and barriers.

(Heilig et al., 2017b) focused on seaports, identifying three generations of DT (Transformation to Paperless Procedures; Transformation to Automated Procedures; Transformation to Smart Procedures), and analyzing the stages of respective DT.

The analysis so far has shown that there are only a few recent studies that have addressed the digitalization and DT in the maritime sector, and none of them offer a comprehensive overview of DT in the maritime transport sector. Most of these studies were focused to identify current status of digitalization, reveal managerial anticipations of DT and identify DT potentials and barriers from the perspective of collaboration in the overall supply chain, not the maritime transport in particular.

3. Research methodology

To provide a better understanding of digital transformation (DT) and to identify drivers, success factors and barriers which can be applied to the maritime transport sector, a comprehensive literature review has been conducted. The research methodology was partially adapted from (Dreyer et al., 2019). Fig. 1 shows the methodological steps of the research.

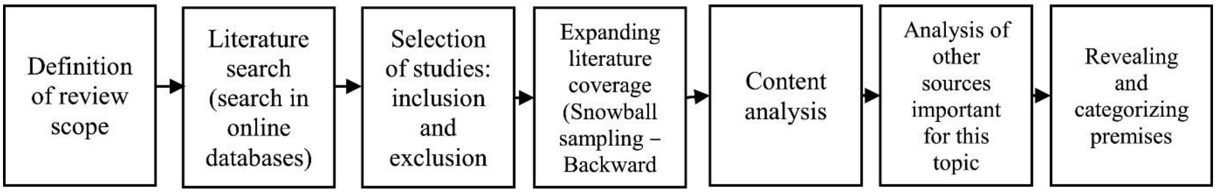

Fig. 1. Methodological steps

The search was carried out using six research databases: Web of Science, Scopus, AISeL, SpringerLink, Emerald Insight and Semantic Scholar. In this research, we have focused on the following keywords:

- Digital transformation
- Digital transformation AND Transport
- Digital transformation AND Maritime transport
- Digital transformation AND Maritime industry
- Digital transformation AND Shipping
- Digital transformation AND Seaport
- Digital transformation AND Port
- Business model AND Innovation AND Transport
- Business model AND Innovation AND Maritime transport

A search was performed in the aforementioned databases in order to determine whether publications contained at least one of the search terms in the title or abstract. Inclusion and exclusion criteria as well as Content analysis and Analysis of additional sources are explained in more detail in the following sub-chapters. Furthermore, snowball sampling phase was utilized to extend the set of relevant primary studies (Myllärniemi 2015).

Fig. 2 shows the literature search process, partially adapted from (Dreyer et al., 2019), and the results.

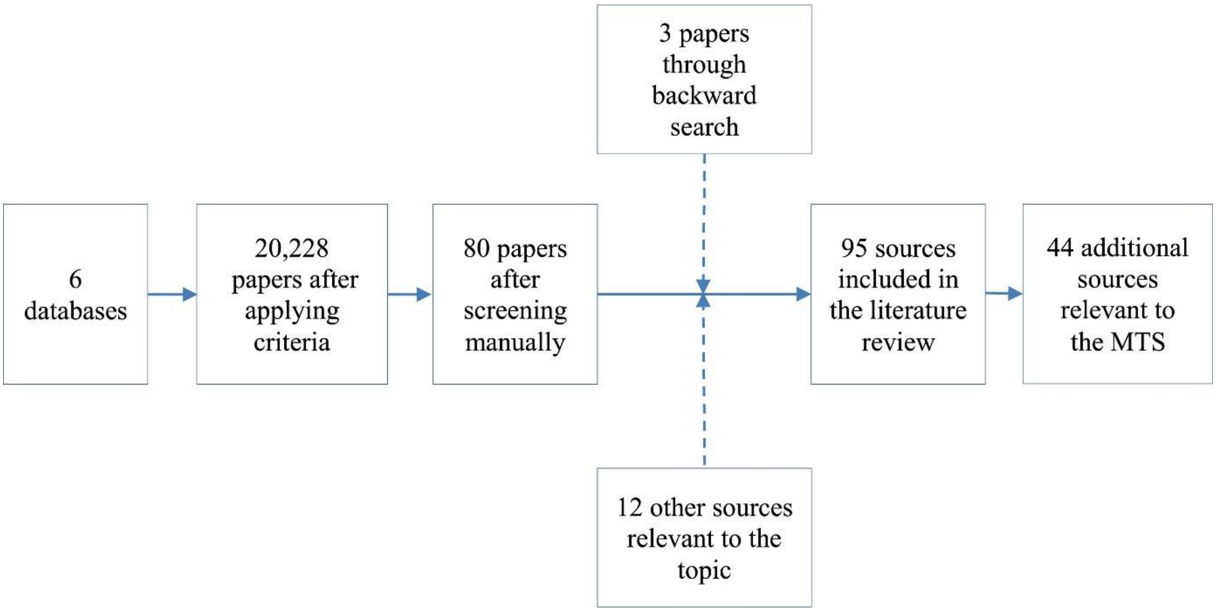

Fig. 2. Literature search process and search results

95 sources have been identified as relevant for this research. Authors have also included 12 additional sources such as the reports and thesis (this step will be further explained). Due to the lack of research related to DT in the maritime transport sector, the authors have also included additional 44 sources related to the maritime transport sector (MTS) (such as scientific papers, reports, dissertations etc.), which do not necessarily contain the selected keywords, but are related to the individual identified drivers, success factors and barriers to DT in the maritime transport sector. If the drivers, success factors and barriers to DT were identified in sources related to DT in general, the authors have further investigated additional resources related to the maritime transport sector to confirm the relevance of such drivers, success factors and barriers to the maritime transport sector.

3.1. Inclusion and exclusion criteria

Inclusion and exclusion criteria were determined to identify the most relevant articles for this topic. Due to the lack of scientific papers dealing with DT in the maritime transport sector, authors have also considered the papers dealing with DT in general and DT of the transport in general. Appendix A shows the number of hits after applying the reduction criteria for each search term found in different databases and number of sources after screening manually. As shown in Appendix A, the following limitations were used:

The search for articles was performed in six databases according to the set time limitation (2015-2020). In the Web of Science database, the search was performed in order to determine whether the publications contained at least one of the keywords in the Topic or Title. The authors limited the search to the following categories: Transport Science Technology, Computer Science, Information Systems, Management, Business, Communication, Economics, and Green Sustainable Science Technology. In the Scopus database the search was performed in order to determine whether the publications contained at least one of the selected keywords in Article title, Abstract, and Keywords. In the AISeL database, the search was performed in order to determine whether the publications contained at least one of the keywords in Abstract, Title or Subject. In the SpringerLink database, the search was performed in the following disciplines: Business and Management, Engineering, Computer Science and Economics, in order to determine whether the publications contained at least one of the keywords. In the Emerald Insight database, the search was performed in order to determine whether the publications contained at least one of the keywords in Title or Abstract. In the Semantic Scholar database, the authors limited the keyword search to the following Fields of study: Business, computer science, Engineering, Economics.

According to (Dreyer et al., 2019), in order to achieve a broad literature review, the search was not limited only to high-ranking journals and conferences. Articles that were not written in English language were excluded, in order to avoid tentative regional overrepresentation of research in the formal analysis (Dreyer et al., 2019).

3.2. Sources used in the research

In order to further overcome the research gap, authors have considered not only journal and conference papers, but have also considered book chapters, dissertations, master theses, editorial materials, reports, etc. All sources are grouped in the Table 1.

Table 1. Sources used in the research

Sources used to identify drivers, success factors and barriers		**Additional sources relevant to the maritime transport sector**	
Journal papers	41	Journal papers	21
Conference papers	36	Conference papers	3
Dissertations	1	Dissertations	3
Editorial Materials	1	Magazine articles	2
Master theses	2	Master theses	1
Reports	7	Reports	3
Scientific series logistics at the Berlin Institute of Technology	1	Official Web Pages	5
Book chapters	5	Book chapters	3
Working papers	1	Brochures (EU Council)	1
		Invitation paper (Marshall University)	1
		Toolkit	1

3.3. Analysis of the identified literature and other sources

The initial focus was placed on papers containing the term “digital transformation” in the title or abstract. As the goal of the research was to identify drivers, success factors and barriers, thorough analysis of the entire content of the papers had to be performed. The authors were also looking for the terms: “driver(s)”, “factor(s)” and “barrier(s)”. The main question during the search for the drivers of DT was: *Why do stakeholders in maritime transport sector decide to pursue DT?* While searching for success factors, authors were mainly led by the question: *What is needed for a successful DT?* During the search for barriers to DT, the main question was: *What prevents a successful DT?* After identifying the drivers, success factors and barriers, the importance of DT in the maritime transport sector is demonstrated through the analysis of several cases. For that purpose, the authors have also analyzed web pages and other relevant sources related to DT in the maritime transport sector. The authors have also included additional scientific papers (which do not necessarily contain the search keywords) related to the maritime transport sector to provide a deeper insight of the maritime transport context.

4. Findings

The identified drivers, barriers and success factors of digital transformation (DT) were classified into organizational, technological and external environment context and were applied to the maritime transport sector context.

4.1. Drivers of digital transformation

Drivers can be defined as external or internal triggers that cause organizations to engage in DT (Osmundsen et al., 2018). Table 2 shows the identified drivers of DT in the maritime transport sector. In total, 76 sources have been used in this process.

Table 2. Identified drivers of digital transformation

	Drivers	Sources
Identified drivers of digital transformation related to the organization itself	**Cost reduction** (9) = Organizations implement new technologies in order to simplify collaboration with other organizations, and thus reduce the cost of exchanging information and executing transactions, etc.; Leaner, more automated, and error-free processes help in cost reduction	(Gausdal et al., 2018), (Ismail et al., 2018), (North et al., 2020), (Viktorovich & Aleksandrovna, 2019), (Korpela et al., 2017), (Wei et al., 2019), (Morakanyane et al., 2017), (Henriette et al., 2015), (Korchagina et al., 2020)
	Streamlining operations (4) = Making processes more efficient and reliable, for example by improved resource planning; Improved information flows through the transport route	(Heilig et al., 2017a), (Jović et al., 2019b), (Schumann et al., 2017), (Viktorovich & Aleksandrovna, 2019)
	Shorter time delays (3) = Goods and information should pass in the required time frame; shorter waiting times for ships and faster processing at the terminal	(Junge, 2019), (Wiedenmann & Größler, 2019), (Fruth & Teuteberg, 2017)
Identified drivers of digital transformation related to technologies	**New and emerging technologies** (63) = Novel technologies open new opportunities for business transformation; at the level either of an organization or wider in the transport chain	(European Commission, 2018), (Huang, 2018), (Heilig et al., 2017b), (Legner et al., 2017), (Shi, et al., 2019), (Henriette et al., 2015), (Ismail et al., 2018), (Alt, 2019), (Verhoef et al., 2019), (Kozak-Holland & Procter, 2019), (Boneva, 2018), (Nwankpa & Roumani, 2016), (Morakanyane et al., 2017), (Quitzau, 2018), (Genzorova et al., 2019), (Piccinini et al., 2015), (Jović et al., 2019b), (Jeansson & Bredmar, 2019), (Fruth & Teuteberg, 2017), (Teece & Linden, 2017), (Matt et al., 2015), (Verina & Titko, 2019), (Carcary et al., 2016), (Kwon & Park, 2017), (Chinoracky & Corejova, 2019), (Peter et al., 2020), (North et al., 2020), (Agrawal et al., 2020), (Kotarba, 2018), (Henriette et al., 2016), (Fuchs & Hess, 2018), (Ponsignon et al., 2019), (Durão et al., 2019), (Mugge et al., 2020), (Reich et al., 2018), (Sehlin et al., 2019), (Malyavkina et al., 2019), (Junge, 2019), (Cichosz, 2018), (Viktorovich & Aleksandrovna, 2019), (Junge et al., 2019), (Jahn et al., 2019), (Korpela et al., 2017), (Iddris, 2018), (Sabri et al., 2018), (Wiedenmann & Größler, 2019), (Reis et al., 2018), (Sayabek et al., 2020), (Vukšič et al., 2018), (Wei et al., 2019), (Hartl &

		Hess, 2017), (Caputa, 2017), (Schwertner, 2017), (Hausberg et al., 2019), (Vial, 2019), (Tsakalidis et al., 2020), (Pagani & Pardo, 2017), (Remane et al., 2017), (Zaman et al., 2017), (Schiavi & Behr, 2018), (Junge & Straube, 2020), (Munim et al., 2020), (Korchagina et al., 2020)
	Processing large amounts of data (6) = The ability to process large amount of data in order to increase organizations' competitiveness	(Gausdal et al., 2018), (Schumann et al., 2017), (Viktorovich & Aleksandrovna, 2019), (Iddris, 2018), (Sabri et al., 2018), (Sánchez, 2017)
Identified drivers of digital transformation related to the external environment	**Changing customer behaviors and expectations** (34) = With the emergence of new technologies, customers' expectations have increased	(Osmundsen et al., 2018), (Legner et al., 2017), (Verhoef et al., 2019), (Boneva, 2018), (Morakanyane et al., 2017), (Piccinini et al., 2015), (Hausberg et al., 2019), (Teece & Linden, 2017), (Verina & Titko, 2019), (Jeansson & Bredmar, 2019), (Alt, 2019), (Carcary et al., 2016), (Kwon & Park, 2017), (Henriette et al., 2015), (Ismail et al., 2018), (Agrawal et al., 2020), (Henriette et al., 2016), (Larjovuori et al., 2018), (Fuchs & Hess, 2018), (Ponsignon et al., 2019), (Mugge et al., 2020), (Sehlin et al., 2019), (Agushi, 2019), (Viktorovich & Aleksandrovna, 2019), (Wiedenmann & Größler, 2019), (Reis et al., 2018), (Sayabek et al., 2020), (Ivančić et al., 2019), (Leipzig et al., 2017), (Hartl & Hess, 2017), (Caputa, 2017), (Vial, 2019), (Acciaro & Sys, 2020), (Korchagina et al., 2020)
	Competitive environment (37) = Competitive environment is changing; DT may disrupt existing markets, recombine existing products and services, etc.	(Osmundsen et al., 2018), (Ismail et al., 2018), (Verhoef et al., 2019), (Boneva, 2018), (Nwankpa & Roumani, 2016), (Morakanyane et al., 2017), (Teece & Linden, 2017), (Fruth & Teuteberg, 2017), (Henriette et al., 2015), (Verina & Titko, 2019), (Jeansson & Bredmar, 2019), (Gausdal et al., 2018), (Heilig et al., 2017b), (North et al., 2020), (Adner et al., 2019), (Henriette et al., 2016), (Durão et al., 2019), (Mugge et al., 2020), (Reich et al., 2018), (Sehlin et al., 2019), (Galimova et al., 2019), (Agushi, 2019), (Cichosz, 2018), (Viktorovich & Aleksandrovna, 2019), (Junge et al., 2019), (Korpela et al., 2017), (Sabri et al., 2018), (Reis et al., 2018), (Sayabek et al., 2020), (Vukšič et al., 2018), (Hartl and Hess, 2017), (Caputa, 2017), (Schwertner, 2017), (Vial, 2019), (Acciaro & Sys, 2020), (Wang & Mileski, 2018), (Schiavi & Behr, 2018)
	Regulatory requirements (4) = Regulations imposed by international and regulatory organizations, with the intention to achieve e.g. "green" transport technologies	(Gausdal et al., 2018), (Osmundsen et al., 2018), (Tsakalidis et al., 2020), (Zaman et al., 2017)
	Improving stakeholder collaboration (4) = Improved collaboration through smooth information sharing between the involved stakeholders	(Iddris, 2018), (Sabri et al., 2018), (Wiedenmann and Größler, 2019), (Hausberg et al., 2019)
	Data transparency (2) = Providing better transparency of the transport route; the transparency at the transport route from the sender to the recipient	(Fruth & Teuteberg, 2017), (Viktorovich & Aleksandrovna, 2019)

Based on the literature review, 3 organizational, 2 technological and 5 external environmental drivers of DT in the maritime transport sector were identified. The following identified drivers are closely related: **new and emerging technologies, changing customer behaviors and**

expectations and **competitive environment**. Due to the emergence of new digital technologies in the maritime transport sector, such as Blockchain, Internet of Things, Big Data, autonomous drones, competitive landscape and customer expectations are changing dramatically (Verhoef et al., 2019). Customer expectations for reliable, flexible, and cost-efficient transport service are increased (Raza et al., 2020) which stimulates organizations to engage into DT to stay competitive (Verhoef et al., 2019). Shipping companies have to adjust to the customer needs, offer appropriate transport services in order to achieve the most efficient and long-lasting commercial operation of its vessels (Plomaritou, Plomaritou, & Giziakis, 2011).

Regarding the **regulatory requirements**, the maritime transport sector is facing stricter environmental requirements approved by the International Maritime Organization, the European Union, and other international organizations (Gausdal et al., 2018), such as the London Convention and Protocol (LC/LP), the Hong Kong Ship Recycling Convention and Annex VI Prevention of Air Pollution from Ships (entered into force 19 May 2005) of the International Convention for the Prevention of Pollution from Ships (MARPOL) (Lee et al., 2019). In order to follow the regulations, investments in technologies and collaboration and technical cooperation of involved organizations are needed (International Maritime Organization, 2020).

Processing large amounts of data, streamlining operations and **data transparency** are closely related drivers. Broad range of stakeholders (such as the maritime logistics enterprises, forwarders and agents) are compelled to accept changes in the maritime transport sector and turn to more effective practices by implementing technologies that can gather and process massive amounts of information (in a cost-effective way) (Jović et al., 2019b), (Marshall University, 2019), as well as improve the stakeholder cooperation and data transparency along the transport chain.

Digitalization has also enabled more far-reaching concepts, such as the Big Data, Internet of Things, Blockchain, and cloud computing, which can provide the maritime industry with new ways to collect, process and exchange valuable data in the real time (European Council for Maritime Applied R&D, 2017).

4.2. Success factors for digital transformation

Success factors may be explained as elements required for achieving desired goals. Table 3 presents the identified success factors for DT in the maritime transport sector classified into three groups: success factors related to the organization itself, related to the external environment and related to technologies. In total, 84 different sources have been considered.

Table 3. Identified success factors for digital transformation

	Success factors	Sources
Identified success factors for digital transformation related to the organization itself	**New business models** (24) = Developing new business models in order to stay competitive and generate new revenues; Smart port may also represent a new business model; Companies must develop business models that maximize innovation and effectiveness in leveraging digitalization	(Mosconi et al., 2019), (Osmundsen et al., 2018), (Legner et al., 2017), (Kutzner et al., 2018), (Fruth & Teuteberg, 2017), (Genzorova et al., 2019), (Hausberg et al., 2019) , (Jović et al., 2019b), (Jeansson & Bredmar, 2019), (Teece & Linden, 2017), (Carcary et al., 2016), (Pappas et al., 2018), (Ponsignon et al., 2019), (Korpela et al., 2017), (Sabri et al., 2018), (Reis et al., 2018), (Ivančić et al., 2019), (Hartl & Hess, 2017), (Schwertner, 2017), (Verina & Titko, 2019), (Remane et al., 2017), (Schiavi & Behr, 2018), (Junge & Straube, 2020), (Korchagina et al., 2020)
	Actively shaping future strategies (50) = Actively shaping future strategies via business optimizations and investments (e.g. in employees' training, technologies), in order to overcome the obstacles and stay competitive	(Mosconi et al., 2019), (Kotarba, 2018), (Heilig et al., 2017a), (Heilig et al., 2017b), (Osmundsen et al., 2018), (Gupta, 2018), (Henriette et al., 2016), (Ismail et al., 2018), (Kane et al., 2015), (Kutzner et al., 2018), (Alt, 2019), (Verhoef et al., 2019), (Nwankpa & Roumani, 2016), (Morakanyane et al., 2017), (Teece & Linden, 2017), (Genzorova et al., 2019), (Holotiuk & Beimborn, 2017), (Matt et al., 2015), (Verina & Titko, 2019), (Carcary et al., 2016), (North et al., 2020), (Schallmo et al., 2019), (Adner et al., 2019), (Larjovuori et al., 2018), (Ponsignon et al., 2019), (Durão et al., 2019), (Mugge et al., 2020), (Kane et al., 2017), (Sehlin et al., 2019), (Galimova et al., 2019), (Moreira et al., 2018), (Agushi, 2019), (Junge et al., 2019), (Korpela et al., 2017), (Sabri et al., 2018), (Reis et al., 2018), (Sayabek et al., 2020), (Vukšič et al., 2018), (Leipzig et al., 2017), (Schwertner, 2017), (Sánchez, 2017), (Kwon & Park, 2017), (Pappas et al., 2018), (Scholz et al., 2020), (Kane et al., 2016), (Vial, 2019), (Pagani & Pardo, 2017), (Remane et al., 2017), (Wang & Mileski, 2018), (Junge & Straube, 2020)
	Clear vision (17) = A strong, clearly communicated vision shared by the entire organization	(Larjovuori et al., 2018), (Ismail et al., 2018), (Mosconi et al., 2019), (Gupta, 2018), (Zeike et al., 2019a), (Kozak-Holland & Procter, 2019), (Holotiuk & Beimborn, 2017), (Carcary et al., 2016), (Kwon & Park, 2017), (Ponsignon et al., 2019), (Mugge et al., 2020), (Reich et al., 2018), (Kane et al., 2019), (Sayabek et al., 2020), (Ivančić et al., 2019), (Schwertner, 2017), (Sánchez, 2017)
	New and dynamic capabilities (13) = Capability to design new business models; Dynamic capabilities to improve business intelligence agility and business value; Dynamic capabilities allow an organization to identify and respond to opportunities by transforming the organization, reconfiguring resources, etc.	(Mosconi et al., 2019), (Osmundsen et al., 2018), (Gupta, 2018), (Holotiuk & Beimborn, 2017), (Morakanyane et al., 2017), (Teece & Linden, 2017), (Verina & Titko, 2019), (Carcary et al., 2016), (Peter et al., 2020), (North et al., 2020), (Pappas et al., 2018), (Sánchez, 2017), (Vial, 2019)

	Cultural readiness for changes (32) = The ability to successfully respond to changes caused by the emergence of new technologies, globalization, etc.; The organizational culture must encourage risk-taking and tolerate failures to succeed	(Mosconi et al., 2019), (Osmundsen et al., 2018), (Larjovuori et al., 2018), (Ismail et al., 2018), (Holotiuk & Beimborn, 2017), (Gupta, 2018), (Kutzner et al., 2018), (Kozak-Holland & Procter, 2019), (Boneva, 2018), (Morakanyane et al., 2017), (Huang, 2018), (Teece & Linden, 2017), (Schumann et al., 2017), (Verina & Titko, 2019), (Jeansson & Bredmar, 2019), (Gausdal et al., 2018), (Peter et al., 2020), (Schallmo et al., 2019), (Henriette et al., 2016), (Pappas et al., 2018), (Ponsignon et al., 2019), (Durão et al., 2019), (Mugge et al., 2020), (Kane et al., 2017), (Kane et al., 2016), (Reich et al., 2018), (Agushi, 2019), (Junge et al., 2019), (Ivančić et al., 2019), (Leipzig et al., 2017), (Hartl & Hess, 2017), (Vial, 2019)
	Organizational agility (12) = Agility to reallocate resources, to reorganize rapidly (at the level of organization) and to detect opportunities for innovation and seize those competitive market opportunities	(Kwon & Park, 2017), (Legner et al., 2017), (Holotiuk & Beimborn, 2017), (Kozak-Holland & Procter, 2019), (Carcary et al., 2016), (Verhoef et al., 2019), (Fuchs & Hess, 2018), (Ponsignon et al., 2019), (Durão et al., 2019), (Agushi, 2019), (Hartl & Hess, 2017), (Vial, 2019)
	Organization's willingness to take risks and make decisions under uncertainty (2) = Experimenting with new, rapidly developing technologies often requires risk taking and making informed decisions under uncertainty	(Hartl & Hess, 2017), (Sánchez, 2017)
	Engagement of managers and employees (32) = Leaders have to encourage forward-thinking, openness, technology acceptance, entrepreneurial spirit, and a startup way of working. Employees have to be ready to cooperate, be ready to develop new skills, etc.	(Osmundsen et al., 2018), (Gupta, 2018), (Legner et al., 2017), (Larjovuori et al., 2018), (Holotiuk & Beimborn, 2017), (Zeike et al., 2019a), (Zeike et al., 2019b), (Boneva, 2018), (Teece & Linden, 2017), (Schumann et al., 2017), (Genzorova et al., 2019), (Jović et al., 2019b), (Matt et al., 2015), (Verina & Titko, 2019), (Carcary et al., 2016), (Kwon & Park, 2017), (Scholz et al., 2020), (North et al., 2020), (Henriette et al., 2016), (Kane et al., 2015), (Ponsignon et al., 2019), (Durão et al., 2019), (Kane et al., 2017), (Reich et al., 2018), (Kane et al., 2019), (Sehlin et al., 2019), (Sayabek et al., 2020), (Vukšič et al., 2018), (Sánchez, 2017), (Vial, 2019), (Remane et al., 2017), (Junge & Straube, 2020)
	Creation of new leadership roles (e.g. a chief digital officer) (1) = A chief digital officer is tasked to ensure that digital technologies are properly leveraged and aligned with the objectives of the organization	(Vial, 2019)
	Digital leadership skills/capabilities (9) = Necessary to achieve increased performance and create competitive advantage for organizations; Seven leadership skills: openness, willingness to fail, adaptability, empathy, motivation, communication, and technological understanding	(Zeike et al., 2019a), (Carcary et al., 2016), (Peter et al., 2020), (Boneva, 2018), (Schallmo et al., 2019), (Pappas et al., 2018), (Kane et al., 2015), (Mugge et al., 2020), (Junge & Straube, 2020)
	Investing in employee and manager knowledge (25) = Changes to the structure as well as the culture of an organization lead employees to assume roles that were traditionally outside of their functions	(Gupta, 2018), (Legner et al., 2017), (Pappas et al., 2018), (Mosconi et al., 2019), (Kutzner et al., 2018), (Nkuna, 2017), (Genzorova et al., 2019), (Huang, 2018), (Henriette et al., 2015), (Verina & Titko, 2019), (Carcary et al., 2016), (Chinoracky & Corejova, 2019), (Boneva, 2018), (North et al., 2020), (Schallmo et al., 2019), (Larjovuori et al., 2018), (Kane et al., 2015), (Ponsignon et al., 2019), (Mugge et al., 2020), (Reich et al., 2018), (Junge, 2019), (Reis et al., 2018), (Ivančić et al., 2019), (Vial, 2019), (Remane et al., 2017)

	Communication within the organization (11) = The organization's intention to build internal networks for knowledge and information sharing	(Carcary et al., 2016), (Heilig et al., 2017a), (Henriette et al., 2015), (Schallmo et al., 2019), (Adner et al., 2019), (Kane et al., 2015), (Ponsignon et al., 2019), (Mugge et al., 2020), (Kane et al., 2019), (Junge et al., 2019), (Hartl & Hess, 2017)
	Cross-functional collaboration (4) = Collaboration between different functional areas of the organization	(Kane et al., 2017), (Kane et al., 2019), (Hartl & Hess, 2017), (Vial, 2019)
Identified success factors for digital transformation related to technologies	**Digital security and compliance** (4): = Enterprises are increasingly exposed to cyber-threats due to intensive use of new technologies, and must take appropriate countermeasures to ensure security	(European Commission, 2018), (Legner et al., 2017), (Ali & Jali, 2017), (Henriette et al., 2016)
	Investing in appropriate technologies (7) = Investing in appropriate technologies according to business needs; Critical factor for creating value in business; for increasing productivity, reducing costs	(Pappas et al., 2018), (Mosconi et al., 2019), (Heilig et al., 2017b), (Schumann et al., 2017), (Gausdal et al., 2018), (Mugge et al., 2020), (Galimova et al., 2019)
	New technologies embedded in aligned business strategies and processes (6) = IT department understands the company's strategy and business	(Alt, 2019), (Kwon & Park, 2017), (North et al., 2020), (Mosconi et al., 2019), (Moreira et al., 2018), (Schwertner, 2017)
	Compatibility, integration and interoperability of ICT and systems (1) = Integration of ICT systems improves data exchange, business planning and management	(Schumann et al., 2017)
	Integration between multiple information platforms (3) = Enabling smoother exchange of information and documents	(Korpela et al., 2017), (Iddris, 2018), (Schumann et al., 2017)
	Development of business process connectivity and standards (3) = For integrating business processes along the transport route	(Korpela et al., 2017), (Iddris, 2018), (Wiedenmann & Größler, 2019)
Identified success factors for digital transformation related to the external environment	**Mutual trust between the organization, its leadership, members and external partners** (1) = A key for an increasingly digitalized working environment	(Hartl & Hess, 2017)
	Understanding stakeholder needs and their expectations (1) = Implementing new technologies to increase collaboration along the transport route and to meet stakeholders' expectations (reduced delays, timely and accurate information)	(Fruth & Teuteberg, 2017)
	Customer and partner engagement and collaboration (30) = An optimal networking of the individual actors who coordinate their activities in the transport chain in order to optimize traffic and goods flows	(Legner et al., 2017), (Kutzner et al., 2018), (Piccinini et al., 2015), (Jović et al., 2019b), (Jeansson & Bredmar, 2019), (Teece & Linden, 2017), (Matt et al., 2015), (Carcary et al., 2016), (Heilig et al., 2017a), (Henriette et al., 2015), (Boneva, 2018), (Agrawal et al., 2020), (Kotarba, 2018), (Larjovuori et al., 2018), (Mugge et al., 2020), (Reich et al., 2018), (Sehlin et al., 2019), (Galimova et al., 2019), (Cichosz, 2018), (Viktorovich & Aleksandrovna, 2019), (Korpela et al.,

		2017), (Iddris, 2018), (Sabri et al., 2018), (Ivančić et al., 2019), (Caputa, 2017), (Schwertner, 2017), (Sánchez, 2017), (Holotiuk & Beimborn, 2017), (Fruth & Teuteberg, 2017), (Pagani & Pardo, 2017)
	Inter-organizational data and knowledge exchange (i.e. across organization boundaries) (5) = The organizations' positive stance towards teamwork, cross-functional collaboration, and readiness for cooperation with external partners (e.g. customers)	(Junge et al., 2019), (Wiedenmann & Größler, 2019), (Hartl & Hess, 2017), (Schwertner, 2017), (Vial, 2019)
	Government/policy-makers support (4) = Financial help given by the government/policy makers	(European Commission, 2018), (Jeansson & Bredmar, 2019), (Legner et al., 2017), (Lavikka et al., 2017)
	Adequate regulation (2) = Rules made by the government or other authorities, encouraging DT	(European Commission, 2018), (Hanna, 2018)

Based on the literature review, 13 organizational, 6 technological and 6 external environmental success factors for DT in the maritime transport sector were identified. Regarding the **actively shaping future strategies**, (Heilig et al., 2017b) state that it is essential to first evaluate competitive potentials, integrate them with the existing port IT/IS infrastructure, and align with individual processes and the port business network. However, less digitally mature organizations tend to focus more on the individual technologies (Kane et al., 2015).

With regard to **new business models**, new entries come into the market with novel and often disruptive business model, while the incumbent companies still rely on the existing business model based on their existing assets that may not be able to fulfil customer and market needs anymore (Venkatesh et al., 2019), (Mihardjo & Sasmoko, 2018). Currently, smart ports may represent the aforementioned "novel business model", in which all parts of the seaport operations and transportation are closely connected through various digital networks (Jović et al., 2019a). (Heilig et al., 2017b) claim that, in smart ports, only the integration of different solutions enables the adequate redesign of business processes.

Clear vision was considered to be either the prerequisite or the first step of the DT (Larjovuori et al., 2018). The importance of clear vision may be shown through the case of Port of Rotterdam: "We continually improve the port of Rotterdam to make it the safest, most efficient and most sustainable port in the world…", "…we are also strengthening the competitive position of the Netherlands." (Port of Rotterdam, 2019c). Indeed, the port area is constantly in development, maintaining Rotterdam's position as the world's leading port"

(Port of Rotterdam, 2019a). The necessity for a clear vision can be demonstrated through the Maersk (the Danish shipping company responsible for 18% of container trade in the world) case as well. “Maersk is delivering on the vision in which DT and technological rationalization become the backbone of delivering a seamless, end-to-end experience for its customers.” (Maersk, 2019a).

In order to realize the vision and further accelerate DT, CMA CGM Group is introducing services such as smart containers which provide notifications in case of humidity or an abnormal rise in temperature (CMA CGM GROUP 2018). Their vision, among others, focuses on customers as well, proving that the changing customer behaviors and expectations are the primary drivers of DT.

New and dynamic capabilities can be defined as “an organization's ways of responding in a rapidly changing environment” (Bleady et al., 2018). (Kuo et al., 2017) claim that in an uncertain environment, with increasingly higher costs and risks, container shipping companies need to focus on dynamic capabilities to renew and adjust their management strategies.

Regarding the **engagement of managers and employees** and **investing in employee and manager knowledge**, senior managers of organizations in the maritime transport sector should effectively develop incentives and encourage employees and invest in their knowledge, as these factors affect the organizational agility (Maymand & Mollaei, 2014). For example, developing new devices for data processing and validating the collected data in the maritime transport sector is labour intensive and requires technological knowledge in analytics, statistics and software modelling (Koga, 2015; Jović et al., 2020).

In regard to **cultural readiness for changes** and **organization's willingness to take risks and make decisions under uncertainty**, leaders in the maritime transport sector need to build a supportive culture that embraces collaboration, risk taking, and experimentation (Kane et al., 2017). Cultural values crucial for DT success are: openness towards change, customer-centricity or willingness to learn (Hartl & Hess, 2017).

With regard to customer and partner engagement and collaboration and inter-organizational data and knowledge exchange (i.e. across organization boundaries), collaboration may help the stakeholders of the port processes to reduce logistics costs through faster information flow, aiming to deliver the cargo faster, to enable the flow of goods, to save time necessary for the completion of business processes and finally, to boost economic growth (Tijan et al., 2012). For example, the Port of Rotterdam plays a decisive part in the process of DT through the cooperation with clients, business partners and digital platforms in order to make Rotterdam a hotspot for the development of the most promising digital innovations; they are also investing in new digital infrastructure that can help create the right conditions for extensive digitalisation etc. (Port of Rotterdam, 2019b). The Maritime and Port Authority of Singapore launched the Smart Port Challenge 2017 to encourage start-up and organizations collaboration, pushing DT into the industry, harnessing technologies to add value to the maritime logistics chain, also collaborating with the Port of Rotterdam in the same kind of endeavor" (Czachorowski et al., 2019). However, according to (Chandra & van Hillegersberg, 2018), collaborations need formal governance to address members' concerns about who owns the data, how the data is protected, and who can access the data. In order to achieve successful collaboration, mutual trust between the organizations, their leadership and members, as well as the organizations' trust in their external partners are necessary.

In order to **understand stakeholder needs and their expectations**, some of the stakeholders (e.g. senders, recipients, shipping agents) use new technologies. In this way, the actors in the maritime transport chain, e.g. terminal operators, ship brokers and forwarders, can bundle and, in case the time of arrival changes, adapt their resources appropriately (Fruth & Teuteberg, 2017). In order to meet the rising customer expectations and to stay ahead of the competition, it is necessary to **invest in appropriate technologies**, as the overall port operation services can be enhanced by moving to a paperless environment and providing a valuable and relevant solution that completely restructures the manual process of documents exchange among the port community members (Attia, 2016).

The following identified success factors are related to technologies: new technologies embedded in aligned business strategies and processes; compatibility, integration and interoperability of ICT and systems; integration between multiple information platforms as well as development of business process connectivity and standards. Integration of existing information systems and data sources as well as more intelligent use of data may help to improve planning, controlling, and management of intra- and inter-organizational operations in the maritime transport sector (Heilig et al., 2017a). Paperless and standardized communication is a prerequisite not only for effective maritime transport operations involving many stakeholders but also for improving the integration, coordination, and performance of the supply chain (Heilig & Voß, 2017). Furthermore, security and transparency must be built in the technology and processes at all levels in the maritime transport sector. It is important that used solutions allow easy audit trail, logging of activities and using some innovative new technologies to assure the proof of authenticity (digital signature or Blockchain).

Government/policy-makers support relates to governments, transport ministries and port authorities that play an important role in DT of the maritime transport sector. It is necessary that governments envision and articulate future development scenarios, maintain frequent consultation with the stakeholders and encourage the stakeholders to invest with confidence in projects that support DT in the maritime transport sector (World Bank Group, 2007).

4.3. Barriers to successful digital transformation

In addition to drivers and success factors, authors have identified the barriers to DT in the maritime transport sector as well (also known as dysfunctional factors (Dehning et al., 2003). Challenges may arise collectively and form barriers that substantially hinder the progress of the DT process. Such barriers require explicit and extensive coping actions that go beyond the mitigation of individual issues (Fuchs & Hess, 2018). In total, 16 barriers were identified using 36 sources (Table 4).

Table 4. Identified barriers to successful digital transformation

	Barriers	**Sources**
Identified barriers to successful digital transformation related to the organization itself	**Heterogeneous organization structures and lack of cultural integration** (2) = Inert organizational cultures preventing DT	(Kozak-Holland and Procter, 2019), (Hartl & Hess, 2017)
	Lack of awareness of how DT may affect the business of organizations (4) = Due to lack of awareness and understanding, organizations do not assess the resources and do not invest in resources by which DT can be achieved	(Boneva, 2018), (Piccinini et al., 2015), (North et al., 2020), (Durão et al., 2019)
	Technology-oriented culture (2) = Digital technologies alone provide little value to an organization without the alignment with the business strategy	(Gausdal et al., 2018), (Vial, 2019)
	Lack of capabilities to change (3) = Leads to a slower DT	(Mosconi et al., 2019), (Gupta, 2018), (Kane et al., 2016)
	Lack of digital skills and qualified labor force (8) = Due to the emergence of new technologies, the labor force is not able to use new technologies properly and to	(Mosconi et al., 2019), (Fuchs & Hess, 2018), (Agrawal et al., 2020), (Kane et al., 2016), (Sehlin et al., 2019), (Agushi, 2019), (Leipzig et al., 2017), (Munim et al., 2020)

	take full advantages of the new technologies; Lack of digital skills and qualified labor force will slow down the DT	
	Employees' and managers' resistance to change (18) = The resistance that employees can demonstrate when disruptive technologies are introduced in the organization: Resistance can be classified as being systemic (cognitive) or behavioral (emotional), where systemic implies the lack of information, skills, knowledge, etc. and behavioral implies the assumptions, perceptions and reactions	(Gupta, 2018), (Kozak-Holland & Procter, 2019), (Matt et al., 2015), (Jeansson & Bredmar, 2019), (Ismail et al., 2018), (Henriette et al., 2016), (Durão et al., 2019), (Mugge et al., 2020), (Sehlin et al., 2019), (Agushi, 2019), (Junge et al., 2019), (Sayabek et al., 2020), (Leipzig et al., 2017), (Gausdal et al., 2018), (Agrawal et al., 2020), (Fuchs & Hess, 2018), (Vial, 2019), (Acciaro & Sys, 2020)
	Lack of employees' and managers' motivation (4) = Negative attitudes and opinions of the organization members who are involved in the DT	(Fuchs & Hess, 2018), (Teece & Linden, 2017), (Verina & Titko, 2019), (Sehlin et al., 2019)
	Lack of vision, strategy and direction (13) = Some organizations do not know in which direction they should lead their digital strategy	(Jeansson & Bredmar, 2019), (Ismail et al., 2018), (Ntsako Nkuna, 2017), (North et al., 2020), (Schallmo et al., 2019), (Kane et al., 2015), (Durão et al., 2019), (Kane et al., 2016), (Agushi, 2019), (Sayabek et al., 2020), (Mosconi et al., 2019), (Gupta, 2018), (Heilig et al., 2017b)
	Lack of coordination and collaboration (2) = Problematic coordination with other business units; at the organizational level	(Fuchs & Hess, 2018), (Acciaro & Sys, 2020)
	Lack of investment and initiatives (4) = No investments related to digitalization or low level of investment in digital initiatives; Lack of cultural and organizational transformation leads to the lack of investments in new technologies and digital initiatives	(European Commission, 2018), (Gausdal et al., 2018), (North et al., 2020), (Durão et al., 2019)
Identified barriers to successful digital transformation related to technologies	**The existence of heterogeneous and independent information systems and lack of standards** (2) = Heterogeneous, non-integrated information systems prevent the successful DT	(Schumann et al., 2017), (Tsakalidis et al., 2020)
	Decreased levels of cyber security (especially in the area of digital operations) and resilience (6) = All players in the maritime supply chain have not ensured the best possible protection in order to ward off cyberattacks; As the digital technologies are rapidly changing, information security must evolve at the same pace	(Nkuna, 2017), (Fruth & Teuteberg, 2017), (Agrawal et al., 2020), (Kane et al., 2015), (Junge et al., 2019), (Tsakalidis et al., 2020)
	High investment/implementation costs (5) = Not all companies chose to digitalize their business due to significant investment/implementation costs	(Gausdal et al., 2018), (Agrawal et al., 2020), (Leipzig et al., 2017), (Mosconi et al., 2019), (Acciaro & Sys, 2020)
	High implementation risks of emerging technologies and return on investment (ROI) concerns (2) = High risk of implementing a radical change in an unknown field such as digitalization or DT	(Leipzig et al., 2017), (Agrawal et al., 2020)
Identified barriers to successful digital transformation related to the	**Lack of industry specific guidelines** (1) = As a result, companies lack a clear vision about what to transform first: internal operations, customer relationships or business models	(Agrawal et al., 2020)
	Missing or inadequate regulations (1) =	(Marija Jović, 2019)

	The regulations in MTS are often specific for each country, and the question is whether it is possible to introduce a particular technology or business model	

Based on the literature review, 10 organizational, 4 technological and 2 external environmental barriers to DT were identified. One of the identified barriers is **heterogeneous organization structures and lack of cultural integration**. Lack of effective organizational culture and poor cultural integration within the organization affect the organization performance and cause the loss of productivity (Tedla, 2016). According to (Theotokas, 2007), the business culture creates a unified "front" of all institutions in the case of tramp shipping, allowing the handling of a crisis at the right moment through a common reaction, which would not be possible without vision, strategy, direction and capabilities to change.

Less digitally mature organizations tend to focus on individual technologies and have **technology-oriented culture only** (Kane et al., 2015). The Port of Rotterdam has successfully digitally transformed its seaport operations by recognizing the benefits of new and emerging technologies. However, the Port of Rotterdam does not focus only on the technologies themselves, but on a clear vision and the collaboration between the stakeholders.

An increasing number of enterprises in the maritime transport sector are offering high-technology solutions to optimize ship operations (in regard to the optimum speed, fuel consumption), or to facilitate collaboration and communication between stakeholders (Jović et al., 2020). Necessary technical modifications depend on the state of existing technologies used in an organization and must be adapted according to the needs of the organization. It usually implies a major upgrade or replacement of the working tools, applications and underlying infrastructure, leading to **high investment/implementation costs** and **high implementation risks and lack of clarity about the pay-off from the investments in emerging technologies**.

Maritime transport may suffer from a **lack of digital skills and qualified labour force**, a problem that is expected to increase in the future because the emergence of new technologies requires additional skill sets, and technological knowledge. Adequate human resources need to be ensured through the cooperation between universities and the private sector (by investing in knowledge, new study and training programs, etc.) for further development and implementation of technologies in the maritime transport sector (Jović et al., 2020; Koga, 2015).

Regarding the **employees' and managers' resistance to change** as well as the **lack of employees' and managers' motivation**, a need arises for the repeated training of employees and managers in order to successfully utilize the technologies or services in the maritime transport sector. Furthermore, resistance of employees and managers to collaborate may present an obstacle in preparations for the imminent change.

Decreased levels of cyber security (especially in the area of digital operations) and resilience are additionally identified barriers. The stakeholders in the maritime transport sector might be unwilling to use the information systems because of skepticism regarding data security (Treppte, 2011). Besides, the stakeholders should ensure both proactive and reactive protection such as threat scanning and perimeter defenses that sift through data streams in real-time searching for security threats and anomalies.

The existence of heterogeneous and independent information systems and lack of standards may represent a large barrier to DT. According to CLECAT, "in recent years, many authorities and business communities have developed their own solutions to exchange information digitally. However, even though they were created with the best intentions, these individual initiatives have led to a multitude of non-interoperable IT solutions". The joint blockchain initiative Tradelens (Maersk and IBM) is an example which highlights the importance of collaboration among stakeholders and building common standards (as lack of standards in one of the barriers for DT) (Maersk, 2019b).

5. Discussion

A summary model of the aforementioned drivers, factors and barriers for digital transformation (DT) in the maritime transport sector identified in this study is presented in Fig. 3. and discussed in detail below. In this model, the identified drivers foster DT in the maritime transport sector and success factors enable/facilitate DT in the maritime transport sector. On the other hand, the identified barriers inhibit the successful DT in the maritime transport sector.

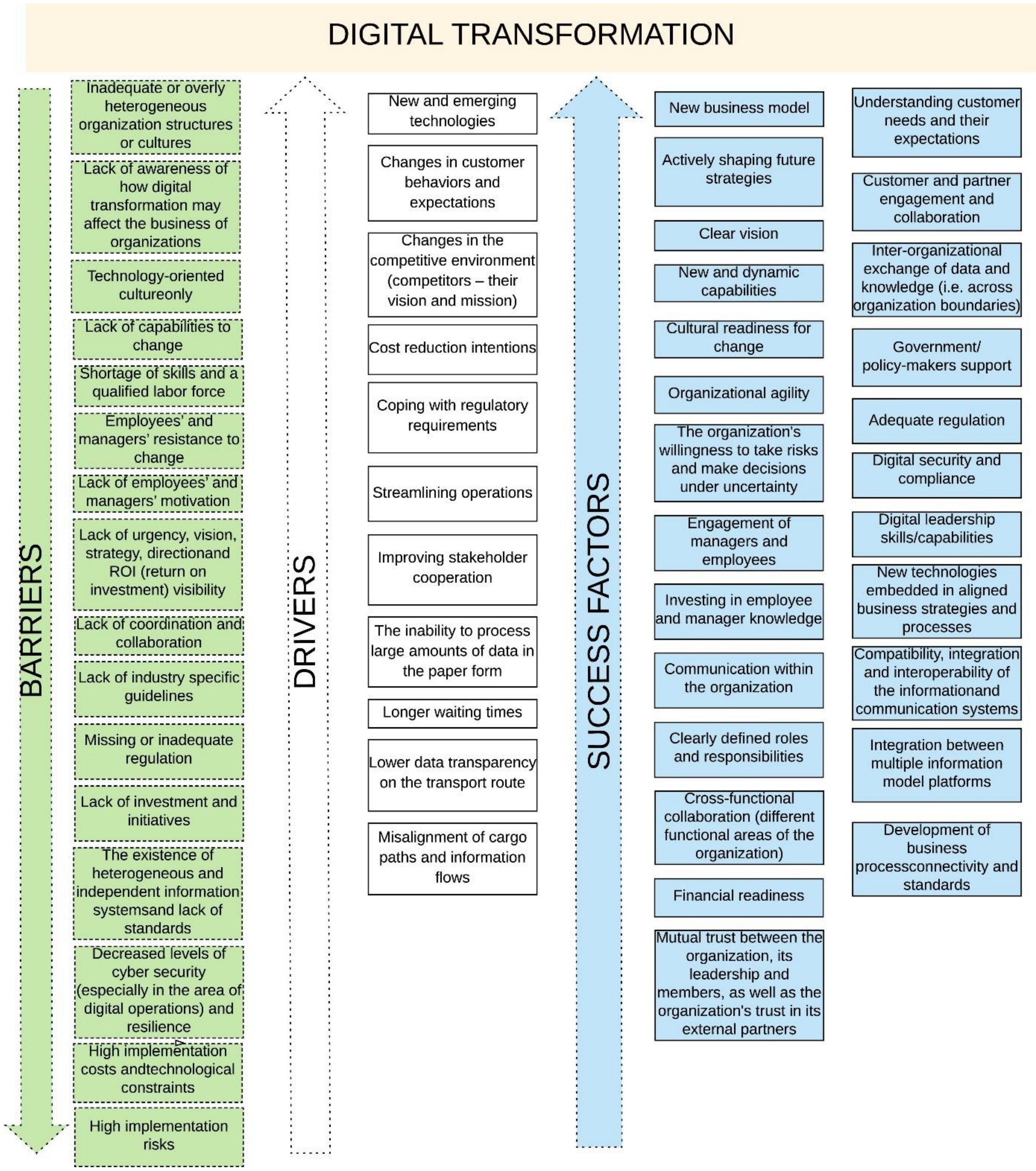

Fig. 3. Model of drivers, success factors and barriers affecting digital transformation in the maritime transport sector

One of the main drivers of DT in the maritime transport sector is **cost reduction** and it mostly refers to reducing costs of exchanging information and executing transactions. **Streamlining operations** (improving of resources planning and information flows) is directly related to **shorter time delays, streamlining operations, processing large amounts of data, improving**

stakeholder collaboration and **data transparency**. Unnecessary bottlenecks result from a large number of uncoordinated stakeholders, non-transparent data, and numerous transactions and documentation processes (mostly paper-based). Stricter environmental requirements in the maritime transport sector may also act as a driver for digital transformation. For example, if incoming ships are provided with the real-time information on availability of the berths in seaports, their navigation speed can be adjusted, shortening the waiting time at the seaport and reducing the volume of emissions at the berth and during the voyage. In this way, digital transformation enables the **regulatory requirements** to be met.

The drivers **new and emerging technologies, changing customer behaviors and expectations** and **competitive environment** are also closely related. The emergence of new digital technologies dramatically changes the competitive landscape and customer expectations. Customers demand reliable, flexible, and cost-efficient transport services stimulating the maritime transport sector companies to engage into DT in order to remain competitive. The crucial phase of the DT is not only the digitalization of the business processes, but also a gradual removal of the outdated business and management processes that are often compartmentalized and highly fragmented. **New business models** are necessary for maximizing innovation and effectiveness in fostering digitalization. The competitive potential should be assessed before **shaping future strategies** which should be focused towards the harmonization. The DT should not only be oriented towards the technology implementation, as the **technology-oriented culture** (without considering other factors) represents one of the main barriers. It must be based on the aligned business and digital strategy of an organization.

The stakeholders should successfully respond to a rapidly changing environment and recognize opportunities and minimize threats which can be defined as **cultural readiness for changes. New and dynamic capabilities** should allow the maritime transport sector organizations to identify the opportunities and to respond to them by organizational transformation. The **engagement of managers and employees** and **investing in employee and manager knowledge** are the important success factors since the new technologies (which requires technological knowledge) emerge rapidly. **Customer and partner engagement and collaboration**, together with **inter-organizational data and knowledge exchange**, may help the stakeholders to reduce costs through smoother information flow.

Stakeholder collaboration may be the most important challenge for the maritime transport sector, because the successful DT in the maritime transport sector should not only focus on the individual needs, but also on the external environment that is more difficult to predict and control. **Government/policy-makers support** can also encourage the stakeholders to invest in the projects that support DT in the maritime transport sector. Since the stakeholders are often reluctant to digitally transform their business, there is a need for constant education about the benefits of DT, but also for the quantification of benefits that can be clearly presented to the decision-makers.

Technological success factors for the DT are closely related. **Compatibility, integration and interoperability of ICT and systems** as well as the **development of business process connectivity and standards** are the prerequisite for the undisturbed data exchange, but **digital security** and **data transparency** are imperative in all technologies and processes at all levels in the maritime transport sector. However, the stakeholders might be unwilling to integrate their information systems because of the skepticism regarding **data and information security**, and may also be **reluctant to collaborate**, continuing to use their **independent information systems**.

In regard to DT, the maritime transport sector is specific compared to the other sectors: the management usually takes a conservative approach, and the resources are often limited. Although the technologies such as the Blockchain or the autonomous shipping foster DT in the maritime transport sector, **the lack of awareness of how DT may positively affect the business** as well as **employees' and managers' resistance to change** is pronounced. The paper documents exchanged between the stakeholders in the maritime transport sector still slow down the business processes and incur higher costs.

6. Conclusions

In the maritime transport sector, transport enterprises and seaport stakeholders are at different stages of their DT journey. While the highly digitalized seaports and enterprises (such as, for example, port of Rotterdam and Singapore) may be observed as the most successful examples of digital transformation (DT), on the other hand many other seaports, seaport stakeholders and enterprises along the maritime supply chains are lagging behind.

The motivation for this research stems from the lack of existing research focused on DT in the maritime transport sector. The existing studies do not provide a comprehensive overview of the current situation, and successful cases or drivers and impediments of DT in the maritime transport sector. To fill these gaps, this research aims to identify the success factors, drivers and barriers for DT which can be applied to the maritime transport sector context. For that purpose, the authors conducted a comprehensive literature review.

The contribution of this study is twofold. First, the results of the study enrich the body of knowledge in the field of digitalization and DT which can be applied to the maritime transport sector. The overview of the identified drivers, success factors and barriers offer other researchers an introduction to the investigated field and may provide a baseline towards the future research design. Due to the lack of research in the field, further studies will be necessary to gain deeper insights into how to design successful DT and apply it to the maritime transport sector. Secondly, the understanding of drivers fostering DT, the success factors facilitating and enabling DT as well as being aware of barriers to the DT can help the practitioners in shaping their DT strategies. In addition, the paper also provides an initial overview of DT in the maritime transport sector, that could also be beneficial for researchers as well as practitioners.

As this research is limited to the literature review, which revealed that not many DT studies exist in the maritime transport sector, the future studies should empirically examine the situation in the field. While in depth case studies will serve as a basis for deeper understanding of the successful and failed DT projects, quantitative approaches with surveys will offer an opportunity for the generalization of understandings.

Along with that, the proposed research questions, or venues for future research in the field of DT in the maritime transport sector that should contribute to academic knowledge and practitioners' understandings are the following:

- What are the activities and actions needed for successful DT, that should be undertaken by enterprises in the maritime transport sector presently at lower levels of digital trends adoption, considering their achieved level of development, available resources and capabilities, and cultural readiness for change?
- Is there a difference, and to what extent, between the SMEs and the larger enterprises in terms of adapting to the changes caused by the emerging technologies, and the changes in competitive landscape of the maritime transport sector?
- What is the government's role in DS in the maritime transport sector?

This comprehensive literature review presents a fundamental basis for the planned future research in DT in the maritime transport sector, in order to gain a deeper understanding of how the maritime transport stakeholders cope with the market and digital/technology changes and challenges. A literature review facilitates identifying the research gaps and provides an overview of the current body of knowledge. However, the authors deem it necessary to conduct further empirical analysis of the maritime transport stakeholders to gain comprehensive understanding of the ongoing activities and to design proper guidelines, strategies and solutions for faster, wider and more successful DT of the maritime transport sector.

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Appendix A: The number of hits after applying the reduction criteria for each search term found in different databases and number of sources after screening manually

Database	Keyword	Articles after applying formal criteria	Articles after screening manually	Criteria
Web of Science	Digital transformation	2027	23	2015-2020; TOPIC or TITLE; Categories: Computer science information systems, management, business, communication, Economics, Transport science technology, green sustainable science technology
	Digital transformation + Transport	32	4	
	Digital transformation + Maritime transport	2	0	
	Digital transformation + Maritime industry	6	0	
	Digital transformation + Shipping	14	0	
	Digital transformation + Seaport	7	0	
	Digital transformation + Port	19	1	
	Business model + Innovation + Transport	162	1	
	Business model + Innovation + Maritime Transport	4	0	
Total		**2273**	**29**	
Scopus	Digital transformation	13061	5	2015-2020; Article title, Abstract, Keywords,
	Digital transformation + Transport	177	4	
	Digital transformation + Maritime transport	5	0	
	Digital transformation + Maritime industry	12	1	
	Digital transformation + Shipping	14	1	
	Digital transformation + Seaport	7	0	
	Digital transformation + Port	41	0	
	Business model + Innovation + Transport	27	1	
	Business model + Innovation + Maritime Transport	2	0	

Database	Keyword	Articles after applying formal criteria	Articles after screening manually	Criteria
Total		**13346**	**12**	
AISeL	Digital transformation	510	7	2015-2020; Abstract OR Title OR Subject
	Digital transformation + Transport	5	0	
	Digital transformation + Maritime transport	1	0	
	Digital transformation + Maritime industry	3	0	
	Digital transformation + Shipping	3	1	
	Digital transformation + Seaport	1	0	
	Digital transformation + Port	4	0	
	Business model + Innovation + Transport	2	0	
	Business model + Innovation + Maritime Transport	0	0	
Total		**529**	**8**	

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C. Maritime National Single Window—A Prerequisite for Sustainable Seaport Business

Abstract: This paper presents a comprehensive review of National Single Window concept and its impact on sustainability in maritime transport and seaports. The theoretical frameworks of sustainability, maritime transport, seaports, the National Single Window and the Maritime National Single Window is provided. The importance of stakeholder connectivity in maritime transport and seaports in improving sustainability is demonstrated, as well as the advantages of smoother data exchange through global analysis of National Single Window examples, the majority of which present national and regional best practices and initiatives. Empirical data has been provided in order to demonstrate the impact of National Single Windows and Maritime National Single Windows on seaport sustainability (economic, environmental, and social).

Keywords: maritime national single window; seaport business; sustainability

1. Introduction

The Single Window concept, which enables all stakeholders involved in the business process to input the data and information used by other stakeholders only once (by using a single point of data entry and storage) has significantly changed the process of information exchange between transport stakeholders, particularly in maritime transport and seaport business. Implementation of a National Single Window as a single-entry point has the potential to harmonize and standardize the information exchange between commercial and administrative stakeholders and to provide fast, reliable, paperless, and efficient transactions. Interestingly, the first Single Window implementations did not necessarily involve information and communication technologies (ICT), instead, they were envisaged as one-stop-shop trade facilitation services at national cargo entry points. With the development of technology and networking, digitalization became a staple concept around which Single Window implementations are developed and implemented. The most commonly accepted definition of a Single Window is the one provided by the United Nations Economic Commission for Europe (UNECE) Recommendation number 33: “A facility that allows parties involved in trade and transport to lodge standardized information and documents with a single-entry point to fulfil all import, export, and transit-related regulatory requirements” [1]. The first electronic Single Windows were set up at the beginning of 2000s in early, adopting countries such as Ghana, Singapore and Senegal [2].

On a global level, the largest percentage of cargo is transported by sea, and it accounts for 80% or cargo by volume and 70% by value [3]. According to the United Nations Conference on Trade and Development (UNCTAD), world seaborne trade continues to grow and sustainability becomes vital for seaport business [4]. Economic, environmental and social aspects of seaport sustainability can be further strengthened by applying the (Maritime) National Single Window (MNSW). Thus, the implementation of (Maritime) National Single Window is getting the prominent and decisive role in seaport business sustainability. This unique maritime interface will align and improve interoperability between the various systems, which will in turn facilitate the exchange and reuse of data. Furthermore, the (Maritime) National Single Window provides the possibility to upgrade from the micro-national to macro-regional system to contribute even more to sustainable seaport business. Considering the number of various involved stakeholders, it is a general consensus that the implementation of a (Maritime) National Single Window systems in maritime transport, on national, regional, and supranational levels is of great importance for the facilitation and enhancement of cargo flow, increase of security, and compliance with legislative requirements.

This paper researches the concept of National Single Window and its applications, with special emphasis on maritime transport and seaports (Maritime National Single Window), and its impact on sustainability. The research problem stems from the increased costs and the lost time due to the archaic or inadequate execution and monitoring of business processes. The goal of the paper is to research National Single Windows and Maritime National Single Windows from economic, environmental and social aspects of sustainability. This paper presents a comprehensive review of research papers dealing with this topic, providing a better understanding of NSW and MNSW implementation and its impact on sustainability in maritime transport and seaports.

2. Research Methodology, Data and Scope

In this section, the methodology, review scope and selection of researched papers are presented. The search for papers was conducted according to the time limitations (2010–2019) although most of the papers were published in 2018, due to the recent popularity of the topic in academia and business. To ensure that possible useful findings from various fields are not excluded, the authors did not limit the queries to a specific field or index. Non-English journal papers were excluded. Table 1 (created according to Shi et al. [5]) shows journals, books and conference papers taken into consideration. In total, several hundred literature units were studied. Thirty-six papers were selected from 12 journals and six papers from six conferences, as shown in Table 1. Two books relevant to this topic were also included.

Table 1. Journals, books and conferences related to sustainability and (Maritime) National Single Window ((M)NSW) research from 2010 to 2019.

No.	Journals	2010-2017	2018	2019	2012-2019
1	MDPI Sustainability	5	14	6	25
2	MDPI Logistics	0	1	0	1
3	Logistics & Transport	1	0	0	1
4	Journal of Cleaner Production	0	1	0	1
5	Transportation Research Part D: Transport and Environment	1	0	0	1
6	Transactions on Maritime Science	0	1	0	1
7	Ocean & Coastal Management	0	1	0	1
8	Soft Computing	0	1	0	1
9	Journal of Korea Port Economic Association	1	0	0	1
10	Transportation Research Record: Journal of the Transportation Research Board	1	0	0	1
11	Asian Journal of Shipping and Logistics	1	0	0	1
12	Transportation Research Procedia	1	0	0	1
	Books				
1	Springer International Publishing, Sustainable Shipping. Springer Nature Switzerland AG	0	0	1	1
2	M. Janić, The Sustainability of Air Transportation: a Quantitative Analysis and Assessment. Netherlands, Routledge: Ashgate Publishing, Ltd.	1	0	0	1
	Conferences				

1	5th International Maritime-Port Technology and Development Conference, MTEC 2017	1	0	0	1
2	Bled eConference eDependability: Reliable and Trustworthy eStructures, eProcesses, eOperations and eServices for the Future	1	0	0	1
3	CITEM Conference on International Trade, Education and Marketing 2012.	1	0	0	1
4	31st Bled eConference - Digital Transformation: Meeting the Challenges Conference Proceedings	0	1	0	1
5	International Conference on Science, Management, and Engineering 2018	0	1	0	1
6	MIPRO 2019, 42nd international convention on information and communication technology, electronics and microelectronics	0	0	1	0

Furthermore, the importance of (Maritime) National Single Window in seaport sustainability was demonstrated through the analysis of various global applications and experiences. For this purpose, the authors have studied several hundred other sources, out of which 55 official web pages (e.g., Deloitte, UNESCAP, Doing Business etc.) and other relevant sources related to MNSW implementation and its impact on sustainable business in seaports were included. The relevant findings have been summarized, demonstrating how MNSWs affect the sustainability of business processes and overall sustainability. Ultimately, authors have summarized the findings and categorized them according to appropriate aspects of sustainability (economic, environmental and social).

3. Threoretical framework

In this chapter, the authors provide a detailed review of relevant literature and previous research regarding the subject. In this respect, it is important to define the term "Sustainable development," which will be a basis for this research. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It consists of three main components: economic, environmental, and social sustainability, known as the "triple bottom line" [6]. Economic sustainability is created by producing various goods and services in a responsible manner. The dimension of economic sustainability is comprised of the elements that include technology and innovation [7]. Environmental sustainability means the ability to maintain the quality and the reproducibility of the natural resources [8]. Social sustainability is vital for businesses, as it contributes not only to business goals, but also to greater well-being, stability, and success of the surrounding society [7].

Transportation is a very dynamic activity that causes harmful emissions which are affecting the sustainable development. Almasi, Sadollah, Kang et al. [9] define transportation as a multimodal, multi-problem and multi-spectral system, as it involves different categories and activities, such as policy-making, planning, designing, infrastructure construction, and development. Furthermore, the authors consider the transport as one of the main contributing factors of economic growth and quality of life, but also as one of the main causes of environmental pollution [10]. In the transport context, there has often been a strong focus on economic outcomes, with less consideration given to social and environmental aspects [11]. The energy consumption related to transportation amounts to one-third of global energy consumption, making the transportation sector the second largest energy consumer after industry [12]. The transportation industry is facing new challenges related to the sustainability of the business models from the economic, environmental, and social points of view [13].

Transport sustainability has become an important factor of sustainable development strategy, due to the strong correlation between transport, economic, and social development, and particularly because of its significant impact on the environment [14]. Bamwesigye and Hlavackova [15] have identified three core values of sustainable transport. First, sustainable transport should provide safe and consistent access to individual and societal basic needs, while securing both human and ecosystem health to ensure stability for future generations. Second, sustainable transport must have value for money through efficiency in operation and affordability, while offering various alternative transports means. Finally, the emissions control and global waste management should be the core goals of sustainable transport.

The overall goal of sustainable transport based on three core values should be providing mobility that safeguards regional economic development while at the same time ensuring a long-lasting future for natural resources [15]. Sustainable transport and logistics is proclaimed as a key area in which sustainable intervention can have the greatest impact in terms of enabling more sustainable trajectories [16]. To achieve and maintain efficient and sustainable transport systems, collaboration and co-operation between freight carriers is both critical and crucial issue. Effective collaboration between stakeholders across the supply chain results in reduction in inventories and costs and improvement in speed, service levels, and customer satisfaction [17].

As mentioned before, maritime transport is the main mode of transport in global trade and one of the cornerstones of globalization [18]. Thus, the integration of sustainability principles becomes crucial for all maritime transport stakeholders. Maritime transport sustainability is the ability to provide transport infrastructure and services that are: safe, socially inclusive, accessible, reliable, affordable, fuel-efficient, environmentally friendly, have a low carbon footprint, and resilient to shocks and disruptions, including those caused by climate change and other natural causes. To achieve complete sustainability goals in maritime transport, all three dimensions should be equally considered and improved [19]. Economic parameters to be evaluated include market access, connectivity, infrastructure capacity, trade competitiveness and transport costs. The environmental issues may include: Air emissions (pollutants and greenhouse gases), waste control, spills and pollution (e.g., oil and other substances), climate change impacts, biodiversity loss, and resource and energy depletion [19]. The social dimension may include safety, health, security, employment, and working conditions.

The maritime industry, including ports, shipping and logistics, has begun to embrace environmental guidelines and regulations to reduce environmental impacts and carbon emissions [20]. The Swedish Environmental Protection Agency has set up the national targets for shipping in the reduction of carbon dioxide (CO_2) in Sweden. Until 2050, the amount of CO_2 from shipping should be reduced by 20% [21]. Although the maritime industry is technologically advanced, innovations in the maritime sector have been primarily related to ship construction, oil and gas exploration, seabed exploitation technologies, and so on. Insufficient attention has been given to sustainability improvements. [22]. One of the most promising areas of maritime innovation is related to digitalization, including the development of smart ships, smart fleet, and smart global logistics [23], so the digitalization can serve as the basis for sustainable maritime transport.

A seaport is the main node of maritime transport, a link in the sea–land transport chain [24]. Seaports play a substantial role as a cluster of loading, unloading, and transshipment activities, and brokerage, warehousing, and storage services [25]. Seaports are essential for the support of economic activities in the surrounding areas [26]. Seaport business causes environmental pollution, noise, and congestion [24]. According to Di Vaio and Varriale [27] the environmental issue is primarily and usually associated with vessel and cargo handling operations, industrial activities in ports, port planning and expansion initiatives, and hinterland accessibility. According to Notteboom and Lam [28] terminal activities are the primary source of environmental impact of seaports, which can be summarized into the following categories: air emissions of ships at berth and terminal handling equipment (such as cranes and yard equipment); noise associated with cargo handling operations; and the environmental effects and potential congestion associated with landside operations of barges, rail, and trucks.

In the Delloite's "Study on Global trends to 2030: Impact on Ports Industry," sustainability is identified as one of the key issues for the future of seaports [29]. Slinger et al. consider the sustainability as a fundamental requirement in seaport business [30]. Seaports are in a unique embedded position in the supply chain, which enables them to provide incentives to industry stakeholders in their efforts to improve the industry's sustainability. Sustainable business is inevitable for seaports also, due to the customers requiring sustainable and green supply chains initiatives that strengthen to the ports' sustainability [31].

Seaports are being pressured to respond to problems related to negative impact resulting from activities in the entire logistics chain [24]. Thus, more attention urgently needs to be paid to the environmental protection to ensure ports' sustainability while facilitating the development of port logistics in the coming decades [32]. The sustainable seaport business is the appropriate planning and management of seaports, balancing environmental, social, and economic interests through mediation and open dialogue. Furthermore, managing the different stakeholders and interactions among them is of the crucial importance in improving sustainable seaport business [33].

The concept of sustainability for seaports is focused to the integration of the environmentally friendly methods in the seaport business. Sustainable seaport business causes the minimum possible impacts, contributing to improving measures and controls for the quality of the air, water, noise, and waste [34]. Therefore, the concept of sustainable seaport business becomes a standard business practice. This model implies business strategies and activities that meet the current and future needs of the port and multimodal transport chain stakeholders, while protecting and sustaining natural resources and environment. Considering the three pillars of sustainability, Oh, Lee, and Seo [35] identified key management criteria for sustainable seaport business. An environmental management criterion includes environmental policy, reduction of environmental risks and collaboration between all stakeholders to develop a green supply chain. Economic management criteria include cost saving by using cleaner technologies, while social management criteria include the improvement of the welfare and working conditions, continuous training, and education, as well as supporting the social and economic activities of the seaport.

The efficiency of port sustainability addresses the comparative relationship between the input in terms of port resources and the actual effective outputs (including the economic, environmental, and social output) as a synthesized measure of the operational status and sustainable development potential of the port [36]. Sustainable seaport business contributes to strategic goals of seaports through increased revenue and market share; reduced cost of operations; reduced environmental and financial risk; more efficient use of financial, human, and natural resources; enhanced brand image; enhanced access to capital; increasing employee productivity; easier hiring and retention of best talent; improved relationship with key stakeholders; more efficient approval of regulatory permits, and an enhanced ability to maintain a license to operate and grow [30]. Seaports must secure the ‘license to operate’ and the ‘license to grow’ by operating and undertaking investments in a sustainable manner, preferably following the guidelines of international port-related organizations. As such, the American Association of Port Authorities is developing and regularly updating guidelines and codes of practice for green (sustainable) port development) [30].

Integrating the sustainability principles into all seaport activities is the aim of sustainable practices in seaport operations. Organizations and industries related to seaport business have progressively started to make sustainability issues central focusses in management activities towards efficiency and competitiveness [37]. Coordinated action between seaports and communities is vital for success in sustainable port businesses and operations [38]. The higher the level of coordination and integration among the stakeholders of port and supply chain, the higher the sustainability of the entire supply chain and of the port. From an economical and societal dimension, a port’s sustainable operation is associated with the close coordination with logistics actors outside the port perimeter and an integrated approach to port infrastructure and resource planning. Government, customers, and various stakeholders are considered as the main actors that motivate firms to incorporate sustainability factors into their supply chain management schemes [39].

Seaports involve numerous cargo manipulation procedures, involved stakeholders and data that need to be exchanged.

Seaports have to improve their operations continuously, both commercial and administrative, in order not only to optimize their business but also to achieve sustainable growth in cargo volumes [40]. Information systems used to improve seaport operations can be divided into different types: Port community systems, vessel traffic services, gate appointment systems, automated gate systems, etc. [41]. The usage of ICT as a tool for conducting electronic business (with special emphasis on the electronic exchange of data and messages within the seaport systems) ensures efficient connection of different segments of business processes that take place among the various stakeholders of seaport operations [40]. The advantage of ICT is that they allow information to be processed and disseminated simultaneously and in real time [42]. The Ericsson sustainability report shows that ICT could help reduce global greenhouse gas (GHG) emissions by up to 15% [43]. There is clear evidence that ICT may positively influence enterprise competitiveness, but also social and environmental issues [44].

However, ship operators, masters, and agents are still burdened with having to fill in paper documents, which include repetitive information, and to distribute them to different government authorities, including port, maritime, safety, security, Customs, border control, and health authorities [45]. Modern transport and logistics environments, therefore, call for investments in an integral ICT solution implementation which will connect the (primarily administrative) seaport stakeholders—the National Single Window.

The Single Window concept permits the trader or transporter to submit all the data needed for determining admissibility of the goods in a standardized format only once to the authorities involved in border controls and using a single portal. It places the onus on the authorities to manage the Single Window and to ensure that the participating authorities or agencies are either given access to the information or are actually given the information by the managing authority. Further to this, it eliminates the need for the trader or transporter to submit the same data to several different border authorities or agencies [46]. Single Window may be considered as a trade facilitator. For UNECE and its UN Centre for Trade Facilitation and Electronic Business (UN/CEFACT), trade facilitation is “the simplification, standardization and harmonization of procedures and associated information flows required to move goods from seller to buyer and to make payment” [47]. Such a definition implies that not only the physical movement of goods is important in a supply chain, but also the associated information flows. It also encompasses all governmental agencies that intervene in the transit of goods, and the various commercial entities that conduct business and move the goods. This is in line with discussions on trade facilitation currently ongoing at the World Trade Organization [47]. Trade facilitation involves a wide and diverse range of public and private stakeholders seeking to establish a transparent, consistent and predictable environment for border transactions based on simple, and standardised procedures and practices [48]. In this respect, many countries and international organisations have recognized the numerous benefits of electronic trade facilitation, promoting the development and implementation of trade portals that allow business operators and governments to process trade information submitted in electronic formats, typically in one place, to all the concerned parties [49].

The Single Window concept, as mentioned before, enables all stakeholders involved in the business process to input the data and information used by other stakeholders only once. This is accomplished by using a single point of data entry, which is basically a unified, networked and interconnected ICT system. Such a system enables the interchange of information between various stakeholders by using a central data repository and by applying the agreed business procedures. The Single Window concept is especially useful in the international trade and transport procedures, which take place in seaport clusters [50]. “The Single Window is a national or regional facility mainly built around an IT platform, initiated by a government or ad hoc authority to facilitate import, export, and transit formalities, by offering a single point for the submission of standardized information and documents, in order to meet all official demands and facilitate logistics” [51].

The National Single Window system enables a single submission of electronic documents by the trader, such as a single data preparation and submission of a Customs declaration and duty payment for Customs release and clearance [52]. The NSW is also a facility that allows parties involved in trade and transport to lodge standardized information and documents with a single-entry point to fulfil all import, export, and transit-related regulatory requirements [53]. The NSW refers to the implementation of a national system that will act as a single point of contact for the electronic submission and exchange of information between public and private stakeholders from different transport modes [54]. It is important to note that Single Window has evolved from the Customs automation era to trade information exchanges, from limited Single Windows connecting traders with a single regulation (e.g., Customs, port, etc.) to nationwide NSWs that allow all parties to submit standardized information only once to fulfil all regulatory requirements [55].

Maritime National Single Window also known as Maritime Single Window (MSW) (the name varies from country to country) is similarly defined as a National Single Window: A place where all information is entered only once and becomes available to various stakeholders [56], but related to the maritime environment. Its focus lies on data related to vessels, and not information about cargo and trading.

Apart from administrative stakeholders and procedures which fall under the scope of NSW, the commercial procedures also need to be performed in an efficient manner. In order to simplify the commercial procedures, a concept a port community system (PCS) was introduced. A PCS is a neutral and open electronic platform enabling intelligent and secure exchange of information between public and private stakeholders in order to improve the competitive position of the sea and air ports' communities. PCS optimises, manages and automates port and logistics processes through a single submission of data and connecting transport and logistics chains [57]. PCS helps the stakeholders of the port processes to reduce logistics costs through faster information flow, to deliver the cargo faster, to enable the flow of goods, and finally, to boost economic growth [56]. As a secondary consequence, it helps to reduce the externalities, such as pollution and harmful emissions [58].

4. Examples of (Maritime) National Single Window Implementation

In this part of the paper authors provide the review of NSW and MNSW examples which underline the impact and the potential benefits of NSW/MNSW on improving sustainable seaport business. Several general studies related to supply chain and shipping have been analyzed as background for this chapter. For example, in the OECD study "Contribution of trade facilitation measures to the operation of supply chains," the results have shown that harmonizing trade documents, streamlining trade procedures, making trade-related information available, and using automated processes could reduce total trade costs by 14.5% for low-income countries, 15.5% for lower-middle-income countries, and 13.2% for upper-middle-income countries. The study also states that the full implementation of Single Windows is one of the main facilitators in streamlining and simplification of procedures, affecting the economic aspect of sustainability [59].

Issues that occur (mostly due to inadequate data exchange) during the shipment process were reported by Maersk, one of the world's largest container shipping companies. Maersk analyzed the entire shipment process of avocado and roses from Kenya to Rotterdam in 2014. 30 different stakeholders were included in the shipment process and 200 communication issues were reported, with delivery time of around 34 days from farm to retailers, including 10 idle days for documentprocessing [60]. The entire shipment process was not sustainable because of increased man-hours, decreased employee productivity, inefficient use of human resources (social aspect of sustainability), increased costs due to unnecessary waiting (economic aspect of sustainability), etc.

Ferro, C., et al. [61] conducted a study about 12 selected trade facilitation mechanisms and determined that Single Windows generates one of the largest long-term cost savings, despite the highest setup costs and operating costs, and average implementation time of about four years. Their focus was on the economic aspect of sustainability. Furthermore, Wagner N. [16] analyzed several important sustainability topics in seaports based on sustainability reports and strategies of the largest European seaports. Leading seaports, such as Port of Rotterdam and Port of Hamburg recognized the stakeholders' communication as one of the most important sustainability issues in seaports.

One of the most relevant examples of the evolution and implementation of National Single Window is the Port of Singapore. In 1989, the Port of Singapore implemented the first National Single Window "TradeNet" with the purpose of gathering various parties from the public and private sectors to exchange trade information electronically. The TradeNet is now used by approximately 2500 companies with 8000 users and providing nine-million transactions per year [62]. The implementation of TradeNet significantly reduced the processing time, which decreased from 2 to 7 days, to a 10 min maximum. Furthermore, document exchange has been transformed. Before TradeNet implementation, the number of documents in each transaction varied from four to 35. After the implementation of TradeNet, only one e-Form/e-Doc is necessary, with 24/7 submission instead of office open hours. The TradeNet is capable of handling more than 30,000 declarations a day; it processes 99% of permits in just 10 min and receives all monetary collections through interbank transactions [61]. Also, TradeNet implementation reduced the average fees charged, which decreased from $6–$13 to approximately $2.10 (Singapore), affecting the economic aspect of sustainability. The faster data exchange includes the social aspect of sustainability as well, because accelerated data exchange enables improved communication and information exchange between stakeholders, decreased man-hours, increased employee productivity, etc.

A step further in Singapore's National Single Window evolution was the implementation of the TradeXchange system in 2007. The TradeXchange is a neutral and trusted integrated IT platform that enables the exchange of both business-to-business (B2B) and business-to-government (B2G) information, and seamless inter-connectivity among commercial and regulatory systems for the Singapore trade and logistics community to facilitate the flow of goods [63]. Trade permit application is often a manual and tedious process for many shippers, and retrieving copies of the approved permits from various logistics service providers (LSPs) adds to the time consumed. IBM Ireland Product Distribution Limited (IBM IPDL) in Singapore (with shipments that include strategic goods, which demand full accuracy in permit declarations) took the advantage of the functionalities of TradeXchange to integrate processes, reuse approved permit data, improve turnaround time, and increase efficiency. After submitting permit declarations through TradeXchange, IBM IPDL decreased the average man-hours from 578 to 102 monthly, achieving the savings of about 130,000 Singapore dollars annually [63], affecting primarily the economic (cost savings) and social aspects (decreased man-hours) of sustainability.

Being aware of the importance of the continuous improvement of NSW for the streamlining of the trade and logistics processes of stakeholders, Port of Singapore has upgraded the NSW to a new level via the implementation of the National Trade Platform—NTP. The NTP is designed to be a trade and logistics IT ecosystem connecting businesses, community systems and platforms, and government systems. The NTP is a one-stop trade portal for business-to-government (B2G) and business-to-business (B2B) service and will completely replace TradeNet for trade-related applications and TradeXchange for connecting the trade and logistics community [64]. Specifically, it aims to be a [65]:

- One-stop trade information management system linked to other platforms;
- Next-generation platform offering a wide range of trade-related services;
- Open innovation platform allowing development of insights and new services with cross-industry data;
- Document hub for digitization at source that enables reuse of data to cut costs and streamline processes.

It is estimated that the NTP could potentially bring about up to 600 million Singapore dollars' worth of annual man-hour savings for businesses [66], including economic and social sustainable aspects of sustainability, as already mentioned above. The NTP encompasses the environmental aspect of sustainability as well (efficient use of natural resources, reduced number of trees cut down, and reduced environmental impact of travel—less fuel is used), by using paperless communication. The main environmental advantage is the minimized need for paper documents (the reduction of CO2) as the demand for logging and deforestation is reduced.

Since 2017, all seaports in China have been included in Single Window Customs Clearance. The standard version covers all trade ports, with a total of 35,000 registered users and more than 100,000 daily declarations. The costs for involved companies could decrease by 10%, and companies could save 10% of time needed for clearance. A third of all clearance procedures will be cut, according to southwest China's Chongqing port. In the Port of Shanghai, cargo clearance efficiency has been increased by about 30% [67]. The average clearance time for imports and exports within the jurisdiction of Shanghai Customs was 21.67 h and 1.35 h, respectively.; for the first eight months of 2017, there was a 26% and 32% reduction in comparison to the same period of the previous year, allowing sustainable business (economic, social, and environmental aspects). The platform also enables authorities of 11 related agencies to share declaration data, logistics control information, and credit standings to create a better business environment. The aim of China is to extend Single Window processing of international trade and nationwide integration of Customs clearance procedures [67].

Integration of different ICT solutions is one of the challenges that exist when developing an IT infrastructure. Not only do ICT systems need to be integrated between each division within a port, but also externally with the other external parties, such as trucking companies, customers, etc. [68]. Indonesian container terminals are integrated via the Indonesia National Single Window (INSW), with the aim to reduce the administration time related to the import and export activity of Indonesia, taking into consideration that logistics cost in Indonesia contributes 24% of the GDP. Through the INSW system, the status of the dwell time and productivity per terminal can be monitored. This INSW is integrated with Customs, where the incoming ships will send planned arrival time of transport means, which will be forwarded to the Customs by the terminal. Therefore, the INSW integrates different ICT solutions in Indonesian seaports [68]. The INSW includes about 5400 registered business stakeholders, and processes around 12,000 documents daily. Average document processing time of INSW is 5 min. Until now, the 18 ministries have processed more than 3,902,800 permits via INSW [69]. Without INSW, sustainable business would be difficult, as INSW enables paperless business, reducing time and costs and responsible using of resources.

Thailand's National Single Window enables electronic data and information sharing and integration between government to government partnerships (G2G), government to business partnerships (G2B) and business to business partnerships (B2B) for import, export, and logistics. It also facilitates international cross-border data and information sharing between government and business sectors in Thailand and other countries. E.g., Thailand NSW includes the economic aspect of sustainability, because in the transport of goods like sugar, rice, rubber, and frozen products, it is possible to achieve up to a 54% time reduction of time necessary for delivery and to reduce the costs up to 9.5 million USD/year [70].

The implementation of National Single Window in the low-income countries and lower-middle income countries enables sustainable business as well, and shows significant benefits. For example, NSW in Azerbaijan has reduced border crossing time from 180 minutes to 20 minutes. In Senegal, NSW implementation has reduced document collecting time from 4 days to 1 day. Customs clearance procedures in Cameroon have been reduced from 6 days to 3 h. Total cargo turnover/dwell time has decreased from 39 days to 6 days In Benin, and from 4 days to 2 days in Malaysia [71]. Reduced document collecting time and accelerated Customs clearance procedures allow cost savings, CO2 reduction and increased employee productivity, encompassing all three aspects of sustainability.

To provide simpler procedures, since June 2015, ship arrivals at all German seaports have to be reported via the National Single Window [72]. It aims to provide sustainable business by minimizing multiple entries of the same data and by distributing the data automatically to the authorized recipients [73]. In addition, parts of this information are available to other EU Member States on request via SafeSeaNet (a Europe-wide system for the exchange of data in order to prevent accidents and pollution at sea, and to reduce the consequences of such events) [74].

The MNSW has the potential to harmonize the seaport business processes and to become the base of sustainable maritime transport and seaport business. Information exchange between seaport stakeholders can be the bottleneck in the achievement of sustainability goals if it is provided through various different information systems. Joining the stakeholders via MNSW is the priority in providing sustainable seaport business, and will bring harmonisation and re-use of information, reducing the administrative burden. Consequently, it will contribute to seaport business sustainability [75].

The Republic of Korea Maritime Single Window “SP-IDC” (Shipping and Port Internet Data Centre)—apart from basic functions, such as port operation management, vessel operation management (vessel arrival/departure notice) etc.—provides non-stop service in spite of system malfunctioning; i.e., intelligent port operation services at disasters and calamities through marine-port distribution disaster recovery system operation [76]. It enables improving task efficiency through association and gathering the information; preparing a base that can be associated with foreign ports’ shipping and port logistics information systems; improving distribution competency with cost cutting for information access and utilization; budget reduction, such as uniformed budget management and the prevention of redundant investment through system-integrated management; information access and processing the cost cutting of related subjects [76]. Although the advantages are mostly visible in the economic aspect of sustainability, reducing paper documents includes ecological and social aspects of sustainability as previously mentioned (CO_2 reduction, etc.).

The “MSW Reportal” is the Swedish Maritime Single Window portal for reporting government information linked to ship calls. The MSW Reportal is managed by the Swedish Maritime Administration and provides collaboration between the Coast Guard, the Customs, the Swedish Maritime Administration, and the Swedish Transport Agency. The environmental aspect of sustainability is improved by reducing paper documents, which also translates to reduced costs (economic aspect of sustainability), etc. When information is submitted to MSW Reportal, it is automatically forwarded to the relevant authorities and systems. Information integrated into MSW Reportal are [77]:

- Information on maritime security, crew and passenger lists, and health declarations—Coast Guard;
- Information related to ship reporting—Swedish Maritime Administration;
- Information related to delays—The Port of Gothenburg;
- Ship clearance information—Customs;
- Lot order and fairway declaration—Swedish Maritime Administration.

The Maritime Single Window in the Netherlands was initially developed for maritime information exchange. Because the Single Window is also intended for use by the aviation sector, the name has been changed to the Single Window for Maritime and Aviation. Regarding the data exchange from the “maritime perspective,” the port authority ensures that received information is forwarded to National Competent Authority (NCA) SafeSeaNet [78]. NCA is the body designated by European Member States as being responsible for the management of the system at the national level [79]. The port systems of all the large ports in the Netherlands are connected to the Single Window for Maritime and Aviation for communications regarding the transport [78]. Larger seaports produce more harmful emissions, causing negative influence on the surrounding community. Furthermore, delays or other issues that are present during the data exchange among stakeholders in larger seaports may cause significant costs. In this respect, the Maritime Single Window, connecting all the large ports in Netherlands, may help the seaports to operate sustainably (paperless work, reduced costs, standardization, etc.). Furthermore, waiting for cargo loading or unloading in seaports due to ineffective and obsolete data exchange among stakeholders causes the increase of CO2 emissions. According to Ascencio et al. [80], unnecessarily long waiting time is the result of the existence of a large number of public and private stakeholders, requiring very large number of transactions and documentation processes, most of them based on paper documents. Development of electronic Transportation Management Systems such as (M)NSW could have a positive effect on fuel consumption and the reduction of CO2 emissions and other harmful emissions (environmental aspect of sustainability) [81].

The similar case of improving sustainability by implementing the MSW can be found in Spain. Dueport is the Spanish Maritime Single Window that includes all 70 seaports in Spain (commercial seaports, regional seaports, fishing ports) as well as nine national administrators. Through Dueport, 50,000 messages are exchanged daily. The advantages of the Spanish Maritime Single Window are the following: all formalities are reported electronically; harmonization of messages (EDIFACT standard); harmonization of spreadsheet (Pax and Crew list) etc. [82], affecting economic and environmental aspect of sustainability.

Portnet is a port information system maintained by the Finnish Transport and Communications Agency, and acts as the national Maritime Single Window system for Finland. The following information is supplied to the Portnet system for all vessel visits to Finnish ports: Preliminary Notice, Cargo Declaration, Dangerous Goods Declaration, etc. [83]. The notifications concerning vessel arrival and departure can be submitted electronically to Customs, as required by the authorities [84], affecting economic (decreased costs, waiting time etc.), ecological (lower use of paper), and social (increased employee productivity, efficient use of human resources etc.) aspects of sustainability.

During the analysis of Italian experiences in improving sustainability by implementing Single Window and closely related ICT systems, the importance of a port community system arose. In certain seaports, for example the Italian Port of Venice, port community system assumes the role of the Single Window. The Port of Venice uses LogIS—a web-based IT system for the stakeholders involved in the port community's shipping and logistics activities, including the Harbormaster's Office, Shipping Agents, Freight Forwarders, Pilots, and Terminal Operators. All the components of LogIS are integrated into a single platform. As a result, LogIS acts as the Port of Venice's Single Window [85]. Similar to MNSW, PCS enables decreased waiting time, decreased costs (economic aspect of sustainability), minimized use of paper documents (environmental aspect of sustainability), efficient use of human resources (social aspect of sustainability), etc.

The analysed examples point out the importance of implementation of MNSW for seaports business and confirm that MNSW possesses great potential for improving sustainable seaport business. Future seaports should be committed to being green, while building prosperity for current and future generations. For this purpose, the seaport sustainability will be the core of development strategies and plans; beyond "systems and policies." It could be the most important step for seaports towards becoming a more sustainable business, setting a foundation in which to evolve. Within the scope of sustainability, the future seaport approach can be achieved through sustainable planning of the crucial steps of smart seaport operations, preservation of the environment, the human element, and planning a bright future with seaport communities [34].

Although many successful cases of Single Window implementation can be found globally, several examples of less successful cases of MNSW implementation can be found, as stated below.

Singapore's aforementioned "TradeNet," which "handles almost all documents that are required for the Customs import and export procedures, such as declarations, various types of permits, certificates and licences, etc.), do not handle other transportation/cargo documents, such as air and sea manifests. For sea manifests (e.g., detailed lists of loaded cargo), the data are submitted and handled by another system, PortNet, which is operated by the port operator, while air transport-related cargo documentation is handled by yet another system, Cargo Community Network, which is operated by a subsidiary of Singapore Airlines [86]. When using multiple heterogenous systems, it is harder to improve the three aspects of sustainability mentioned earlier.

Another case of a less successful NSW implementation is the Croatian NSW. In the 2000s, the Croatian Ministry of the Sea, Transport and Infrastructure, recognized the importance and advantages of digitalization and stakeholder connectivity (such as forwarders, maritime agents etc.), in maritime transport [87]. As a result, three projects were launched that were supposed to solve the administrative problems faced by stakeholders in the logistics chain of freight transport, thereby facilitating data control. The first project refers to the establishment of a National Single Window, an information platform for data exchange and processing through the cooperation of the Ministry of the Sea, Transport and Infrastructure, the Customs Administration of the Ministry of Finance, the Port Authority of Rijeka and the Port Authority of Ploče [88]. Two studies were produced in order to enable successful NSW implementation (the first study was produced in 2011 and the second one in 2017). Several issues have slowed down the implementation of Croatian NSW, such as less cooperative stakeholders who mostly own and operate separate ICT systems, insufficient governmental support, and financial issues. In the meantime, the Croatian Ministry of the Sea, Transport and Infrastructure (MMPI) has developed CIMIS system, the unique Maritime Single Window system that implements all national level processes related to the administrative aspect and aspect of navigation safety. In order for CIMIS to be able to exchange data with external systems, a new service CIMISNet has been established, which aims to improve data exchange, reduce administrative procedures among Ministries, all Port authorities, the Ministry of the Interior, the Customs administration, Coastal Shipping Agency, Croatian Bureau of Statistics, etc. Security in cross-border traffic will also be improved in accordance with Schengen rules [88]. Finally, in 2019, Croatia still does not have a functional NSW. CIMIS and CIMISNet can be considered as a MNSW, but with lacking functionalities. Because of that, obsolete methods of data exchange are still present, causing increased waiting time and unnecessary costs; therefore, decreasing the sustainability of Croatian seaports.

The final example of a less successful NSW implementation is the Italian NSW "UIRNet." According to Ferrari et al. [89], efficient administrative procedures, already present in several European ports (e.g., "pre-clearing" activity), cannot be easily implemented in Italian ports due to the co-existence of several authorities with their own administrative and information systems within the seaport. Due to this issue, it is difficult to improve sustainability/sustainable business because of increased costs, increased waiting time, etc. The issue may be solved through the unification of the control and information systems (so-called “one-stop-shop”) of the different authorities and with the simplification of the administrative procedures improving the coordination of the several public bodies involved [90]. Furthermore, most Single Window and total logistics chain systems will have to be aligned in the future with significantly increased requirements of the proposal for a Regulation of the European Parliament and of the Council establishing a European Maritime Single Window environment and repealing Directive 2010/65/EU (COM (2018) 0278–C8-0193/2018–2018/0139 (COD)). If the above-mentioned issues were solved, every party involved (both commercial stakeholders and administrative authorities) could benefit from the implementation of a Single Window (reducing costs, reducing average processing times, increasing service predictability, etc.); therefore, increasing sustainability.

During the research process, significant effort was undertaken to research both the existing successful and challenged implementations of NSW globally. In all these cases, the research was focused to identify all major aspects of the sustainability principles, namely economic, environmental and social seaport sustainability enhancements directly derived and attributed to introduction of NSW, that would otherwise not be in effect. Furthermore, cross-component benefits of MNSW implementations were also identified, resulting in creation of the synergy effect and positive impact on the seaport business. Some of the identified effects are elaborated here:

- Reduction or elimination of paper documents contributes not only to the economic seaport business sustainability in terms of reduced costs or time for providing operations, but also to the environmental sustainability through reduced demand for logging and deforestation, which is a typical example of synergy effect crossing individual stakeholder lanes.
- The MNSW, as the “single entry point” system, reduces time-consuming activities in seaport business by enabling the reuse of already entered data which finally contributes to the economic sustainability of seaport business. Further benefits are achieved through reduction of the fee charges, increasing stakeholders’ liquidity and financial position.
- Decreased time affects the environmental sustainability aspect through the elimination of unnecessary movements, enabling the efficient use of natural resources and decreasing emissions.

- Enforcement of the “single entry” principle via MNSW enables improved communication and information exchange between stakeholders and eliminates the differences between individual systems and input errors during information and document exchange. MNSW also provides common regulations (legal framework) which simplifies communication and information exchange between stakeholders. The social sustainability aspect is improved via MNSW through decreased man-hours and increased employee productivity.

A comprehensive identification of all examples is provided in Figure 1. All identified benefits of MNSW implementation for sustainable seaport business are shown in a three-pillar form according to sustainability aspects—economic, environmental, and social seaport sustainability—along with all of their identified sub-categories and references to sources.

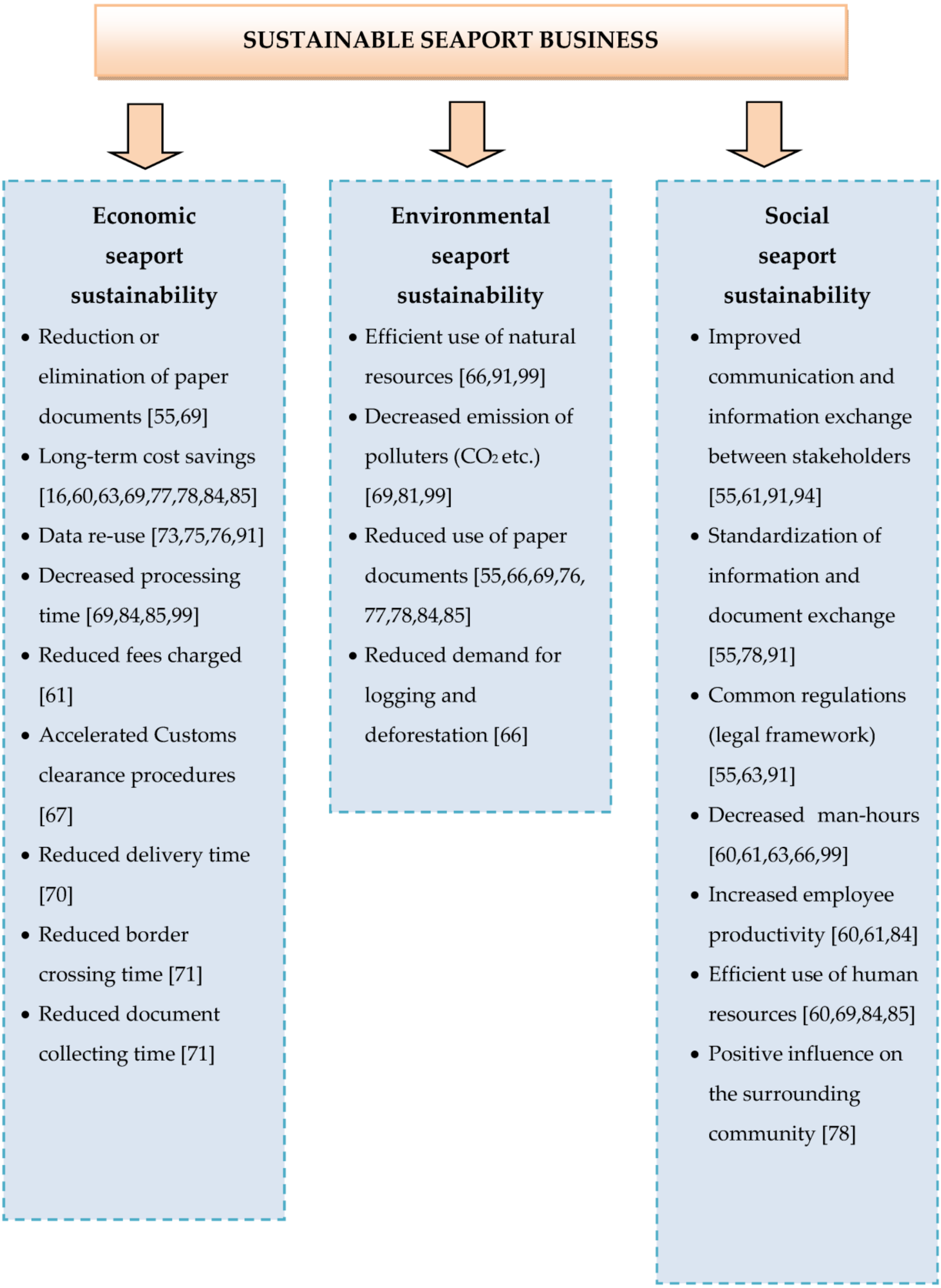

Figure 1. The three aspects of sustainable seaport business by implementing MNSW (authors).

5. Future Perspective of the Maritime National Single Window Concept

National Single Windows and Maritime National Single Windows are continuously evolving and transiting beyond national borders towards regional cooperation and implementation of the Regional Single Window concept and similar systems for collaboration of seaport business stakeholders. The reason is that economic groupings or countries from same territorial area recognize the benefits of NSW, and its possible impacts on the economic, environmental, and social aspects of sustainability. In 2018, five southeast Asian countries: Indonesia, Malaysia, Singapore, Thailand, and Vietnam formed the initiative ”ASEAN Single Window—ASW.” The aim of ASW is to transform the Association of Southeast Asian Nations (ASEAN) into a single market and production base, enabling sustainable business. Trade facilitation measures—such as the ASW, the harmonization and integration of Customs’ procedures, and the removal of tariffs and nontariff barriers—are key to the free flow of goods and services within ASEAN [91]. The ASW will provide economic sustainability (almost paperless clearance in ASEAN, more efficient and predictable supply chain management, data re-use, reduced costs of doing business improved risk and profile management), environmental sustainability (predictability, disaster management), and social sustainability (improved compliance, mutual recognition agreements, robust legal framework) for business and government stakeholders.

In 2017, the Monetary Authority of Singapore (MAS) signed a Memorandum of Understanding with its Hong Kong counterpart to jointly develop a cross-border distributed ledger technology (DLT) based utility infrastructure that will link up digital trade platforms and trade-related DLT platforms and communities around the world. This initiative is called the Global Trade Connectivity Network—GTCN. The GTCN aims to be an industry-neutral, service-agnostic, cross-border utility infrastructure that does not aim to control or dominate partner networks. In the beginning, GTCN will provide a common hub for trade finance applications between Singapore and Hong Kong. Further vision for the GTCN overcomes simple collaboration between Singapore and Hong Kong and extends beyond financial issues. The GTCN will integrate the digital platforms of Singapore and Hong Kong to provide digital solutions to address challenges prevalent in international trade, where different trade regulations and documentation standards are present. The end outcome is to enhance supply chain transparency, integrity, and security which contributes to goals of economic, environmental, and social sustainability: Simplified financial and other transactions, reduced paper administration, savings, the conservation of natural resources, a common communication platform for all stakeholders, equal regulations and standards for all stakeholders, a positive influence on society, etc. [55].

The process of digitalization and new technologies extend the range of possibilities and move the limits of Single Window concept in maritime industry and seaport business. The example of such an initiative is the Maritime Connectivity Platform (MPC), previously known as the Maritime Cloud. The mission of the Maritime Cloud was to enable an open vendor-neutral platform for the maritime sector that facilitates information exchange boundary-free and secured across various communication channels, such as internet, satellite, and cellular phone networks, and digital radio links [92]. The objective of the Maritime Cloud was to provide a secure platform to enable maritime stakeholders to securely access technical services to gain further information for decision-making onboard and ashore during a voyage from berth-to-berth. The Maritime Cloud shall not be considered as a product but as a common communication framework for maritime users to register, discover, and use the technical services, such as route optimization or weather forecast. Clients and Services communicated by standardized web service technologies supported by standard services to set up and facilitate the communication [92]. The new name, Maritime Connectivity Platform, "has been chosen to provide clarity and support e-Navigation going from testbed to real life implementation" [93]. MCP is a communication framework enabling efficient, secure, reliable and seamless electronic information exchange between all authorized maritime stakeholders across available communication systems [94], and thus, the MCP can contribute to the sustainable seaport business.

For the past several years, the EU has been working on the development of the European Maritime Single Window—EMSW, with the aim to fully harmonize interfaces available to ship operators in order to provide required information all across the EU [56]. The purpose of EMSW is to standardize information needed for port management so that the submitted data can be publicly available to all relevant stakeholders [95]. The harmonised EMSW environment for ships will build on the already existing framework (National Single Windows structure) [96]. The National Single Windows will continue to be mainly a coordination mechanism, serving primarily as a router (with technical converter between data formats where needed) to pass two-way information between the maritime transport operators and the data recipients (e.g., port authorities, Customs interfaces and reporting systems, border control authorities, the

SafeSeaNet, statistics authorities) with the aim to facilitate reporting for the maritime industry [96].

Due to the strategic importance of creating a common field for all modes of transport across Member States, the EMSW has been given a prominent position. In 2017, the EU Transport Ministers underlined in the ‘Valetta Declaration,’ the shortcomings of the Reporting Formalities Directive and invited the Commission to propose a follow-up to the evaluation of it (the RFD), which would include a harmonized EMSW environment [97].

In the beginning of 2019, the European Commission signed the agreement with the European Parliament and Council on the implementation of EMSW, which is expected to enter into force in 2025. Although the agreement was well accepted by the maritime sector, including European seaports, the ports of Hamburg, Antwerp, and Rotterdam, have urged the European Transport Committee to vote against the EMSW when an amendment proposal sought to introduce an EU level access point interface, in addition to the new harmonized interface that would be developed at the European level for the NSW [98].

As the EMSW includes all EU countries, it will maximize the potential of improving economic, environmental, and social sustainability of seaports business across the EU. The economic sustainability could be improved via hours saved on reporting—22 to 25 million staff hours from 2020 to 2030, worth around €650 million for shipping operators. Furthermore, EMSW could improve the use and sharing of data, optimizing cargo flows and serving the whole logistics chain, while increasing the competitiveness of maritime transport. The environmental sustainability will be improved through optimized cargo flows which will reduce transport CO_2 emissions and the use of natural resources. [99].

6. Conclusions

Sustainable development is based on the consideration of present needs, without compromising the needs of future generations. It consists of the “triple bottom line” principle, or three aspects: Economic (producing goods or services efficiently), environmental (protection of natural resources), and social (well-being of surrounding society). Seaports, as the main nodes of maritime transport, should conduct their operations according to principles or aspects of sustainability as well: The economic principle (providing seaport services efficiently), the environmental principle (efficient use of natural resources, decreased emission of polluters and reduced use of paper documents), and the social principle (well-being of seaport employees and stakeholders).

Various stakeholders are still faced with a tedious task of producing and distributing paper documents to numerous administrative authorities. Multiple entry of the same data may result in increased errors and higher costs. Existence of these issues has encouraged the development of the Single Window concept, which allows stakeholders involved in the business processes to input the necessary data only once, and to reuse the data according to their scope of work and authorization.

The systematic literature review of numerous successful examples of NSW/MNSW globally has led to the conclusion that the implementation of NSW/MNSW has potential for improving sustainable seaport business. This potential arises from the advantages of a single-entry point for the administrative procedures among stakeholders involved in seaport business. Due to the complexity of seaport business, improved administrative processes via NSW/MNSW could have an important role, making seaport business more sustainable. Based on the researched examples, the main elements and potential benefits of NSW/MNSW in improving the economic, environmental, and social aspects of sustainability of seaport business have been identified, as follows:

The NSW/MNSW reduces or eliminates paper documents and enables data re-use, which improves economic seaport sustainability through savings (e.g., the once entered information or document in Swedish MSW Reportal is automatically forwarded to the relevant authorities and systems which reduces paper documents and obtains savings; via Thailand NSW costs reduce up to 9.5 million USD/year). Furthermore, NSW/MNSW could contribute to economic seaport sustainability by decreasing processing time, accelerating Customs procedures and reducing document collecting time (e.g., via TradeNet document, processing time decreased from 2–7 days to 10 min the Port of Shanghai; cargo clearance efficiency improved by around 30%; and via Senegal's NSW, document collecting time has been reduced from 4 days to 1 day). Delivery time and border crossing time could also be reduced (e.g., by using NSW, total cargo turnover/dwell time has decreased from 39 days to 6 days in Benin, and from 4 days to 2 days in Malaysia; NSW in Azerbaijan has reduced border crossing time from 180 min to 20 min). The fees as an important element of economic seaport sustainability can be significantly reduced as well (e.g., via TradeNet, the average fees have decreased from $6–$13 to approximately $2.10).

The environmental seaport sustainability can also be improved by implementing NSW/MNSW. The Netherlands MSW, connecting all large seaports and airports, reduces waiting time for cargo loading and unloading, and thus provides efficient use of natural resources and decreased emission of CO_2 and other polluters via the elimination of unnecessary movements in cargo due to inefficient data exchange among stakeholders. The need for paper documents is minimized, therefore reducing the demand for logging and deforestation.

The NSW/MNSW can also improve social seaport sustainability of seaport operations, stakeholders, and community. With the help of NSW/MNSW, it is possible to use human resources more efficiently, to increase employee productivity, and to decrease the workload (e.g., IBM IPDL via TradeXchange decreased the average man-hours from 578 to 102 monthly). The NSW/MNSW improves communication and information exchange between stakeholders and standardization of business processes (e.g., via Spanish MSW Dueport, including all 70 seaports operating in Spain, which report all formalities electronically). Finally, the surrounding community may also benefit from NSW/MNSW through the elimination of harmful emissions, which is especially evident in larger seaports.

Although the majority of researched NSW/MNSW examples have been successful in recording improvement of the seaport sustainability, less successful cases such as Italian's UIRNet and Croatian NSW/MNSW also exist. They are not fully functional (or implemented yet) because of legal restrictions, administrative procedures, financial issues and less cooperative stakeholders who operate separate ICT systems.

The utilization of NSW/MNSW shows the potential well beyond the national level. Having awareness of the benefits obtained by using the NSW/MNSW, several countries or economic groupings have made a step forward and have started to establish the regional NSW/MNSW and similar initiatives, such as ASEAN NSW or EMSW-European Maritime Single Window. The integration of individual NSW's into the regional NSW/MNSW leads to further improvement of economic, environmental, and social aspects of seaport sustainability. For example, EMSW could have a positive impact on all three aspects of sustainability: The economic aspect (via hours saved on reporting—22 to 25 million staff hours from 2020 to 2030, worth around €650 million for shipping operators), the environmental aspect (through optimized cargo flows which will reduce transport CO2 emissions and the use of natural resources), and the social aspect (the efficient use of human resources, etc.).

In the future research, authors plan to analyze further development of Regional Single Windows and similar initiatives in order to gain a deeper understanding of NSW/MNSW implementation and impact on sustainable seaport business.

Author Contributions

Conceptualization, E.T., A.A., M.J. and S.A.; methodology, E.T.; validation, E.T. and S.A.; formal analysis, M.J. and A.A.; investigation, E.T., S.A. and M.J.; resources, A.A. and M.J.; writing—original draft preparation, A.A., E.T. and M.J.; writing—review and editing, E.T. and S.A.; visualization, M.J. and A.A.; supervision, E.T. and S.A.; project administration, E.T.; funding acquisition, E.T. and A.A.

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Conflicts of Interest

The authors declare no conflict of interest.

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D. National Maritime Single Window – Cost-Benefit Analysis of Montenegro Case Study

Abstract: In this paper, the costs and benefits of the National Maritime Single Window (NMSW) for coastal countries that have limited human resources and infrastructure related to maritime traffic are researched. A general method for conducting a cost-benefit analysis of NMSW implementation is proposed. Using this method and the input data for Montenegro, as an example of a small-sized coastal country, the authors assess whether such an investment in NMSW implementation can be beneficial to coastal countries with limited resources.

Keywords: National Maritime Single Window (NMSW), cost-benefit analysis, Montenegro case study

1. Introduction

Numerous continuous and often very radical changes occur today in the maritime port service market [1]. The Single Window concept, which enables all stakeholders involved in the business process to input the data and information used by other stakeholders only once (by using a single point of data entry), has significantly changed the methods of information exchange between transport stakeholders, particularly in maritime transport and maritime port business [2]. The Single Window is a national or regional facility mainly built around an ICT platform, initiated by a Government or ad hoc authority to facilitate import, export and transit formalities, by offering a single point for the submission of standardized information and documents, in order to meet all official demands and facilitate logistics [3].

Maritime transport is composed of organizations and activities such as shippers, maritime port stakeholders, and a wide range of professional services around the maritime activities etc. [4], [5]. In 2018, 11 billion tons of cargo were transported by sea [6]. In this respect, maritime transport also involves a lot of procedures and data that need to be exchanged [7]. The International Maritime Organization’s Convention on Facilitation of International Maritime Traffic (FAL Convention) plays an essential role in facilitation of data exchange in maritime transport, as its main objectives are to prevent unnecessary delays in maritime traffic, to aid co-operation between Governments and to secure the highest practicable degree of uniformity in formalities and other procedures [8], [9]. In this respect, IMO has developed standardized forms, i.e. IMO FAL Forms to simplify formalities, procedures regarding the arrival and departure of ships and to unify the documents that are requested to be present to authorities.

A mandatory requirement for contracting states to IMO FAL Convention (currently 123 states, including Montenegro [10]) to introduce electronic information exchange between ships and ports is effective from April 8th 2019. The provision, necessary under IMO's (FAL Convention), is part of a package of amendments under the revised Annex to the FAL Convention, adopted in 2016 [11]. The Convention encourages the use of a "single window" for data, to enable all the information required by public authorities in connection with the arrival, stay and departure of ships, persons and cargo, to be submitted via a single portal, without duplication [11].

National Maritime Single Window (NMSW), also known as the Maritime Single Window, is a place where all information is entered only once and becomes available to various stakeholders [12]. NMSW is an important instrument for facilitating and expediting maritime transport. NMSW is considered primarily to be a business to administration (B2A) system. Seaborne trade could be increasingly affected by the IMO decision to make NMSW mandatory. It could be a potential opportunity for developing countries, but also a threat if it is not appropriately implemented. Actually, there is a risk that the costs of implementation may be higher than the benefits.

Many endeavors are being undertaken globally to delineate the concept for NMSW and define standards and issue recommendations on its implementation [13]. In the early 80s, systems based on electronic data interchange (EDI) have been implemented in more significant maritime ports. The aforementioned systems are called Port Community Systems (PCS), and they are still in use in Hamburg-Germany, Felixstowe-UK, Port-MIS in Korea, FCPS in the UK, Portbase in Netherlands and others [14], [15]. The levels of electronic reporting, remote monitoring, and control have rapidly increased in recent years in all industrial fields. Furthermore, new trends and concepts are developing such as maritime clouds, e-navigation, e-maritime, “maritime Big Data” and Internet of Things (IoT) that entail both challenges and opportunities for maritime transport [16], [17], [18], [19], [20]. All these trends, even if they are partly overlapping, could lead to digitalization, real-time information [21], and improved connectivity in the maritime transport sector that could not only facilitate shipping, but also improve energy efficiency, reduce emissions, and develop traffic management and routing.

Undoubtedly, the implementation of NMSW is a challenging task in terms of costs, complexity, re-engineering of existing business processes and system maintenance. Dozens of regulations, recommendations and other related documents have to be studied before taking the first steps in the demanding process of NMSW implementation. This motivated the authors of this paper to provide a comprehensive research of the regulations, recommendations, implementation options, experiences and expected benefits of deploying the NMSW. More importantly, in this paper the authors provide a method for conducting a cost-benefit analysis of NMSW implementation, which is general and applicable to any country intending to implement the NMSW. Using the known input data for Montenegro, a cost-benefit analysis of NMSW implementation and the appropriate concluding remarks is provided. The presented case study could be used as a reference point for different small-sized developing countries, which are aware of their limited resources, but are required (or are willing) to implement the NMSW.

2. Framework of Single Windows

This section aims to analyze and describe the framework of Single Window and NMSW. The most commonly accepted definition of a Single Window is the one provided by the United Nations Economic Commission for Europe (UNECE) Recommendation No. 33: "a facility that allows parties involved in trade and transport to lodge standardized information and documents with a single-entry point to fulfil all import, export, and transit-related regulatory requirements" [22]. The Single Window concept permits the trader or transporter to submit all the data needed for determining the admissibility of the goods in a standardized format only once. The data should be forwarded to the authorities involved in border controls and at a single portal. It places the onus on the authorities to manage the Single Window and to ensure that the other participating authorities or agencies are either given access to the information or are actually given the data by the managing authority [2]. Further to this, it eliminates the need for the trader or transporter to submit the same data to several different border authorities or agencies [23].

Single Window may be also considered as a trade facilitator. For UNECE and its UN Centre for Trade Facilitation and Electronic Business (UN/CEFACT), trade facilitation is "the simplification, standardization and harmonization of procedures and associated information flow required to move goods from seller to buyer and to make payment" [24]. Such a definition implies that not only the physical movement of goods is essential in a supply chain, but also the associated information flows. It also encompasses all governmental agencies that intervene in the transit of goods and the various commercial entities that conduct business and move the goods. This is in line with discussions on trade facilitation currently ongoing at the World Trade Organization [24]. Trade facilitation involves a broad and diverse range of public and private stakeholders seeking to establish a transparent, consistent and predictable environment for border transactions based on standardized and straightforward procedures and practices [25]. In this respect, many countries and international organizations have recognized the numerous benefits of electronic trade facilitation, promoting the development and implementation of trade portals that allow business operators and governments to process trade information submitted in electronic formats, typically in one place, to all the concerned parties [26].

A National Single Window (NSW) system enables a single submission of electronic documents by the trader such as single data preparation and submission of customs declaration and duty payment for customs release and clearance [27]. The NSW is also a facility that allows parties involved in trade and transport to lodge standardized information and documents with a single-entry point to fulfill all import, export, and transit-related regulatory requirements [28]. The NSW refers to the implementation of a national system that will act as a single point of contact for the electronic submission and exchange of information between public and private stakeholders from different transport modes [29]. It is important to note that Single Window has evolved from the customs automation era to trade information exchanges, from limited Single Windows connecting traders with a single regulation (e.g. customs, port, etc.) to nationwide NSWs that allow all parties to submit standardized information only once to fulfill all regulatory requirements [30].

As mentioned before, National Maritime Single Window is similarly defined as a National Single Window: a place where all information is entered only once and becomes available to various stakeholders [12], but related to the maritime environment. Its focus lies on the data associated with vessels, and not the data about cargo and trading.

NMSW, as an authority operated SW for clearance of ships, should at a minimum cover the handling of IMO FAL data related to the vessel, where general safety and security information regarding the transported cargo is included. Furthermore, NMSW should be developed to deal with reporting formalities that are the result of international laws that the individual country has acceded at the regional and international levels. Additionally, NMSW should also cover the information related to the ship clearance which is required by national legislation.

For the past several years, the EU has been working on the development of the European Maritime Single Window – EMSW, with the aim to fully harmonize interfaces available to operators of ships in order to provide required information all across the EU [12]. The purpose of EMSW is to standardize information needed for port management so that the submitted data can be publicly available to all relevant stakeholders [31]. The harmonized EMSW environment for ships will build on the already existing framework (National Single Windows structure) [32]. The National Single Windows will continue to be mainly a coordination mechanism, serving primarily as a router (with technical converter between data formats where needed) to pass two-way information between the maritime transport operators and the data recipients (e.g. port authorities, customs interfaces and reporting systems, border control authorities, the SafeSeaNet, statistics authorities) with the aim to facilitate reporting for the maritime industry [32].

Due to the strategic importance of creating common regulations for all modes of transport across the Member States, the EMSW has been regarded as a matter of high priority. In 2017, the EU Transport Ministers underlined in the 'Valetta Declaration' the shortcomings of the Reporting Formalities Directive (RFD) and invited the Commission to propose a follow-up to the evaluation of the RFD, which would include a harmonized EMSW environment [33].

At the beginning of 2019, the European Commission signed the agreement with the European Parliament and Council on the implementation of EMSW, which is expected to enter into force in 2025. Although the deal was well accepted by the maritime sector, including European maritime ports, the ports of Hamburg, Antwerp and Rotterdam have urged the European Transport Committee to vote against the EMSW when an amendment proposal sought to introduce an EU level access point interface, in addition to the new harmonized interface that would be developed at the European level for the NSW [34].

Apart from administrative stakeholders and procedures which fall under the scope of the NMSW, the commercial procedures also need to be handled in an efficient manner. In order to simplify the commercial procedures, a concept of a Port Community System (PCS) was introduced. A PCS is a neutral and open electronic platform enabling the intelligent and secure exchange of information between public and private stakeholders to improve the competitive position of the sea and airports’ communities (Figure 1).

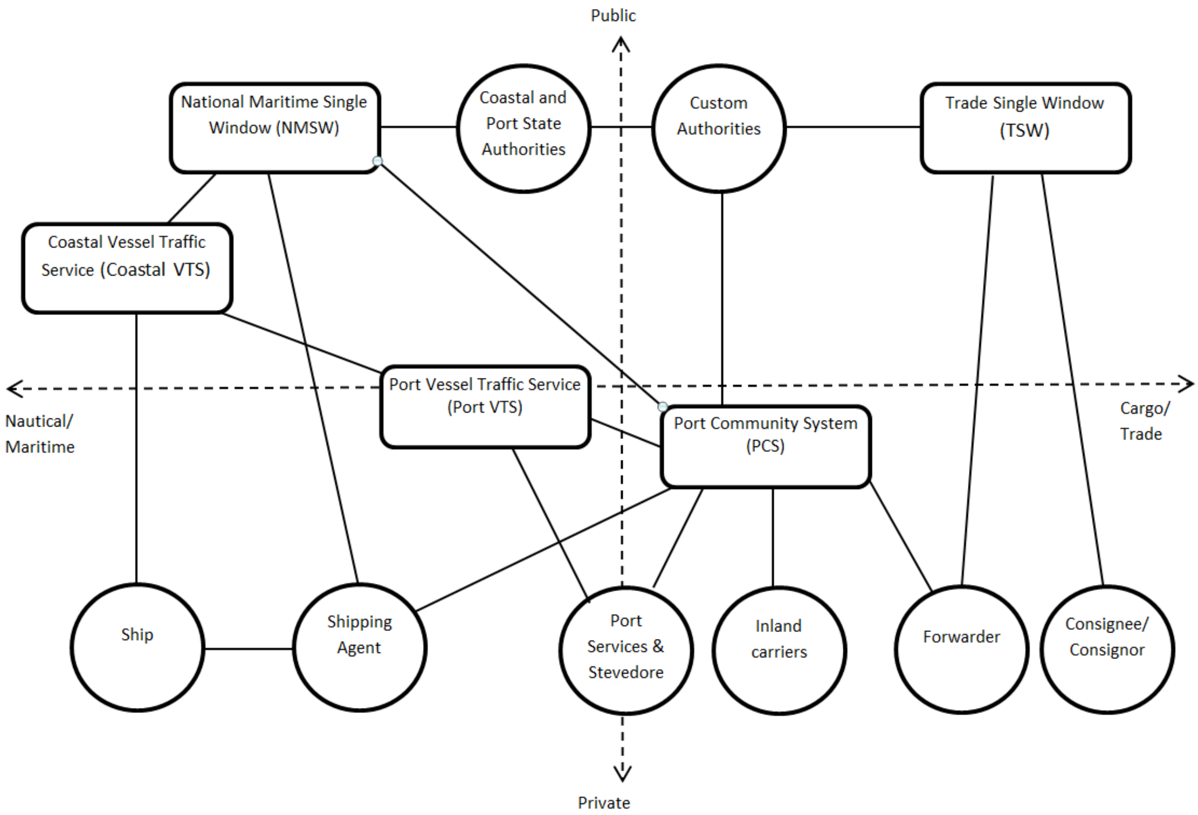

Figure 1. Model of NMSW environment

Source: adapted from [14] and [35]

PCS optimizes, manages and automates port and logistics processes through a single submission of data and connecting transport and logistics chains [36]. PCS helps stakeholders of the port processes to reduce logistics costs through faster information flow, to deliver the cargo faster, to enable the flow of goods, and finally, to boost economic growth. As a secondary result, it helps to reduce the externalities such as pollution and harmful emissions [12].

3. Costs and benefits of NMSW implementation

NMSW is usually developed by the national maritime authorities. For its successful implementation, a selection of the business model is of utmost importance. NMSW business model could be fully developed and funded by public authorities or by commercial port companies. For example, users could finance the NMSW as a fee-per-transaction, as is usually the case with privately operated PCSs [13]. Imposing the fees for NMSW could be seen as a business barrier and could reduce the competitiveness of ports and countries, as charges will lead to higher transportation costs. Obviously, the no-fee business model requires a commitment to long-term government funding for the implementation and operation of the system [13]. In this chapter, an overview and quantification of costs of NMSW deployment have been provided, as well as the overview and quantification of NMSW implementation benefits.

3.1. Costs of NMSW deployment

The costs of NMSW deployment could be divided into two principal categories: implementation costs and running costs. Implementation costs could be further divided into preparation costs, technical costs and human resources costs [13].

Preparation costs encompass all costs at the initial phase of NMSW implementation, which is critical for success. The initial phase should start with establishing a Project Management Group (PMG), which will initiate the first steps and have a lead role during the implementation phase. If the country has previously established a National Facilitation Committee according to the FAL Convention [37], it could also take the role of the PMG. PMG should define the scope of the feasibility study at the very beginning. The study should provide answers to numerous questions such as: what are the project needs, what are the potential benefits of NMSW services, what is the scope of the NMSW, what are the possible scenarios for implementation, what are the costs, resources and time frame of deployment under the different scenarios, etc. Besides this, the feasibility study should identify possible risks and potential benefits of the NMSW application. In addition to the feasibility study, other studies could be used, focusing on particular aspects such as the legal framework, business model, technical issues, business processes, human resources, training, and others. During the preparation phase, a business model should be proposed, which should include the efforts to update existing regulations to achieve the highest possible harmonization and simplification of procedures. This phase should detect any obsolete or unnecessary regulations and propose their abolishment. Maritime port regulations affect maritime port efficiency in a non-linear way, and an excess of the rules could have a negative impact on maritime port efficiency [38].

The overall technical costs of a new NMSW system will be determined by the expenses of necessary software and hardware investments, as well as by the costs of changes of existing legacy systems like PCS, etc. Thus, to keep costs down, careful consideration should be given to which legacy systems, processes and information flows should be changed [13]. However, the emphasis should be on the harmonization of processes and data models. Legacy systems are more present in developed countries than in transition economies such as Montenegro.

Human resources costs are related to the training of end users for using the system and for the preparation of personnel who will be the first level of support and who will deal with the management and basic maintenance of the system. Service level agreement for the maintenance and the extent of "outsourcing" depends on the capabilities of the technical staff of the organization in charge of operating the system. Human resources costs are also related to consultants who are in charge of monitoring system design and implementation.

Running costs incorporate all costs after the roll-out and handing over the system to the competent authority, including the maintenance of software and hardware, user support services, communication links, and other operation costs.

According to previous experiences, total implementation costs could be from less than 1 million US dollars (Guatemala) up to 4 million dollars (Finland, Senegal, Malaysia) or sometimes even more, for example in the US [39].

3.2. Quantification of costs

For the purpose of costs quantification, NMSW is presumed to be an information system with a life cycle of *N* years. It is assumed that during the first *N* years only running costs will occur, with no additional hardware/software implementation costs. Therefore, overall costs *C* for the *N* years will be:

$$C = P + T + M + \sum_{i=1}^{N} R_i \qquad (1)$$

where P are preparation costs, *T* are technical costs, *M* are human resources costs and R_i are running costs for each year.

Preparation costs should cover all expenses related to conducting fundamental/feasibility studies and the preparation of tender documentation that will precede NMSW implementation. The preparation phase is a paramount step, and decisions made in this phase will determine the future costs of NMSW implementation.

Technical costs could be further elaborated depending on how many legacy systems have to be updated (existing PCSs, customs, etc.). Assuming *M* legacy systems exist, the technical costs can be calculated as follows:

$$T = H_0 + S_0 + \sum_{j=1}^{M} L_j \qquad (2)$$

where H_0 are hardware costs, S_0 are software costs and L_j are the costs of updating each legacy system for $1 \leq j \leq M$.

Running costs R_i present the annual expenses of NMSW after its implementation. These costs should cover the costs for "in-house" first level support (if there is any) and for outsourcing one or more companies for hardware and software maintenance. These companies will perform second level support.

"In-house" support considers that national competent authority (NCA) for NMSW employs technically skilled personnel that could provide basic support such as password reset, client configuration and basic hardware and software maintenance. First level support should gather and analyze information about different end user's issues, and determine the best way to resolve their problems. The advantage of having an "in-house" support team is that the response time is quicker, while the costs of outsourcing contracts will be lower. Costs related to the "in-house" support team are their wages and expenses of their continuous training. Assuming that NCA is also the authority in charge for other systems like VTMIS (Vessel Traffic Monitoring Information System), AIS (Automatic Identification System), etc, the costs for "in-house" support could be shared, as the same personnel could provide support for various systems. This scenario should be recommended for Montenegro. Otherwise, establishing the new "in-house" support team only for NMSW is not cost efficient, and outsourcing should be considered as a more appropriate solution.

Hardware maintenance (according to Gartner IT glossary (Gartner IT Glossary n.d.)) includes preventive and corrective services that physically repair or optimize hardware. It also provides hardware warranty upgrades and technical troubleshooting.

Software maintenance is an integral part of a software life cycle. It consumes most of the budget during the software life cycle but is needed for many reasons. It ensures that software satisfies end-user requirements, corrects faults, implements enhancements and policy changes, interfaces with other software, etc. Software maintenance should also improve existing functions, and identify security threats and installation of necessary security patches for vulnerabilities. Besides the preventive and corrective software maintenance, it is also required to include adaptive and preventive software maintenance. Adaptive support deals with inevitable future changes if the working environment of software changes. Preventive support will take care of future variations in the software that occurs while adding new modules or functionalities in the software.

Therefore, running costs for year i, where $1 \leq i \leq N$ can be formulated as:

$$R_i = P_i + H_i + S_i \qquad (3)$$

where P_i are costs of "in-house" first level support team, H_i costs of second level hardware maintenance support and S_i costs of second level software maintenance.

Thus, for the overall costs, the following is provided:

$$C = P + T + M + \sum_{i=1}^{N} R_i = P + H_0 + S_0 + \sum_{j=1}^{M} L_j + M + \sum_{i=1}^{N} (P_i + H_i + S_i) \qquad (4)$$

Regarding factors j and i, it is possible to observe the difference between developed and undeveloped countries.

The developed countries, assuming that they have still not implemented a NMSW solution, will have a higher number of legacy systems that need to be updated, while developing countries will have a lesser number (or none) of legacy systems to update.

Factor i is also correlated with the development of the country. If the state is developing, N should be higher $(15 \leq N \leq 20)$ then for the developed countries $N \leq 15$.

3.3. Benefits of NMSW implementation

The implementation of an NMSW can be highly beneficial for both the state where it is deployed and the stakeholders that are involved in maritime transport [41]. Benefits of NMSW implementation could be numerous, such as increased revenues through more effective and efficient utilization of human and financial resources for authorized inspections, transparent and predictable interpretation and application of rules, and enhanced safety and security due to improved and preemptive risk management [30], [25].

Maritime traders could reduce their costs via NMSW by reducing delays trough faster clearance and release of their goods, increased transparency, and predictability of rules. Finally, they could deploy their resources more effectively and efficiently as a result of the one-time electronic submission of information [42].

It is estimated that the introduction of EMSW will cost 29.4 million EUR between 2020 and 2030 and will directly save from 22 to 25 million staff hours in the 10 year time frame from 2020 to 2030, which is equivalent to a value of 625 to 720 million EUR for all EU member states, while indirectly it will also positively affect the shift of transport mode from road to waterborne transport [43]. An electronic document-exchange system for maritime port operations in the port of Hamburg (Germany) saves approximately €22.5 million yearly, mainly through the reduction of labor costs [44]. In Senegal, National Single Window implementation has reduced the average document collecting time from 4 days to 1 day. Customs clearance procedures in Cameroon have been reduced from 6 days to 3 hours. Total cargo turnover/dwell time in Benin has decreased from 39 days to 6 days, and in Malaysia from 4 days to 2 days [43].

NMSW will introduce electronic documents that are better structured and more reliable than paper documents. Such documents may assist in risk management, for example, to determine whether the ship is safe or whether it may be carrying contraband goods or similar. NMSW enhances automated track and tracing systems of ships and cargo, monitoring of document processing, security, and non-repudiation. In some countries, the introduction of improved clearance led to fewer customs and Port State Control (PSC) inspections [45].

The ability of ports to decrease transport costs is an essential dimension of their competitiveness. Container freight rates between Shanghai and the Mediterranean are around 739 USD and have dropped by 41% in seven years (2010 – 2016) [46]. In some maritime ports, paperwork costs still present a significant share of overall transport costs. A World Bank Report states that improving trade efficiency could be done through port and customs automation. The average export border compliance time for the ports with no electronic data exchange is almost 100 hours, which is more than double compared to the ports with automatic data exchange [47].

3.4. Quantification of benefits

To quantify the benefits of NMSW implementation, the overall processing time required for each document associated with the port call (arrival and departure) or transit should be determined, before NMSW implementation (t_1) and after implementation (t_2). The difference between these two working times (t_d) will quantify the time that will be saved after NMSW deployment for one port call or transit.

$$t_d = t_1 - t_2 \quad (5)$$

Saved time, represented in hours, could be multiplied by the average cost per working hour so that the benefit of NMSW could be quantified. For this purpose, it is assumed that *K* documents exist that should be handled by *I* governmental agencies or data providers (agent or ship master).

Overall time consumed for managing all these documents for one ship call before NMSW implementation is equal to:

$$t_{1=}\ \sum_{i=1}^{I}\sum_{j=1}^{K} t_1^{i,j} \qquad (6)$$

Likewise, time spent on processing the paperwork during the ship call after NMSW implementation will be:

$$t_{2=}\ \sum_{i=1}^{I}\sum_{j=1}^{K} t_2^{i,j} \qquad (7)$$

Furthermore, assuming that an average cost of working hour is *p*, and that NMSW will serve *V* number of vessels yearly, the overall benefit, *B*, for *N* years could be calculated through:

$$B = NVpt_d = NVp\left(\sum_{i=1}^{I}\sum_{j=1}^{K} t_1^{i,j} - \sum_{i=1}^{I}\sum_{j=1}^{K} t_2^{i,j}\right) \qquad (8)$$

It is assumed that NMSW will serve only SOLAS ships. If NMSW also serves non-SOLAS vessels, that will be an added value feature.

It is also assumed that NMSW serves *V* ship calls on an annual basis, out of which *C* are calls to national ports, while *T* is the number of transits served by NMSW annually. Hence:

$$V = C + T \qquad (9)$$

4. Research results and discussion: Montenegro case study

Montenegro has four ports of national importance, which are open for international traffic: Port of Bar, Marina Bar, Port of Kotor, and Shipyard Bijela [48]. There are other official ports of entry of local importance open for international traffic: Porto Montenegro, Porto Novi, Dukley Marina Budva and Port of Zelenika.

Port of Bar is the largest and the crucial port in Montenegro. It can handle dry cargo, liquid cargo, general cargo, cruise ships, and ro-ro ships. Port of Bar also has a Passenger terminal but is mostly oriented to transport of goods. Almost 95% of products coming from the sea to Montenegro are transported through this port. Although the Port of Bar alone is designed to handle 5 million tons of cargo, in the last years, the total cargo load in the whole of Montenegro did not exceed 2 million tons on a yearly basis (Table 1). According to data from Harbour Master Office (HMO) Bar [49], 596 ships have called to Port of Bar during 2018, carrying 21,887 passengers and 2,028,172 tons of cargo.

Port of Kotor has lately become a top-rated cruising destination. The number of cruise ships had almost tripled, while the number of cruise passengers has increased more than tenfold since Montenegro gained independence in the year 2006 [51], [52] and [53], owing to the fact that size of the cruisers has also increased. According to data from Harbour Master Office Kotor [49], 445 ships have called to the port of Kotor and other ports in Boka Bay during 2018, with 493,444 passengers and 1276 tons of cargo.

Marina Bar is dominantly oriented to pleasure crafts, as other points of entry of local importance, while Shipyard Bijela is in the process of transformation. HMO Bar has issued 1,494 vignettes, while HMO Kotor has issued 3,582 vignettes to foreign pleasure yachts that have arrived in Montenegro ports [49].

More comprehensive and accurate data with a total throughput of maritime traffic in the last twelve years in Montenegro is shown in Table 1, as it will be a valuable input for NMSW concept planning.

Table 1. Montenegro maritime traffic data for period 2007-2018

Year	**Maritime Traffic**					
	Passengers in ports	Turnover in ports in tons	Foreign yachts	Passengers in foreign yachts	Cruisers	Cruise Passengers
2007	-	-	-	-	174	45,653
2008	-	-	-	-	245	50,554
2009	-	-	-	-	268	70,749
2010	-	1,758,692	2,807	12877	313	142,259
2011	-	1,749,982	2,964	13,977	319	187,171
2012	-	1,227,877	2,987	14,494	348	244,084
2013	-	1,295,366	3,786	15,778	409	314,961
2014	107,814	1,241,431	3,961	18,129	350	306,397
2015	98,974	1,488,399	4,018	20,859	411	441,513

2016	110,127	1,645,797	4,384	21,544	480	532,337
2017	118,535	2,096,122	4,598	23,001	430	540,445
2018	98,455	1,963,204	4,710	27,685	424	506,198

Source: (Statistical Office of Montenegro 2018a), (Statistical Office of Montenegro 2018c) and (Statistical Office of Montenegro 2018b)

It should be emphasized that MontStat and HMO data on Maritime traffic are incoherent. Implementing NMSW could remove the inconsistencies in data collected by different institutions by different methods and criteria.

As maritime administration and arrival/departure procedures are carried out similarly in Croatia, the steps in the implementation process are explained through the case of Croatian NSW. Two studies were produced in Croatia in order to enable successful NSW implementation (in 2011 and 2017). Several issues have slowed down the implementation of Croatian NSW: less cooperative stakeholders (who mostly own and operate separate ICT systems), insufficient Government support and financial issues. In the meantime, Croatian Ministry of the Sea, Transport and Infrastructure has developed the unique Maritime Single Window system (CIMIS) that implements all national level processes related to the administrative aspect and aspect of navigation safety. In order for CIMIS to be able to exchange data with external systems, a new service CIMISNet has been established, which aims to improve data exchange, reduce administrative procedures among all Port authorities, various Ministries, the Customs administration, Coastal Shipping Agency, Croatian Bureau of Statistics etc. [2].

In this chapter, the authors have elaborated the current situation of ship reporting formalities in Montenegro and have shown the desired state of the art for eMaritime services in Montenegro. Ultimately, costs and benefits estimation of NMSW implementation in Montenegro has been provided.

4.1. Current situation of ship reporting formalities in Montenegro

The process of reporting and clearance of ships calling Montenegro ports is time-consuming for the shipmasters and ship agents. Shipmaster or ship agent should, for each port call, deliver in the paper form, via fax or e-mail, various documents to different authorities responsible for the ship clearance process. Pre-arrival documents are mainly sent electronically, while port documents are handed in paper form upon arrival. Also, ship masters with dangerous cargo on board transiting ADRIREP [53] Montenegro zone of responsibility are supposed to send information regarding dangerous cargo on board to MRCC Bar via VHF.

The Law on Maritime Safety [54] requires the agent to electronically report the pre-arrival information 24 hours in advance to Maritime Safety Department (MSD). The agent mostly reports safety-related information to the MSD, such as the NOA (Notice of Arrival), DGM (Dangerous Goods Manifest - FAL 7), ISPS (Ship pre-arrival security information form for all ships prior to entry into the port of Montenegro), Notification of ship-generated waste, BWR (Ballast water reporting form) and NOD (Notice of Departure). Requested forms should be delivered via e-mail as an XLS file in a specific template. Upon reception, MSD forwards some of the data to other authorities. Information which is received from MSD or directly from ship agents, Port operators enter in their improvized systems (spreadsheet tables and/or stand-alone applications) for their internal use and reporting, therefore these systems could not be considered as legacy systems. Regulation of this Law [55] appoints Harbour Master (HM) for issuing “Free Pratique” and “Permit of Vessel’s Departure”. The agent must electronically send to HM, 24 hours in advance for arrival and 2 hours before for the departure, all FAL forms and MDH (Maritime Declaration of Health). Other authorities (Police, Health, Customs, etc.) also require reporting via e-mail in advance.

Before the ship arrives in one of the ports in Montenegro, paper copies of various documents should be prepared by the ship crew, and delivered upon arrival to authorities responsible for ship clearance.

4.2. Desired state of the art for eMaritime services in Montenegro

Future NMSW in Montenegro should facilitate maritime traffic by simplifying and minimizing the formalities on arrival, stay and departure of ships in international voyages. It should also introduce electronic reporting, making paper reporting obsolete. NMSW should be the foundation for future eMaritime services, as presented in Figure 2.

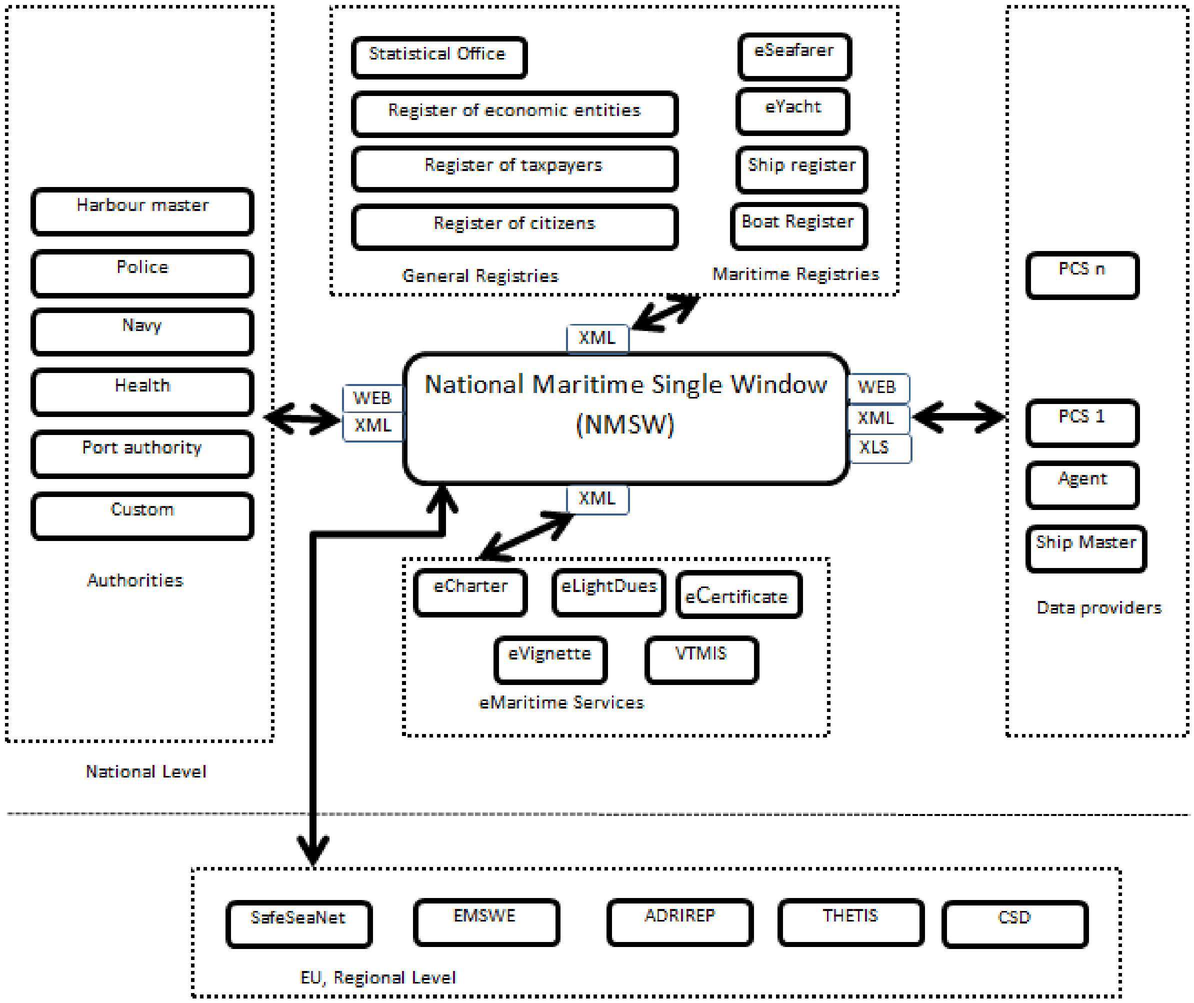

Figure 2. TO-BE model of communication among stakeholders for ship clearance in Montenegro (authors)

A proposal of system architecture for NMSW implementation in Montenegro, as well as the initials steps and tools necessary for NMSW implementation, are given in [56].

4.3. Costs and Benefits estimation of NMSW implementation in Montenegro

Estimation of costs

As a starting point for cost estimation for setting up and running an NMSW, equation (1) will be used and its elements will be discussed.

For estimating the preparation costs (P), MSD experience in the VTMIS project [57] will be used. The overall preparation expenditure for this project was 150,000€. Preparation funds covered all relevant studies, including a draft of national VTMIS regulation and tender preparation. The same amount is proposed for NMSW preparation. Also, it is recommended to plan the funds for two study visits to two EU countries. Visits are beneficial for people who will be leading the NMSW project implementation. It is also proposed that, along with preparation expenses, the expenses of the Technical Assistance team should be included during the tendering process.

For the implementation of NMSW, a turnkey solution for hardware, software and training is suggested. The estimation for equipment (Ho), software (So) and human resources costs (M) is 500,000€ [58]. Bearing in mind that, at the moment, there are no legacy systems in Montenegro that should be updated, the overall implementation costs are estimated at 500,000€.

The MSD (as future NCA for NMSW) already employs skilled staff for technical maintenance of VTMIS and ICT equipment. Following the scenario of VTMIS maintenance, it is suggested that existing technical staff should be trained to carry out the first level support services. Costs of their additional training should be covered with the implementation budget. Same as for the implementation phase, a turnkey solution for needed outsourced maintenance is suggested. If possible, one company should be a single point of contact for both hardware and software maintenance issues. Implementation of the VTMIS system was worth 1,800,000€, while yearly maintenance contracts, including spare parts, were 67,938.89€ for the year 2018 [59] and 64,995,00€ for the year 2019 [60]. For the year 2020, the deal of the total worth of 89,382.00€ will be signed [61]. It is possible to calculate that the mean value of yearly maintenance contract with spare parts for the VTMIS system is 4.1% of implementation costs.

Maintenance of VTMIS is more complex, bearing in mind different type of state-of-the-art telecommunication equipment, such as solid-state radars, direction finders, radio links, VHF and AIS transponders, etc., all positioned at locations with severe weather conditions (thunderstorms and lightning). The majority of corrective and preventive maintenance operations on the VTMIS system are performed by MSD technical staff. NMSW maintenance contract will most likely require fewer hardware interventions and will mostly be focused on software improvements and changes. The highly skilled team (such as developers) is needed, and for the time being, MSD does not employ such staff [62]. It can be concluded that the maintenance contract shall not exceed 4.1% of the total value of implementation, which is 20,500.00€ yearly. This figure is based upon the experience of MSD with VTMIS maintenance contracts in the last three years.

Finally, to determine the overall costs, NMSW life expectancy of 15 years is assumed. According to the equation (4):

$$C = P + T + \sum_{i=1}^{N} R_i \ = 150{,}000€ + 500{,}000€ + 15\ x\ 20{,}500€ = 957{,}500€$$

<u>Estimation of benefits</u>

To quantify the benefits of NMSW implementation in Montenegro based on the equation (8), several things will be assumed:

1. The number of SOLAS ships calling Montenegro ports is expected to be 1000 on a yearly basis;
2. The life cycle of NMSW is 15 years;
3. To estimate the overall time that can be saved per ship call by using an electronic NMSW, research results from [63] and [64] are used. Research in Croatia has shown a 3.7 person-hours working time savings after reengineering the process “Vessel arrival to the port”. Bearing in mind that the procedures for ship calls in Montenegro are similar to ones used in Croatia, research results from [63] and [64] can be used to quantify benefits for Montenegro.

The average monthly gross salary in Montenegro in the “Transport and Storage” sector, according to the latest data from the Statistical Office of Montenegro is 812€ [65]. The average price of the working hour (*p*) can be obtained by dividing the gross average wage with 174 (the number of working hours in one month). Therefore, the average price of the working hour in the “Transport and Storage” sector in Montenegro is 4.67€ per hour.

Bearing in mind the above assumptions, the overall quantitative benefit of NMSW will be:

$$B = NVpt_d = 15\ \times 1000\ \times \frac{3{,}7x}{174h} \times 812€ = 15\ \times 17{,}266.67 = 259{,}000.00€$$

Apparently, the overall quantitative benefits are lower than the costs. Even more, quantitative benefits on a yearly basis are lower than the running costs of the system. It has to be noted that many topics in quantitative benefit estimation were not included. Only the benefits for SOLAS ships have been quantified. According to Table 1, there is a growing tendency of foreign yachts calling to Montenegro ports and marinas. Undoubtedly, if pleasure crafts will be included in NMSW, more savings in working hours will be achieved, while revenues from Vignettes will be higher and more control on yacht rental will lead to more income for the country. Likewise, Montenegro will become more attractive as a yachting destination, owing to simplified and timely clearance procedures.

Advanced reporting, in combination with the VTMIS system, will help to organize maritime traffic in congested areas like Boka Bay. It will increase safety at sea and have an impact on reducing emissions. Police and customs will have the possibility to improve risk assessment and influence in mitigation of criminal activities that will decrease transport costs [38].

Light dues paid by commercial ships entering ports in Montenegro are a primary source of income for the MSD. Vessels can receive discounts depending on the number of entries in Montenegro waters. The process of invoicing will be more transparent and with less workload, if eLightDues would be introduced as a part of an NMSW in Montenegro. Pilot and tug service data exchange will be an added value for the system if pilots and tugs are incorporated in NMSW. Moreover, pilot engagements could be cross-checked in advance with the seafarer database (eSeafarer module) if the appointed pilot has requested certificates for that area. NMSW will imply shorter port time for the ships and shorter export/import delays in Montenegro. It will definitely position Montenegro's economy higher in "Making Business reports" issued by the World Bank.

5. Conclusion

NMSW facilitates communication among stakeholders in maritime trade and enhances maritime transport efficiency, safety, reliability, and security. Many developed countries have already implemented the NMSW, while in some regions, such as the EU, NMSW has become mandatory. For further promotion of maritime trade facilitation and the use of standardized electronic systems for ship clearance at the global level, IMO has agreed to amend the FAL Convention and NMSW has become mandatory since April 2019. This necessary system should at least cover reporting documents included in the FAL Convention.

Previous research related to NMSW shows that previous papers and studies are mostly focused on ports or systems located in developed countries. Little attention has been given to developing coastal states that have to fulfill the obligations stemming from signing the FAL convention. Thus, in this papera comprehensive overview of NMSW has been provided, as well as the cost-benefit analysis of NMSW implementation, with the case study of Montenegro as a representative of a small developing country.

The main concern for developing (and smaller) countries is the cost of NMSW implementation, and the running costs afterward. Creating a Regional NMSW that could encompass the needs of several countries is one way of cost reduction. Such initiatives already exist in Adriatic-Ionian Region, European Union (where direct benefits are estimated to be several times higher than costs) and in some smaller developing island countries. However, regional and global Single Windows or cloud solutions pose a threat to data privacy. The issue of how to protect the commercial data will have to be addressed during the implementation. Even more, in some countries such as Montenegro, it is forbidden that public servers of governmental entities are located out of the country.

Regardless of all obstacles and expenses in NMSW implementation, NMSW can definitely be recommended for the smaller developing countries. In this paper, economic benefits have been quantified such as the value of time and labor saved. Numerous other benefits that could not be quantified are mentioned, which can be subject to further research, such as the prevention of illegal activities and corruption, decrease in tax frauds and smuggling, and in this way, increasing revenues and overall efficiency.

It is important to simplify the national procedures and harmonize the reporting formalities at the national level before the NMSW implementation. The harmonization process is time consuming, but it will enable the stakeholders (mainly the Ministry of Transport and Maritime Affairs of Montenegro and Maritime Safety Department) to fully benefit from the NMSW system. Not being a member of EU, Montenegro has expressed interest to participate as observer in the Expert group on Maritime administrative simplification and electronic information services (eMS group), SafeSeaNet Group (managed by EMSA) and the High-Level Steering Group on SafeSeaNet (managed by the European Commission), by sending official request to European Commission in 2014.

A large challenge is to introduce the NMSW in conjunction with the existing legacy ICT infrastructure. Transition economies and smaller countries, such as Montenegro, should have fewer issues with legacy systems, because fewer legacy systems are implemented.

Finally, for tourism-dependent destinations such as Montenegro and numerous small developing countries, adding non-SOLAS vessels and pleasure crafts in NMSW will provide an added value, creating more income for the country. All this will lead to a higher ranking in the "Doing business" list, which is very important for countries that largely depend on foreign investments.

NACIONALNI JEDINSTVENI PROZOR U POMORSTVU: ANALIZA TROŠKOVA I KORISTI NA STUDIJI SLUČAJA CRNE GORE

SAŽETAK

U ovom radu istražuju se troškovi i koristi Nacionalnog jedinstvenog prozora u pomorstvu (NMSW) u obalnim državama koje imaju ograničene ljudske resurse i infrastrukturu vezane za pomorski saobraćaj. Predložena je opšta metoda sprovođenja analize troškova i koristi prilikom uvođenja NMSW-a. Koristeći ovu metodu i ulazne podatke za Crnu Goru, kao primjer male obalne države, autori procjenjuju može li ulaganje u primjenu NMSW-a biti korisno za obalne države koje raspolažu ograničenim resursima.

KLJUČNE RIJEČI

Nacionalni jedinstveni prozor u pomorstvu; Analiza troškova i koristi; Studija slučaja Crna Gora

DRITARJA UNIKE KOMBËTARE NË DETARI: ANALIZA E SHPENZIMEVE DHE TË ARDHURAVE NË RASTIN STUDIMOR MALI I ZI

PËRMBLEDHJE

Në këtë punim hulumtohen shpenzimet dhe të ardhurat e Dritares Unike Kombëtare të Detarisë (NMSW - National Maritime Single Window) në lidhje me komunikacionin detar në shtetet bregdetare të cilat kanë burime të kufizuara në njerëz dhe infrastrukturë. Është propozuar metoda e përgjithshme e zbatimit të analizës së shpenzimeve dhe të ardhurave në rastin e implementimit të NMSW-së. Duke shfrytëzuar këtë metodë dhe të dhënat hyrëse për Malin e Zi, si shembull i një shteti të vogël bregdetar, autorët vlerësojnë se a mund të jetë i dobishëm investimi në implementim të NMSW-së për shtetet bregdetare me resurse të kufizuara.

FJALË KYÇE

Dritarja Unike Kombëtare në Detari; Analiza e shpenzimeve dhe të ardhurave; Rasti studimor Mali i Zi

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E. Improving Maritime Transport Sustainability Using Blockchain-Based Information Exchange

Abstract: In this paper, the authors perform a comprehensive literature review of the positive impacts of blockchain-based information exchange in the maritime transport sector, as well as the challenges and barriers for successful blockchain-based information exchange, considering all three aspects of the sustainability (economic, environmental, and social). The papers from relevant databases (Web of Science and Scopus) and selected studies have been used. The literature coverage was expanded by using backward snowball sampling. In total, 20 positive impacts and 20 challenges/barriers were singled out. Despite the identified barriers and challenges (such as the slow acceptance of blockchain technology in the maritime transport sector or the high implementation cost), blockchain technology possesses a definite potential to improve the information exchange between all involved stakeholders (for example, by improving the visibility across transport routes and by reducing the paper-based processes), positively affecting all three aspects of sustainability. The authors contribute to the existing research of the economic aspect of maritime transport sustainability by blockchain-based information exchange by expanding it and by researching the environmental and social aspects of sustainability.

Keywords: blockchain; information exchange; maritime transport; sustainability; positive impacts; challenges; barriers

1. Introduction

The shipping industry is still a traditionally oriented industry, despite numerous technological revolutions [1]. The companies in the maritime transport sector are facing notable challenges resulting from the emergence of disruptive technologies, for example, the lack of regulation and the issues of security and privacy. Nevertheless, the disruptive innovations definitely possess a potential to improve transport business [2]. The blockchain, as a disruptive technology and a driver of digital transformation, is projected to be the latest transformative innovation and is increasingly gaining attention from academics, practitioners, and regulators across various industries [3,4]. The blockchain research frequently lacks theoretical foundations, and it is unclear which organizational theories (and to what extent) are being used to research the blockchain technology in the logistics and transport fields [4].

The movement of goods and related information through a supply chain can be a complex process, involving numerous and various stakeholders such as the importers, exporters, and logistics firms [5] that should closely cooperate in order to achieve smoother information exchange. The inability to effectively manage documents may represent a burden for port management, since standard vessel shipping includes numerous stakeholders (shipping companies, terminal operators, etc.) as well as numerous iterations of confirmations and various regulations [6]. A part of the problem arises due to the lack of mindfulness about the upcoming transport, and this refers to informing the parties about the arrival, the type of cargo, checking of documents, etc., along the supply chain [6].

The environmental regulations and rules are one of the key drivers of developing sustainable practices in organizations. Organizations invest and strive to meet minimum sustainability criteria, and that can at the same time prevent their creativity and innovation in applying sustainable methods [7]. The blockchain may transform the maritime industry and could provide various benefits to the exporters, importers, shipowners, and governments [8]. However, the stakeholders and enterprises in the maritime transport sector, as many enterprises in other industries, struggle with the lack of awareness, collaboration, and commitment for a successful blockchain implementation. The majority of contemporary research is focused on the blockchain impact in the supply chain. A lack of research and scientific papers offering a comprehensive overview of the blockchain-based information exchange (in terms of sustainability) in the maritime transport sector is particularly pronounced [6]. To overcome this research gap and to provide a better understanding of the blockchain-based information exchange in the maritime transport sector, the authors have conducted a comprehensive literature review focusing on the period from 2015 to 2020 in order to capture the recent research in the field of blockchain. Moreover, the aim of the research endeavor was to identify the positive impacts of blockchain on information exchange among the stakeholders as well as the challenges and barriers to successful blockchain-based information exchange in the maritime transport sector, considering all the aspects of sustainability. To achieve this aim, the following research questions were addressed in this study:

- What are the positive impacts of the blockchain-based information exchange in the maritime transport sector (considering all three aspects of the sustainability)?
- What are the challenges and barriers to successful blockchain-based information exchange in the maritime transport sector?

After analyzing the connection between the maritime transport and sustainability as well as the theoretical part of blockchain technology, the authors analyzed the positive impacts of blockchain-based information exchange in the maritime transport sector and have identified the challenges and barriers of the blockchain technology in the maritime transport sector, considering all three aspects of sustainability.

2. Theoretical Background

2.1. Maritime Transport and Sustainability

Over the last century, maritime transport has been the predominant mode of transport for global trade, involving a large number of stakeholders [9]. According to [10], due to economic globalization and the rapid growth of international trade, maritime transportation has become the main conveyor belt of cargo flow between countries. Maritime transport sustainability means the ability to provide accessible, affordable, reliable, safe, socially inclusive, economical, and environmentally friendly transport infrastructure and services [11]. The shipping should be efficient and sustainable in order to enable the growth of the global economy, but it should also focus on protecting the environment, cost-effectiveness, and providing safe and energy-efficient global transport of goods [8].

While researching the three pillars of sustainability, Oh, Lee, and Seo [12] identified the key management criteria for sustainable seaport business: an environmental management criterion includes environmental policy, environmental risks reduction, and stakeholder collaboration [12]. Economic management criteria include cost-saving by using cleaner technologies. Criteria in social management include welfare and working conditions improvement, education and training, and supporting economic and social activities [12]. With regard to the economic sustainability aspect, economic parameters may (among others) include connectivity, market access, trade competitiveness, infrastructure capacity, and transport costs [11], which represent a significant portion of total logistics costs for many organizations [13,14]. Currently, the attention is being paid not only to the economic but also to the ecological issues of transportation, with the aim to lower the damaging impact on the environment [15]. In maritime transport, an increasing focus is placed on the environmental aspect of sustainability because of tightening emission regulations and stakeholder demands. Non-compliance or inactivity related to environmental sustainability can ultimately lead to unexpected costs for companies

[16]. With regard to the social aspect of sustainability, safety and security, health, employment, employee engagement, and working conditions should be considered [11,17].

Seaports represent the important logistics and transport chains' nodes and are at the core of national and regional economies [18]. In order to achieve seaport sustainability, it is necessary to integrate environmentally friendly methods of seaport activities, operations, and management. As loading and unloading are among the main activities in seaports, unnecessary waiting for cargo due to ineffective, obsolete document exchange causes the increase of CO_2 emissions [13]. The paper documents that are exchanged between the seaport stakeholders and the necessity of physical presence during the so-called "coordination meetings" slow down the business processes and produce higher costs. Furthermore, the bottlenecks and truck congestion inside and outside the container terminal can lead to serious local environmental problems such as noise and harmful emissions, but also to major inefficiencies in various operations [19]. The importance of the environmental aspect of seaport sustainability is increasingly recognized by the port authorities, port users, policy makers, and local communities. Despite the numerous environmental benefits that innovations can provide, resistance to change is often present [20].

2.2. Blockchain

The blockchain is a decentralized ledger that uses peer-to-peer consensus to verify and authenticate all information recorded within the ledger [21]. The blockchain may be defined as a record-keeping system that stores transaction record information that is shared peer-to-peer, including all computers within the network [22]. In blockchain technology, transactions are stored in a distributed ledger; the copies are available with each node, enabling transparency [23]. This node network will be secured against inaccurate or malicious alterations caused by a defective data source (either one of the nodes or an external attacker) [24]. The blockchain is a "chain of blocks" containing details of a transaction for a specific time period that cannot be edited easily. The "block" is related to transactions and represents the basic blockchain unit, while the "chain" connects the transactions into one chain. In other words, each block includes a list of transactions and links to the previous block within the chain. The blockchain technology principle is achieved through a decentralized peer-to-peer network, i.e., through a network through which the data is shared between many working units [25]. The blockchain can be divided into two types according to openness and access to data: public and private [26]. According to [27], the public and private networks differ in terms of access to the ledger. In the public network, each user has a copy of the ledger and participates independently in the conforming transactions, while in the case of a private network, participants need permission to keep a copy of the general ledger and participate in the confirmation of transactions [27].

The blockchain also supports more advanced concepts, such as smart contracts and the smart property, also known as tokenized assets [3]. Smart contracts may be characterized as distributed transactions that are stored on the blockchain, allowing highly automated workflows that do not require human interaction [28]. A smart contract is a self-executing pre-evaluated contract that aims to digitally facilitate, verify, or enforce the negotiation or the contract execution [29,30]. The smart contracting may be defined as the usage of a blockchain technology-based computer program in order to support and automate the execution of contractual agreements [31]. The smart contracts may perform numerous functions, such as the automatic change of ownership of goods, execution of payments, and even compensation or insurance payments for late deliveries to the compensate the relevant parties [5].

The blockchain provides numerous benefits and can be used in various areas such as logistics and supply chain management, Industry 4.0, etc., to provide more security and to successfully process large quantities of data [32]. The blockchain is an innovative technology that promises to disrupt the applications and use-cases across most industry sectors, including the maritime industry [1]. The blockchain technology has already been introduced into the maritime industry in the form of a bill of lading, regulatory compliance, etc., and should bring cost-saving to the industry [33].

3. Methodology

In total, 99 sources have been identified as relevant for this research. Table 1 shows the journals, books, and conference papers categorized based on topics. 62 papers were selected from 43 journals, and 10 papers were selected from 10 conferences. Two books relevant to this topic were also included.

Table 1. Categorized journals, conferences, and books (related to sustainability and blockchain-based information exchange) based on topics from 2012 to 2020.

Categorization Based on Topics	2012–2018	2019	2020	TOTAL
Sustainable development and management	2	5	6	13
Supply chain	0	2	0	2

Logistics and transport	2	6	3	11
Maritime industry	4	4	3	11
Economy	0	5	0	5
Engineering	1	0	1	2
Security and privacy	1	0	0	1
Management, strategy, and policy	0	3	3	6
Technologies and systems (general)	6	10	7	23

To provide a better understanding of the blockchain as a tool for improving information exchange in the maritime transport sector, a comprehensive literature review has been conducted. The research methodology has been adapted from [34]. **Figure 1** shows the methodological steps of the research.

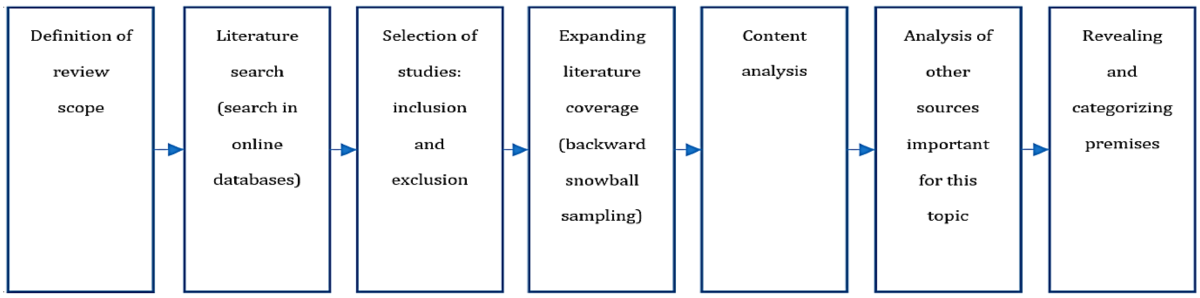

Figure 1. Methodological steps for the research.

The search was carried out using two databases: Web of Science and Scopus.

In this research, we have focused on the following keywords:

- Blockchain AND Sustainability
- Blockchain AND Document exchange
- Blockchain AND Information exchange
- Blockchain AND Transport
- Blockchain AND Sustainability AND Transport
- Blockchain AND Maritime transport

- Blockchain AND Maritime industry
- Blockchain AND Shipping
- Blockchain AND Seaport
- Blockchain AND Port

A search was performed in order to determine whether the publications contained at least one of the search terms in the title, abstract, or the entire manuscript (formal criteria). As shown in Figure 2, the highest number of hits was obtained by searching for the keyword “Blockchain AND Information exchange”. The lowest number of hits was obtained by searching for the keyword “Blockchain AND Seaport”, because seaports are in themselves a narrow topic.

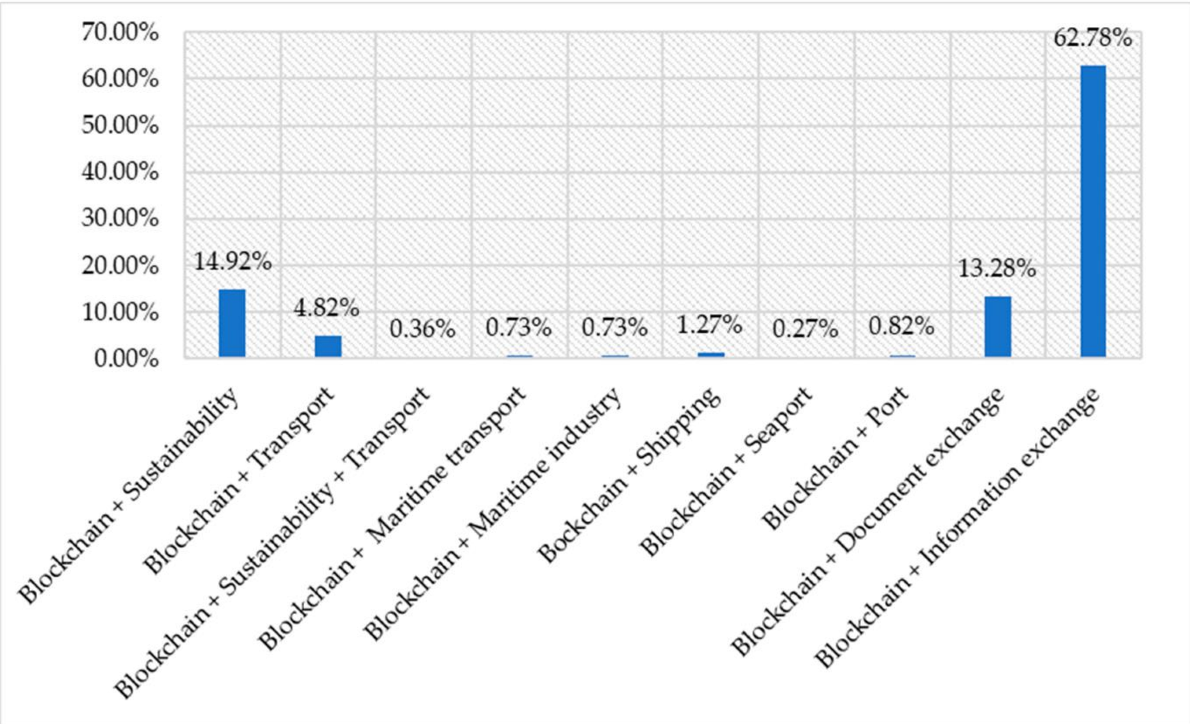

Figure 2. Keyword search distribution in %

In the Web of Science database, the following limitations were used: 2015–2020, TOPIC or TITLE. In the SCOPUS database, the limitations used were: Article title, Abstract, Keywords, 2015–2020, Document type: all. Furthermore, backward snowball sampling was utilized to extend the set of relevant primary studies [35]. According to [36], relevant papers should be defined as those that can contribute to new insights into the similarities, differences, or types of relationships between the concepts studied. If a new paper is included in the sample, its references should also be examined for new data, and these repetitions should continue until a new and/or significant insight relevant to the research is found. Eight papers have been identified though backward snowball sampling. After identifying the positive impacts of blockchain-based information exchange and challenges and barriers to successful blockchain-based information exchange, the importance of blockchain-based information exchange in the maritime transport and seaports is demonstrated through the analysis of several cases such as Port of Koper, CMA CGM, Maersk and IBM, Port of Rotterdam, Port of Veracruz, Mexico, and The Nautical Institute in partnership with Navozyme.

4. Results and Analysis

4.1. Positive Impacts of Blockchain-based Information Exchange

In this chapter, the positive impacts of blockchain-based information exchange in the maritime transport sector, divided by all three aspects of sustainability, have been analyzed and presented in Table 2. In total, 78 sources have been used in this process.

Table 2. The positive impacts of blockchain-based information exchange in the maritime transport sector.

Aspects of Sustainability	Positive Impacts	Sources
Economic	**Cost reduction** = Reduced global shipping costs, improved supply chain visibility, and eliminated inefficiencies resulting from paper-based processes; Reduced transaction and administrative costs; Reduced governance cost and the optimization of governance structure; Reduced cost of maintaining records and transportation costs; Lower costs due to the elimination of intermediaries, lower transaction costs, less paperwork, etc.; Reduced costs of trade information (the costs of coordinating trusted information on the characteristics of goods for consumers, producers, and governments); Reduced cost for clearance and movement of the cargo; Reduced issuance costs	[1,3–5,7,8,22,26,33,37–52]
Economic	**Improving transparency and visibility and real time information** = Real time data provided from the blockchain network; More efficient cooperation within the transport sector	[1,3,6,7,22,26,27,37–39,41,42,44–47,49,51–60]
Economic	**High data availability on the network** = High data availability even after the node crash or quitting, transactions can be performed at any time	[1,44,47,49,51]
Environmental	**Reduced need for paper documentation** = Automated paperwork (bill of lading, customs declaration, etc.) and secure sending and signing of contracts	[1,6,8,37–39,42,44,47,51,52,54,55,57]
Social and Environmental	**Smoother information exchange, a peer-to-peer network** = Improved transparency and data sharing; Resilient and truly distributed peer-to-peer systems, trustful and auditable peer interaction; Reduced need of transmitting electricity over long distances, creating significant savings	[1,3,7,37,44,49,51,52,55,58,61–63]
Social	**Data and Information Immutability** =	[1,6,22,26,51,57,58,60,63]

	Immutability—records cannot be modified without network members' consensus; record history is unchanged and reliable	
Social	**Establishing trust** = Assessing logistics company's performance based on previous performance, timely pickups and deliveries; Affective trust for authentication, access to resources, delegation, provision, and infrastructure	[1,3,6–8,22,27,37–39,42–46,49,53,54,56–59,61,64,65]
Social	**Improving the security and privacy in distributed networks** = Improved security of privacy-sensitive data; Secure data processing and storage; Theft prevention—pick up only after the digital approval from other parties and the system; Blocking of counterfeit certificates, enabling the management of certificates in a secure and transparent manner	[1,6–8,24,26,33,37–39,42–44,46–49,51,54–59,63–67]
Economic, social and Environmental	**Enhancing collaboration and cooperation** = Reduced overall costs and improved profitability; Reduced energy consumption and carbon emissions	[6,8,16,22,27,37–39,42,45–47,49,51,53,58]
Social	**Facilitated determination and setting of rules and governance norms at the transport, logistics, and supply chain levels** = Improved visibility—facilitates government oversight of the transport and logistics industry	[39,42,53,61]
Economic, Social and Environmental	**Ability to trace and track goods or transactions** = Improved temporal and spatial visibility of the flow of goods; Improved cargo tracking and recording vessel information, smart contract and maritime insurance policies usage, etc.; Reliable and consistent information regarding the logistics process of the goods; Recording each step during transactions	[1,3,5,6,16,22,26,38,39,41–44,46,47,49,51–55,57,58,60,61,63,64–66]
Economic	**Possibility of integration with the disruptive technologies (Internet of Things, Big Data)** = Improving the sustainable operations of logistics	[5,6,7,22,26,38,39,43,44,47,48,52,53,55,62, 64–66]
Economic, Social and Environmental	**Reducing human errors and eliminating the possibility of providing inaccurate or incomplete information; reducing the rework and recall, the possibility of losing documents; enhanced job performance** = Reduced resource consumption and GHG emissions; Reduced task completion time, simplification, enhanced job performance; Reduced transport costs by error elimination	[3,7,8,38,42, 44,49,51, 52,54]
Economic	**Possibility of increasing the trade contract efficiency and harmonizing conflicting objectives** = Efficient monitoring and execution and increased effectiveness of a trade contract; Harmonization of conflicting stakeholder interests	[4,51,68]
Economic, Environmental and Social	**Reduced transaction delays** = Reduced delays and improved transparency by reducing errors and malpractice; Saved time because of the elimination of sending physical documents; Accelerated pick-up process of the freight forwarder due to reliable and secure flow of information between the consigner bank and the seaport network; Reduced execution time (smart contracts can enforce a set of rules that everyone involved in the process agrees with)	[1,3,6,7,33,42,44,47,50–52,54,55]
Social	**Automated compliance to freight and trade regulations and standards** = The development of high-quality policy settings by crypto-friendly countries in order to encourage policy learning, the emulation of similar policies by other legislatives in the region, spread of relatively consistent blockchain policy responses; The development of upper-level policy forums or governance bodies in order to create open standards	[3,5]
Economic and Environmental	**Improved decision making** = Equal access for all involved parties to the transaction-related information; Possibility to choose more efficient modes of transport, affecting the environmental aspect of sustainability	[45,51,54]
Social	**Ensuring human rights and fair working practices** =	(Saberi et al. 2019)

Environmental	The capability of smart contracts to independently monitor and control sustainable conditions and regulatory policies; Implementation or management of appropriate corrective activities **The basis for supply chain mapping and the application of low carbon transportation** = Reduced carbon emissions in the product transport chain by providing the basis for supply chain mapping and the application of low-carbon transportation	(Saberi et al. 2019)
Environmental	**Reduction of energy and fuel consumption, pollution, and environmental degradation** = Energy saving due to faster tracking and less paperwork; Improved monitoring and storage of activities related to data responsible for environmental pollution and degradation; Real time collection and analysis of low-carbon data for quicker decision-making; Considerable reduction of fossil fuel usage and emissions	[1,44,45,49,50]

According to [53], trust can be improved by increasing traceability and transparency, for example by increasing operational efficiency, improving sustainability performance, meeting stakeholder needs, reducing illicit practices, and enhancing the information flow and stakeholder collaboration.

One of the benefits of the blockchain is the reduced need for documentation. According to [42], "for international shipments, companies and customs officers are compelled to fill out over 20 different kinds of paper documents to have the goods transported from the exporter to the importer and vice versa. Most of these documents do not provide visibility in real time and data quality, which often leads to obstacles in financial reconciliation". Paperless trade presents a number of potential benefits, including reduced shipping and communication costs, lower paper handling costs, reduced errors and faster receipts, reduced trade financing costs, and reduced inventory [5].

The blockchain technology can potentially solve the following problems: interruptions in cargo monitoring (as the maritime transport involves numerous stakeholders) and the lack of data transparency (due to poor data handling) [37]. Apart from the economic benefits, according to [39], real-time optimization of the vehicle routes is also possible, which positively affects both the congestion and the carbon emissions, improving the ecological aspect of sustainability. Furthermore, all shipment requirements and specifications are recorded in the blockchain, and users can retrieve them and set optimization targets [39], affecting the economic and ecological aspects of sustainability.

According to [54], all shipments can be tracked in real time, from the origin to the delivery. The paper documents are being replaced by smart contracts and unnecessary parties are being removed from the transport process, making the global logistics sector less centralized [54]. According to [42], by tracking the cargo (shipment) in real time using blockchain technology, the shipping companies and ports can plan ahead for the land manipulation, thus expediting the terminal operation and reducing the costs.

According to [47], enabled by the automation of smart contracts in the online market, shipowners can transparently present their services and availability periods to charterers. The charterers can similarly indicate their service demand. All this can be achieved without the necessity of an interposed shipbroker.

Du et al. [10] have researched the berth allocation problem by modelling the impacts of tides on the entrance/exit of vessels into/from ports and by borrowing the so-called virtual arrival policy. The blockchain can solve a part of the problem by consequently affecting the reduction of bunker fuel consumption and vessel emissions. Nguyen et al. [67] have investigated the potential operational risks of the blockchain-integrated container shipping systems, but have also identified a potential of the blockchain technology adoption in strengthening security and improving efficiency in container shipping operations. The focus of the Venturini et al. [69] has been the optimization of assigning the berthing times and positions to the vessels in container terminals. By implementing the blockchain, the collaboration between port terminals and the shipping liners can be improved (leading to the reduced costs, affecting the economic aspect of sustainability), and operations and sailing times can be optimized (leading to reduced bunker consumption, fuel cost, and air emissions, affecting the environmental aspect of sustainability). Zhang et al. [70] have researched the cold chain shipping mode choice problem. The blockchain could simplify the maritime cold chain mode choice, the shipment scheduling, and the ship deployment problem by utilizing speed optimization for time sensitive products.

The maritime transport sector and the seaports involve numerous stakeholders and documents. One of these documents is the bill of lading. The bill of lading is one of the most significant and valuable documents in the shipping industry, acknowledging that the cargo has been shipped and can contain details such as the quantity, descriptions, weight, loading, and discharge port of the cargo and shipping marks [1]. According to the information by DHL, up to 10 percent of bills of lading contain incorrect data that could lead to disputes and litigation [71,72]. The blockchain technology may have an important role in mitigating the mentioned issues. Regardless of that, the blockchain could largely affect the port digitalization [37]. This will be particularly evident in the development of smart contracts with the further implementation of the blockchain [38].

According to [55], integrating the blockchain into maritime transport can increase sustainability, reduce fraudulent activities, reduce delays and waste caused by paperwork, and identify problems more quickly. Furthermore, this might increase global GDP by almost 5% and global trade volumes by 15%. According to the IDC Group report on digital transformation for 2021, blockchain-enabled in-industry value chains will have extended their digital platforms to their entire ecosystems, therefore reducing transaction costs by 35% [73]. It is hard to predict the container freight rates, but it is possible to expect that a company that starts using the digital bill of lading will reduce their costs by up to USD 30, and compared to other companies will achieve larger market share and will earn more profits [1].

Although the Port of Koper is not as developed as the Port of Rotterdam, it presents a good example of a port in development that has recognized the importance of digital transformation in order to achieve competitiveness. The first step was the implementation of blockchain technology. In August 2018, the first processed container was released in the mentioned port using the blockchain-based CargoX's "Smart Bill of Lading". CargoX is an independent supplier of documentation transaction systems that provide a fast, secure, reliable, and cost-efficient way of processing shipping documents globally [74]. The bill of lading for this shipment was electronically issued and transferred using an extremely secure and reliable public blockchain network in minutes instead of days or more, and the chances of theft, damage or loss of the Bill of Lading were reduced to almost zero [75]. India's Ministry of Shipping has given the green light to launch test the shipments with bills of lading, submitted on CargoX's technology via the country's Port Community System [76]. According to Alejandro Gutierre, founder of Forward Together (a logistics network), the ability to conduct shipment transactions and ownership transfers without the need for physical interaction creates a breakthrough case for logistics and freight forwarding, especially when health measures are of importance [77]. CMA CGM have recognized the importance of blockchain technology as well in order to offer a paperless and secure bill of lading [78].

Stakeholder collaboration plays a very important role in achieving sustainable business [79]. The following case demonstrates the importance of the blockchain (an enabler of digital transformation [80]) and the importance of collaboration. Maersk and IBM jointly developed a blockchain solution in order to digitalize global trade, calling it TradeLens. According to IBM, a joint blockchain initiative could significantly reduce the cost and complexity of trading [81]. CMA CGM and Mediterranean Shipping Company S.A. have recognized the importance of blockchain and joined TradeLens. According to [82], TradeLens enables the connecting of participants, information exchange and collaboration in the shipping supply chain. Members gain a comprehensive insight into their data and can collaborate digitally as the cargo moves globally, helping to create a secure, transparent, and unchanging transaction record. According to [27], Maersk managed to save billions of dollars after joining with IBM to manage the maritime containers via the blockchain.

The Port of Rotterdam is involved in several blockchain projects, for example the IBM and Maersk TradeLens [83]. Furthermore, the Port of Rotterdam presented a new pilot project based on the blockchain to handle the containers more safely and efficiently by eliminating the use of a pin code [84]. Blockchain technology applied to port management will make it possible to store and share the information on ship loads and improve financial operations and contracts, among many other possibilities [85]. The possible positive impact of the blockchain is visible in the Blockchain Port Community System. The port of Veracruz, Mexico, has contracted a blockchain logistics company dexFreight to develop a proof-of-concept project for a blockchain Port Community System [86]. The goal is to improve the efficiency of the freight and logistics at the port as well as the optimizing and streamlining the carrier onboarding processes.

Another case is blockchain-powered Cargo Community System in the Port of Marseille Fos. Data in the Cargo Community System is collected from a variety of sources, for example the freight forwarders, shippers, customs, port agents, and road transporters [87]. The aim is to streamline and accelerate the exchange of cargo data between all the involved stakeholders (public and private) [88]. According to [47], the implementation of the blockchain and smart contract solutions breaks down the central control and information system architecture, and by doing so, in the frame of port logistics processes, fosters existing as well as novel entrepreneurial collaborations of different actors in the comprehensive port environment and along the supply chain. This is especially interesting and beneficial for SMEs due to the low participation costs.

According to [89], digital transformation may represent a challenge for a company, but integrating IoT with blockchain eases it due to the nature of digital emergence. This cohesion increases business efficiency and productivity, providing the collaboration and secure communication between the stakeholders. For example, Maersk has invested in the Internet of

Things and the blockchain to improve the security, transparency, and cost-effectiveness of its maritime cargo. It is estimated that the blockchain will save billions of dollars for the shipping industry through more precise container tracking and automation of the shipping transactions [90]. However, blockchain technology's shortcomings are the general lack of standards and the knowledge gap. For this reason, blockchain technology has been slow to catch on in the enterprises [91]. Blockchain technology is considered potentially disruptive for transport systems according to the Catapult Transport Systems report. In parallel, numerous experts participating in a survey on blockchain trends do not appear to be well informed about this emerging technology [92].

According to [47], the implementation of IoT sensors with a direct linkage to the blockchain could provide the distributed and decentralized network with real-time data at all times about the cargo condition and location. The Nautical Institute in partnership with Navozyme has developed a maritime industry specific educational program titled "Blockchain for Maritime Decisionmakers" (BMD) for the IMO Member States and international organizations [93,94]. The BMD Program's objective is to raise awareness of maritime leaders about digital transformation issues and specifically about the applications of blockchain technology for the maritime industry. The BMD Program's larger goal is to equip the global community of maritime changemakers with the knowledge, confidence, skills, and mindsets that can act as a catalyst to transform and futureproof the maritime industry [93].

One of the benefits of blockchain technology is the improved security. The sophisticated data encryption greatly reduces the risk of cyber-crime and dishonest and disloyal competition, whereby a fairer deal is secured for all parties involved, [42], affecting the social aspect of sustainability. Blockchain provides some preventive mechanisms to mitigate cyber-attack threats (e.g., cryptography and distributed consensus) [38].

4.2. Challenges and Barriers to Successful Blockchain-based Information Exchange

According to [7], the effective implementation of blockchain to trace sustainable practices starts with defining the barriers and challenges that need to be managed. In this respect, the authors have analyzed and identified the challenges and barriers to successful blockchain-based information exchange in Table 3. All stakeholders should understand and prepare for these challenges in order to successfully adopt and implement the blockchain.

Table 3. Challenges and barriers to successful blockchain-based information exchange.

Challenges and Barriers	Sources
Data storage and transmission = Each blockchain network node requires significant storage capacity, because the data is stored multiple times in each node, resulting in the waste of storage entry; Not suitable for storing large quantities of data, although there are various ways to bypass it	[27,39,58]
Development and implementation cost and risk = Increased device costs, costs of training, operation costs, and maintenance costs; The companies' operations are vulnerable to disruption when technical problems appear; The necessity for updates on materials, facilities, and machines in order to reduce GHG emissions, energy consumption, water pollution, carbon footprints, and waste; Risks: the lack of legal frameworks, possible cyberattacks, etc.	[3,7,27,37,39,67]
Issues regarding performance and scalability = All nodes within the chain must process all transactions—an issue when it comes to large (and particularly global scale) roll-outs; Performance issues: system flexibility, throughput performance, and low interoperability	[3,7,37,38,41,58,67]
Lack of data protection = No protection against intentionally manipulated input data, even stemming from sensors or RFID tags	(Schmidt and Wagner 2019)
No central authority = No central authority to notify in case of an apparent breach of security; Supply chain stakeholders are used to the trust mechanism that is supported by some form of a centralized authority; Lower confidence about the effectiveness of a thrustless distributed paradigm	[37,38,58]
Lack of consensus and standards = Present in a range of issues ranging from building immutability through proof-of-work activities to industrial use case adoption; The lack of standard tools, indicators, and methods, etc., presents an obstacle to the successful implementation of sustainability practices in a blockchain environment; The creation of data structure standards is needed for efficient communication between different blockchains	[5,7,37,38,45,46, 53,55,59]
Lack of solid rules for information sharing or for lost and stolen data = The lack of rules related to the exchange of information or to lost and stolen data ultimately affects the cooperation between partners	[7,51,67]
The absence of regulation leads to insecurity = Some aspects of smart contract technology may be adopted by the logistics industry, just to be overregulated, or even considered illegal	[27,38,51,55,59,67]
Lack of government and industrial policies and willingness to guide and encourage sustainable and safe practices = Unclear government laws and regulations regarding the use of blockchain	(Saberi et al. 2019)
Stakeholders' hesitation and resistance to change = Changes in organizational hierarchy or culture caused by the transition to new systems; Stakeholders' hesitation and resistance; Scepticism towards the transparency of blockchain	[7,22,27,59]
Energy intensiveness = The consumption of energy required for key algorithms, computations and processing; Significant processing power consumed by proof calculations	[37,38,45,48,55,57, 58,65]
Reduced privacy, unwillingness to share information = Central authority does not exist; Strong interest to keep transaction data private, even forfeiting smaller efficiency gains; Information may be assumed as a competitive advantage by some organizations	[3,7,27,37,38,39, 41,45,53,58,59,65]
Immaturity = Immaturity and high technological uncertainty of blockchain technology	[3,7,37,38]

Data quality = Dependence on the input data quality	(Schmidt and Wagner 2019)
Network effect = Only creates value for participants given sufficient diffusion of the technology	(Schmidt and Wagner 2019)
Lack of management commitment = Absence of management commitment hinders the integrity of business sustainability practices and poses a challenge to resource allocation and business decisions	[7,27]
Lack of the required new organizational policies = Lack of new organizational policies needed to clarify the use of blockchain technology	(Saberi et al. 2019)
The policy barriers of blockchain adoption = Dependence on the nature of trade, which is inherently inter-jurisdictional; The existence of a range of regulatory environments, in accordance with various rules	(Allen et al. 2019)
Inadequate knowledge and technical expertise regarding the blockchain technology usage = The limited number of blockchain applications and developers	(Saberi et al. 2019)
Challenge of connecting the physical and the digital = Large investments needed to connect physical and non-digitized elements to the digital space using various communication technologies (NFC, RFID, IoT, etc.)	(Song, Sung, and Park 2019)

One of the identified challenges and barriers is the lack of consensus and standards. According to [53], many standards are at an early stage of development, limiting the structured governance. The standards are currently being generated by institutions such as the Blockchain in Transport Alliance, a trucking industry consortium [31]. The blockchain in Transport Alliance was founded to drive the adoption of the blockchain technology in the transport industry [95]. Furthermore, the lack of regulation results in insecurity, as the logistics market could adopt some segments of smart contract technology, just to be over-regulated or even considered illegal [96]. According to [5], the development of blockchain standards can result in two broad approaches: standards that are open or closed. The closed standards run the risk of being defined and developed by an "early" dominant player. If several small parties will control the development of standards, this can ultimately limit the entrepreneurial contestability of constructing this economic infrastructure [5]. A solution may be the creation of open standards that allow the entrepreneurs to adapt the rules within which the blockchain solutions can be applied and to allow the later solution interoperability [5].

Distributed trust as well as security and privacy are at the center of blockchain technologies, and can make them successful or cause failure [97]. According to [8], the use of the blockchain in the shipping industry and environmental protection is a positive step, but all stakeholders, particularly the shipping companies, should recognize the advantages of blockchain technology. The advantages of the blockchain can change the entire shipping industry and the trading processes, but the risks related to the blockchain should be properly mitigated [37].

5. Discussion and Conclusions

Although the blockchain has been one of the most discussed topics in the recent years, there is still a lack of research regarding the blockchain-based information exchange in the maritime transport sector. The authors have first analysed the positive impacts of the blockchain-based information exchange in the maritime transport sector, including all three aspects of sustainability. Although attention is often being paid to the economic or environmental aspects of sustainability in the maritime transport sector, research has proven the importance of the blockchain-based information exchange on the social aspect of sustainability as well. The social aspect is usually related to the trust among stakeholders and data security, the reduction of human errors, the reduction of rework and recall, and enhanced job performance. All three aspects of sustainability are closely related, which can be proven by the following example. Although loading and unloading are among the main activities in seaports, unnecessary waiting for cargo due to the inefficient and outdated document exchange causes environmental issues, such as the increased CO_2 emissions. The paper documents exchanged between the seaport stakeholders slow down the business processes (e.g., due to human errors) and create higher costs, affecting both the economic and social aspects of sustainability.

Despite the many positive effects of the blockchain on maritime transport, the maritime industry is considered to be the least technologically advanced, compared to the other industries. One reason is the resistance of stakeholders to change, who continue to use traditional ways of exchanging documents, despite the inefficiency. Additionally, shipping is very diverse and not as uniform as other sectors of the transport industry, and each company in the market searching for its own solution is failing to drive new synergies across the supply chain [98,99].

Although the authors of this paper have singled out 20 positive impacts of blockchain-based information exchange, they have also singled out 20 challenges and barriers to successful blockchain-based information exchange, which proves that the blockchain technology can further be improved. One of the barriers is the lack of consensus and standards, since the stakeholders can still implement their own blockchain solutions and platforms, which can ultimately lead to interoperability issues. One of the barriers related to the environmental aspect of sustainability is the large energy consumption required for processing, key algorithms and computations within the blockchain. One of the challenges is the resistance and the hesitation of individuals and organizations; however, the only way to successfully implement blockchain technology is to engage the stakeholders and build trust among them. The blockchain can enable collaboration among stakeholders, consequently reducing the energy consumption and the carbon emissions, and increasing profitability, affecting all the aspects of sustainability. Some of the players in the maritime industry, such as Maersk and IBM, have recognized the importance of the blockchain and have begun to develop alliances in order to utilize the advantages of blockchain technology. Despite the slow acceptance of blockchain technology in the maritime transport, it should eventually streamline and accelerate the information exchange between the involved stakeholders, positively affecting all three aspects of sustainability.

Although the studies such as [51,52] analyse the blockchain applications in the shipping industry extensively, the goal of this paper was to provide a deeper insight of the challenges and barriers as well (by using the same methodology as for identifying the positive impacts in order to simplify the comparison between positive impacts and challenges and barriers). From this work, it is possible to clearly see that the numerous challenges and barriers exist, despite all the benefits that the blockchain-based information exchange provides. The rapid changes in blockchain technology continuously raise new challenges. This paper (when compared to previous research) focuses on sustainability, providing a clear insight into the impact of the blockchain-based information exchange from the economic, environmental, and social aspects of sustainability. This research is based on the literature review (which also presents the main limitation of the research), and as such offers an initial overview of the importance of the positive impacts, challenges and barriers of the blockchain-based information exchange. As the lack of studies that offer a comprehensive overview of the blockchain in the maritime transport sector is particularly pronounced, it is necessary to analyse this topic further. Future research will be focused towards investigating the specific nature of maritime transport in relation to the other industries in terms of acceptance of disruptive technologies such as the blockchain, and the role of government authorities in terms of the acceptance and use of the blockchain in the maritime transport sector, since the rapid technological change poses new challenges for the government authorities.

Author Contributions

Conceptualization: E.T., D.Ž., M.J. and S.A.; methodology: E.T.; validation: E.T. and S.A.; formal analysis: M.J. and D.Ž.; investigation: E.T., S.A. and M.J.; resources: D.Ž. and M.J.; writing—original draft preparation: D.Ž., E.T. and M.J.; writing—review and editing: E.T. and

S.A.; visualization: M.J. and D.Ž.; supervision: E.T. and S.A.; project administration: E.T.; funding acquisition: E.T. and D.Ž. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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F. The Role of Port Authority in Port Governance and Port Community System Implementation

Abstract: This paper researches the role of the port authorities in port governance, and the role of the port authorities in Port Community System implementation. The authors provide the theoretical frameworks of seaports, port authorities, port governance, and Port Community Systems. The literature review was carried out using the Web of Science database and additional relevant sources. The authors concluded that although different port governance models exist (regarding the type of port authority), there is no evidence as to which governance model is universally preferable, as it is specific to each seaport. In addition, the research has shown that port authorities play a very important role in the implementation of a Port Community System, increasing the sustainability of seaport operations. Its implementation enables the port authorities to evolve into real digital hubs and neutral data managers, which ultimately leads to the optimization of seaport processes and more efficient use of transport infrastructure.

Keywords: seaports; port authorities; port governance; port community systems; governance models; sustainability

1. Introduction

Seaports, as important nodes in maritime transport, have a significant influence on the economic, social, and environmental development of countries [1] on a local, regional, and national level [2]. Nowadays, sustainability issues are becoming a critical component of maritime logistics [3]. In order to achieve sustainable business, governments (or other types of decision makers) implement port governance structures with clear policy goals [4]. Port governance refers to the interactions between the public and private sectors that influence port organization at various levels, from local to global [5]. It is a complex issue that is inseparable, in different spatial and temporal combinations, from the different stages of history, cultures and geography, and from the different forms of political, economic and administrative organization [6]. Extensive seaport reforms have challenged the conventional models of seaport organization in recent decades [7]. The transformation of the port governance models, including developments such as devolution and regionalization policies, has expanded the autonomy and responsibility of the port authority, giving it a broader role outside the port itself [8]. Port governance has attracted significant attention from scholars, port authorities, policy and decision-makers in the maritime sector over the past three decades, and port governance itself has become an important academic and practical concept in the port sector [9].

Port authorities have traditionally been responsible for the development and improvement of the port area [10] related to port operations, ranging from infrastructure development and maintenance to the marketing and management of port facilities [11]. Acting as a port managing body, port authority takes over public, commercial and economic roles [12]. Several objectives of the general interest of society are followed by the port authorities, such as: promoting trade and industry, ensuring long-term sustainable port operation, improving maritime and hinterland connectivity, etc. [13]. Port authorities, as port governance bodies, have been proactive in developing port information systems through the availability and distribution of information technologies, improvement of interaction and exchange information between stakeholders, such as customs, freight forwarders and carriers [11]. In the last decade, new developments in port strategies have emerged around the world: port authorities are changing their nature and function, increasingly taking an active role in the management of logistics systems and sometimes adopting management and entrepreneurial behaviors [14].

Numerous ports are developing and implementing the Port Community Systems (PCS). The introduction of a PCS is identified as one of the key elements facilitating seaport development [15]. Acting as a digital platform, a PCS facilitates the intelligent and protected exchange of information between public and private port users in seaport communities, affecting the sustainable business [16]. It is an effective, real-time, flexible, and complex information system which enables improved efficiency at all stages of the cargo process in the unloading and loading of ships, customs clearance, etc. inside and outside the seaport terminal [17]. The higher the level of collaboration and integration between the port and supply chain stakeholders, the greater the sustainability of both the overall supply chain and the port [18]. Port stakeholders often have individual goals, which can decrease the willingness of certain members of the port community to embrace the PCS. Nonetheless, many seaports like the North Sea ports of Rotterdam, Amsterdam, Antwerp, Zeebrugge, Wilhelmshaven, Bremerhaven, Hamburg, and others have adopted the PCS. These independent PCSs also share and exchange common global shipping data among each other as well as with governmental authorities, i.e., local port authorities [19].

The port authority plays a crucial role in implementing the PCS, considering that in most of the countries it is responsible for coordinating private companies operating in the port area [20].

A lack of research and scientific papers offering a comprehensive overview of the role of port authorities in port governance and the role of port authorities in PCS implementation is particularly pronounced. To overcome this research gap, the authors conducted a literature review on this topic. The goals of this paper are to research the role of the port authority in governing and managing the seaport and the role of the port authority (as the governing body of the port) in the implementation of a PCS. The research problem stems from often outdated execution and monitoring of business processes in seaports. This paper presents a comprehensive review of existing literature, providing a better understanding of the role of port authorities in port governance, the role of port authorities in PCS implementation, and the impact of PCS implementation on sustainability in seaports.

2. Theoretical Framework

In this section, the authors provide a review of relevant literature regarding the seaports, port governance, port authorities and PCS.

2.1. Seaports, Port Governance and Port Authorities

Seaports are a way of joining the global economic system and play an important role in the growth of trade and the global economy [21]. They are often described as economic entities providing a service between different modes of transport or as facilities through which cargo passes, making an important part of the supply chain and logistics [22]. Owing to their size and complexity, modern seaports cannot be viewed as a single entity. In this respect, as an important part of the transport system, the seaport includes strong cooperation between various stakeholders, such as port authorities, shipping companies, freight brokers, etc. [23].

Governance is a term used for the adoption and implementation of laws regulating behavior and property rights. Adjusting policies and organizational priorities to comply with the contextual economic climate is the scope of governance reform [24]. Port governance is characterized by the laws and regulations imposed by the government on a seaport, and it can be regarded as the corporate governance of the seaport in which the port organization has a fiduciary duty to serve the corporation′s ultimate objectives and to serve the shareholders′ interests [9].

Port authorities are institutions of a hybrid nature that incorporate elements of both public and private law, regardless of the ownership and management traditions to which they belong [25]. This hybrid nature makes port authorities ideally prepared to face the various challenges placed on the seaport by both market forces and society [12]. In general, the port authority, also known as port management or port administration, is the administrative body of the port [26]. There are many definitions of a port authority such as “the official organization that controls and manages the activities in a port” [27], “land manager with responsibility for a safe, sustainable and competitive development of the port” [28], “state, municipal, public, or private body, which is largely responsible for the tasks of construction, administration and sometimes the operation of port facilities and, in certain circumstances, for security” [26]. In most countries, the port authority is a public or semi-public body responsible for managing and improving the port area through the construction and maintenance of infrastructure, the leasing or concessionary provision of this infrastructure to private companies, and the growth and competitiveness of the port cluster. In a basic context, most port authorities function according to the ‘landlord’ model, which will be elaborated in the fourth section [29].

Port authorities can be established at all levels of government: national, regional, provincial, or local. The most prevalent form is the local level of government, which means it manages only one port area [26] through its power position and interactions with landlord, regulatory, and community manager functions [30]. The power balance with government is a major factor affecting the legal and regulatory structure, the financial capacity, and the space for a pro-active management culture at the port authority corporate level [25]. Most port authorities, regardless of whether the level of government is national (e.g., Cyprus), regional (e.g., Belgium and the Netherlands) or local (e.g., Korea), have retained at least control over, if not ownership of, the port infrastructure. One exception to this is the case of Taiwan, as most port operations remain state-run in the hands of the port authority [31].

In 2014, PIANC (the World Association for Waterborne Transport Infrastructure) published a Guideline for Port Authorities “Sustainable Ports” which aims to increase the awareness about sustainability issues in ports (such as land use planning, modalities and connectivity, air quality, etc.) and help the port authorities to better face the challenge of becoming sustainable ports with many practical solutions [32]. For example, the Port of Rotterdam Authority is aware of the importance of sustainable business and therefore aims to enhance the port’s competitive position as a logistics hub, but at the same time leads the transition to sustainable energy and encourages the digitalization of business processes in order to make the port, and the supply chain, more efficient [33].

2.2. Port Community System

PCSs are complex systems for concentrating, centralizing, serving and optimizing business processes within port communities [34] promoting faster and safer data exchange among private and public organizations, with the main goal of improving the seaports' competitiveness [35]. PCSs are defined as centralized port information and data hubs that integrate and distribute data from different sources [36]. The PCS is a system that centralizes the vessels′ information and the goods they transport so that the stakeholders can better control and coordinate the movements of goods [37]. The main goals when developing a PCS are, most of all, increasing data quality, paperwork reduction, facilitating data connection between various stakeholders, improving and supporting operations across the entire transport and logistics chain [38]. While both port performance and services provided to stakeholders can be increased by the implementation of the PCS, Saragiotis [39] argues that the effect of the implementation of the PCS is higher for the port authority than for the stakeholders.

PCS functions have been divided by Keceli (2011) into three main categories: port management functions (documents provided to port authorities or terminal operators), customs functions (documents needed for customs clearance) and online platforms for electronic commerce between port users [40]. The concept of enhancing collaboration within the port cluster is widespread in the various PCSs, and also included the following elements: the electronic means of communication between the stakeholders in the cluster, the basis for a collaborative working environment, online access to port-related information and the reuse of data and information [41].

Nabais et al. (2018) [42] categorized the PCS development as follows. At the beginning, the PCS included the notification of arrival and departure of ships and cargo for reporting. In a second phase, the PCS included customs and inspection services. In a third phase, consolidation and specialization of procedures occurs, leading to the implementation of automatic processes, in particular automatic billing, with a significant reduction (in some cases elimination) of paperwork at the seaport. The fourth phase is associated with regionalization, with the expansion of the seaport towards the hinterland, including information about maritime supply chains that cross the seaport (information related to road and train operators, dry ports, maritime carriers) making it possible for all actors to access relevant data [42].

3. Methodology

To provide a better understanding of the link between port authorities and port governance and the link between the port authorities, as the governing body of the port, and PCS, a comprehensive literature review has been conducted. In total, 73 sources have been identified as relevant for this research. Initially, the search was carried out using the Web of Science database as it represents the world's leading scientific citation search and analytical information platform [43]. We have focused on the following keywords:

- port governance;
- port authority AND port governance
- Port Community System;
- port authority AND Port Community System.

In the Web of Science database, the following limitations were used: TOPIC or TITLE (formal criteria). A search was performed in order to determine whether the publications contained at least one of the search terms in the title, abstract, or the entire manuscript. Articles that were not written in English language were excluded, in order to avoid tentative regional overrepresentation of research in the formal analysis [44]. Table 1 shows the number of hits after applying the reduction criteria for each search term found in the Web of Science database, and number of sources after screening manually.

Table 1. The number of hits after applying the reduction criteria for each search term found in different databases and number of sources after screening manually.

Keyword	Articles after Applying Formal Criteria	Articles after Screening Manually
port governance	112	12
port authority AND port governance	37	3
Port Community System	48	16
Port Community System AND port authority	13	3

The research methodology has been partially adapted from [44]. Figure 1 shows the methodological steps of the research.

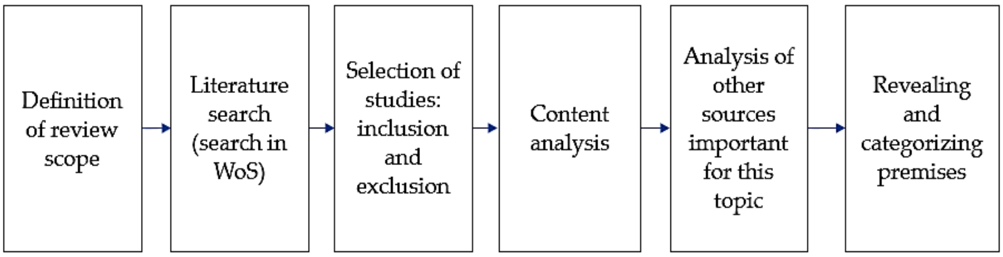

Figure 1. Methodological steps for the research (authors).

Table 2 shows the journals, conferences, books, and the countries of origin, from 2007 to 2021.

Table 2. The list of journals, conferences, books, and the countries of origin from 2007 to 2021.

Journal	Country	2007–2017	2018–2019	2020–2021
Decision Support Systems	Netherlands		1	
Maritime Business Review	United Kingdom		1	
International Journal of Engineering Business Management	Croatia		1	
Research in Transportation Business & Management	Netherlands	4	1	1
Promet–Traffic &Transportation	Croatia	1		
Scientific Journal of Maritime Research	Croatia	1		
Estudios de Economia Aplicada	Spain		1	

Transportation Research Record: Journal of the Transportation Research Board	United States	1		
Production Planning & Control	United Kingdom			1
Maritime Policy & Management	United Kingdom	3	2	
Journal of Object Technology	Switzerland			1
IEEE Access	United States		1	
Case Studies on Transport Policy	Netherlands		1	
Transport Policy	United Kingdom		4	
Procedia Computer Science	Netherlands	1		
Transactions on maritime science	Croatia			1
Research in Transportation Economics	United Kingdom			1
European Transport\ Trasporti Europei	Italy	1		
Conference	**Country**	**2007–2017**	**2018–2019**	**2020–2021**
6th International Conference LDIC 2018, Bremen	Germany	1		
Carpathian Logistics	Poland	1		

Conference 2016				
8th International Conference on Software Quality Days	Austria	1		
2016 Eighth International Conference on Measuring Technology and Mechatronics Automation	China	1		
Book		**2007–2017**	**2018–2019**	**2020–2021**
Reshaping Accounting and Management Control Systems		1		

Afterwards, the authors have also included 17 additional sources important for the topic (including scientific papers, books and PhD theses). After analyzing port governance models and identifying the role of port authorities in PCS implementation, the authors have also included the analysis of several cases in order to demonstrate the importance of port authorities in PCS implementation, such as the Italian "Tuscan Port Community System", the Jamaican PCS, the Polish "Polski Port Community System", Port of Rotterdam, Netherlands, the Port Authority of Valencia, Spain, the Port of Los Angeles, California, the Port Authority of Nagoya, Japan, the Port Authority of the Western Ligurian Sea, Italy, etc.

4. Port Governance Models

Port governance structures are implemented by governments or other applicable decision makers with clear policy goals in mind, such as optimizing traffic capacity, maximizing profitability, etc. [4]. In a comprehensive analysis of the port industry 'Port Economics, Management and Policy' (2020), it is stated that the close cooperation between the responsible government department (such as ministry or other relevant policy-actors) and the port authority (which is responsible for the management and operation of the port), is important for the successful governance of a port and/or a port system [45].

Under the influence of external environmental factors, decisions regarding the port governance model can be taken by many stakeholders [8]. At the very start, improvements in governance models may be attributed to changes in the sector, the setting of new targets, etc., but over time, the reasons behind governance reforms are evolving (for example, conventional ports facing physical constraints requiring the creation of new facilities) [46]. The nature of port authority, its main roles and relationship with port operators has been one of the main elements of port governance [8].

Four models of port governance have been classified by the World Bank (2001) as shown in the Table 3 ([47]): the public service port, the private port, the tool port (a hybrid model where private sector operators carry out some of the operations but under the direction of public sector managers) and the landlord port (the public sector maintains control, while the terminal management and activities are leased to private sector operators) [48].

Table 3. Basic port management models.

Type	**Infrastructure**	**Superstructure**	**Port Labor**	**Other Functions**
Public service port	Public	Public	Public	Majority private
Tool port	Public	Public	Private	Public/private
Landlord port	Public	Private	Private	Public/private
Private	private	Private	Private	Majority public

Ago et al. (2016) suggest that neither of the governance models is more efficient than the other [47]. Except for the public service port model, private firms participate in port operation with varying degrees of involvement. In that case, concession contracts play a key role as a port governance tool [49].

The landlord port model has become the most prevalent and dominant model of port governance, through which a public port authority operates as both a landlord and a regulatory entity, while port operations are conducted by private companies. There are a few forms of the landlord model, based on the extent of decentralization and autonomy of the port authority involved, the cultural disposition of the country considered, or the level of involvement of the landlord in the promotion and enhancement of port activities [31]. Acting as landlords, port authorities are managing bodies in charge of the port area and infrastructure as well as its development [12] including the economic exploitation, the long-term development, etc. [26]. With regard to the strategic importance of land, because of its direct and indirect impact on the regional and sometimes national economy and public health, its inherent value and potential scarcity, port property is hardly sold directly to private parties [26]. According to the analysis of the PCS in a landlord port model by Di Vaio and Varriale (2017), the PCS becomes the primary communication mechanism between the port users [35], which is particularly important for the second part of this research.

The World Bank has established a World Bank Port Reform Tool Kit for developing countries in the quest for a perfect model, which focuses on the role (landlord, tool, service or private) and activities of port authorities as a core topic of port governance, but does not provide any evidence as to what governance models lead to better performance results or how ports themselves can respond to a government-imposed governance reform [24].

Port authorities should play a key role in improving the digital transformation of the transport and supply chain, operating as connectors amongst all involved stakeholders in port, seaside and port hinterland [50]. A new management model, the “community manager” model, has been developed in view of recent socio-economic changes and global strategic challenges, which means that port authorities invest into port hinterland ICT network, manage information system on behalf of entire port community etc. [51]. Port authorities are limited to supporting facilities that are beneficial to a broader port community under such an organizational model, like the waste management or the supply of electricity to ships docked at the port [51]. Public stakeholders and, in most cases, port management often provide technological and nautical facilities. Even so, privatization has led to the loss of access by port authorities to essential information that affects their ability to achieve some business needs [51].

5. Port Authority and PCS Implementation

Port authorities can develop into real digital hubs and neutral data managers at the service of the transport and logistic chain. By gathering and exchanging real-time information among different parties in the process, logistics processes can be optimized, and transport infrastructure can be used in a more efficient way [12]. Port Authority holds an important role as initiator and creator of the port development strategy and coordination of the entire Port Community [42]. As the port authority is responsible for safe, sustainable and competitive development of the seaport, it may represent the most important factor of PCS implementation [52]. The implementation of the PCS can provide benefits for the port authority because port authorities will be able to more easily coordinate port activities, monitor the activities of port operators and control port operations [53]. In this way, port authorities will be able to make better-informed decisions that will encourage sustainable seaport operations.

Value-added services of PCS are considered as co-innovations, namely a new form of innovation where several stakeholders participate together to create new knowledge, insight and opportunities for cooperation [54], which further improves sustainable business. The role of such initiatives becomes vital particularly for competing ports located in close geographical markets [54]. In this respect, the following case indicates the importance of cooperation between stakeholders. The Italian "Tuscan Port Community System" (TPCS) is the Port Community System of the Port Authority of Northern Tyrrhenian Sea (Ports of Livorno, Piombino, Capraia, Portoferraio, Rio Marina and Cavo). The TPCS is a web-services based platform with multilevel access control and data recovery facilities [55], with the aim to digitalize and simplify the complex logistics flows. The TPCS Technical Commission, established in 2016, is coordinated by the Port Authority of Northern Tyrrhenian Sea, and is composed by representatives of Terminal and Category Association. The TPCS Technical Commission has intervened on the system to improve the service quality and design new functions compliant with both the recent legislative provisions and the users' needs [56]. TPCS processes a huge amount of information allowing a reduction in costs and streamlining bureaucratic procedures [55], affecting the economic aspect of seaport sustainability.

The Jamaican PCS is developed by the Port Authority of Jamaica in partnership with the Customs Agency, along with support of the Shipping Association of Jamaica [57]. The Jamaican PCS integrates private-sector companies with public-sector entities, allowing for improved efficiency and effectiveness in trade and logistics-related activities, affecting the sustainability of business processes and overall sustainability (e.g., reducing the need for people to congregate at the ports, thereby limiting the need for physical interaction, which is critical in the fight against the novel coronavirus) [57].

The following case indicates the importance of cooperation of different port authorities in the implementation of a PCS in order to achieve sustainable business. The Polish PCS, "Polski Port Community System" is owned by Port of Gdańsk Authority S.A., Szczecin and Świnoujście Seaports Authority S.A. and PGZ System Sp. z o.o. in Radom, and the Port of Gdynia Authority S.A., Poland is expected to join. Each Port Authority will be the holder of equal percentage of the shares in the Polski PCS [58]. The basic aim of the Polski PCS system is to optimize the management of transport processes by collecting, combining and processing traffic data and other logistics-related data in one place, and to ultimately enable sustainable business throughout the supply chain [59].

Chandra and van Hillegersberg (2017) [60] have conducted the case study of Port of Rotterdam, Netherlands, in which the importance of port authorities in PCS implementation has been researched (Figure 2).

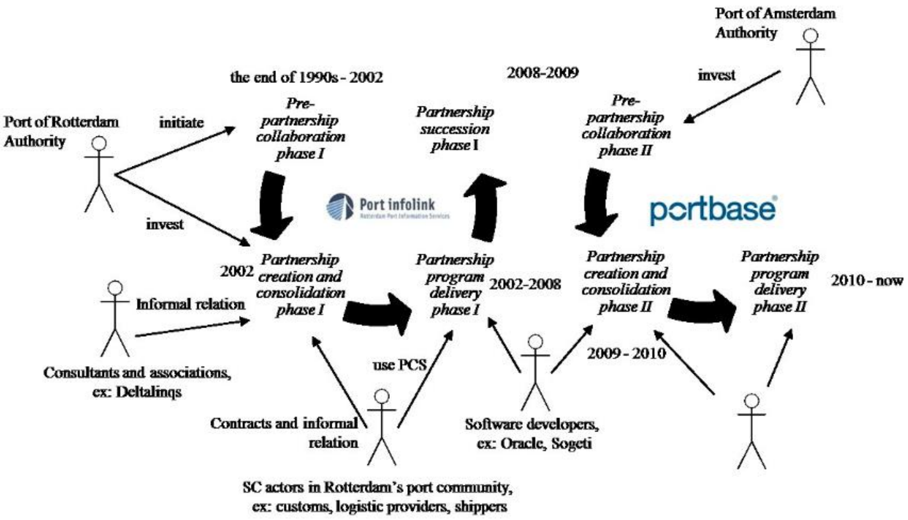

Figure 2. The governance lifecycle of Rotterdam's port community and the involved actors.

According to the study, due to dissatisfaction with the Port of Rotterdam information system, Port Infolink B.V. was established in 2002 as a separated governance entity. The pre-partnership cooperation phase was initiated by the Port of Rotterdam Authority and began by identifying the most critical problem that hinders the efficient flow of goods through the seaport, which were the import processes. The Port Authority was the sole owner of Port Infolink, which means that it bore the initial investment in the development of the information system, as seen in Figure 2. This project involved other stakeholders in the partnership program delivery phase (e.g., Customs, as one of the lead user). In early 2009, the next governance life cycle was marked by the merger of Port Infolink in Rotterdam and PortNET in Amsterdam, which provided the Ports of Rotterdam and Amsterdam with a joint PCS [60]. In this case, it is visible that Port of Rotterdam Authority has played an important role from the beginning, first as an initiator, and then as the initial investor.

The Port Authority of Valencia, Spain, is equipped with a series of tools intended to increase the competitiveness of port community companies and to improve sustainable business, and one of them is the technological platform ValenciaportPCS [61]. Through ValenciaportPCS, the Port Authority of Valencia provides e-commerce solutions that facilitate the passage of goods through the ports of Valencia, Sagunto, and Gandía, adding clearly perceptible value for customers and port users [61].

The Port of Los Angeles, USA and the Port Authority of Nagoya, Japan inked a Memorandum of Understanding to boost cooperation and exchange information on projects focused on operational efficiency and environmental sustainability. Through the Memorandum of Understanding, the port of Los Angeles will develop its port community system as the port optimizer and the digital data platform. In this way, cooperation and exchange of information on port community systems will be improved [62].

Furthermore, as supply chains become more integrated, hinterland operations become more pronounced. Port authorities can start up strategy relations with other transport nodes in the hinterland, which are usually aimed at: traffic management, land management, hinterland connections, etc. [63]. Baccelli and Morino (2020) [64] have analyzed the role of port authorities in the promotion of logistics integration between ports and the railway system. The Italian Port Authority of the Western Ligurian Sea (which includes the seaports: Genoa, Prà, Savona and Vado Ligure) and Rete Ferroviaria Italiana railway operator have defined the last elements of the agreement of interoperability between the Railway Circulation Integrated Platform and the Port Community System [64]. The interoperability of these two systems through a structured and organized electronic dialogue will allow a better and more efficient management of documents [64], affecting the sustainable business. It will be possible to have information and documents which are judged important by shipping companies and port terminal operators well in advance, e.g., the position of the train on the railway network [64].

6. Discussion and Conclusions

Seaports are providing a major contribution in the growth of global trade as well as major impact in national economies. Seaports involve a broad range of stakeholders, where a strong collaboration and communication is inevitable. Seaports also play an important role in sustainable development, where the implementation of port activities, operations and management practices should be environmentally friendly.

The body that is responsible for the implementation of laws, port development and port improvement is usually the port authority. In other words, port authorities are usually responsible for growth and competitiveness of a port cluster by governing the port area, managing port activities, handling hinterland connections and collecting real estate revenue.

Port authorities also have extensive administrative powers to implement policies, laws and regulations. In recent times, the focus is put on the sustainable port development, raising awareness of resolving port sustainability issues (such as air quality, land use planning, modalities and connectivity) that affect port authorities to make some fundamental changes in the process of transforming the ports that they govern into sustainable ports. Various port governance models regarding the type of port authority exist and there is no evidence as to which governance model results in better performance outcomes, as it is specific to each seaport.

Port governance models depend on external environmental impacts as well on the nature of port authority, such as levels of autonomy and centralization, its key functions and collaboration with the port operators. Depending on the influence of beforementioned factors, the World Bank classified four port governance models: the public service port, the private port, the tool port and the landlord port. Each model is unique, and there is no given evidence on which model performs better in terms of productivity and financial outcomes. Recent digital transformation accompanying socio-economic changes and global strategic challenges have triggered a new management model known as community manager model. With such a function, the role of the port authority is manifested in ensuring mutual coordination and the efficiency of different port service providers, investing into port hinterland network, managing information system on behalf of entire port community, etc.

To remain competitive, numerous seaports have begun to implement Port Community Systems, where all port information is centralized and data exchange between port stakeholder is safer and faster. Desired outcomes from the implementation of PCS, apart from increasing the quality of data are minimizing paperwork, supporting data connections between different stakeholders, enhancing and facilitating activities across the entire transport and logistics chain to stakeholders, etc. Port authorities act as initiators and creators of the sustainable port development strategy on behalf of the whole port community. By developing and implementing a PCS, port authorities are becoming real digital hubs, where available data is gathered and exchanged between various stakeholders.

Table 4 shows the case studies elaborated in this paper, with the respective port authorities, countries, port governance models, and characteristics of the PCS implementation.

Table 4. Port authorities, port governance models and PCS implementation.

Port Authority	Country	Port Governance Model	PCS Implementation
The Port Authority of Northern Tyrrhenian Sea (Ports of Livorno, Piombino, Capraia, Portoferraio, Rio Marina and Cavo).	Italy	Landlord [65]	"Tuscan Port Community System" aims to digitalize and simplify the complex logistics flows
Port Authority of Jamaica	Jamaica	Landlord [66]	PCS aims to integrate private-sector companies with public-sector entities, to improve efficiency and effectiveness in trade and logistics-related activities
Port of Gdańsk Authority S.A.; Szczecin and Świnoujście Seaports Authority S.A.; Port of Gdynia Authority S.A.	Poland	Landlord [67]; Landlord [68], Public-service [69]	Polski Port Community System aims to optimize the management of transport processes; to enable sustainable business throughout the supply chain
Port of Rotterdam	Netherlands	Landlord [70]	Portbase aims to make supply chains that run through the Netherlands stronger and smarter
Port Authority of Valencia	Spain	Landlord [71], [72]	ValenciaportPCS aims to facilitate the passage of goods through the ports, adding a clearly perceptible value for customers and port users
Port Authority of Nagoya	Japan	Public-service [73]	Cooperation and exchange of information between different port community systems
The Port Authority of the Western Ligurian Sea (Port of Genoa, Prà, Savona and Vado Ligure)	Italy	Landlord [65]	Interoperability between the Railway Circulation Integrated Platform and the Port Community System

In this paper, the concrete relation between the different types of governance model and the different types of PCS implementation is not visible. For example, the Port of Nagoya may be considered as a public service port, while port of Rotterdam represents a landlord port. In all cases, port authorities have played an important role in PCS implementation-as initiators, with the aim to facilitate data exchange, either by focusing on the port itself or on the supply chain. However, the success depends on collaboration between all involved stakeholders.

The Italian “Tuscan PCS”, Jamaican PCS and the Polish “Polski PCS” are some of the most prominent examples of the PCS implementation in means of improved collaboration among stakeholders and safer and faster data exchange, affecting the economic, social and environmental aspects of sustainability. By identifying the issues that hinder the efficient flow of goods through the seaport, Port of Rotterdam implemented a PCS by merging the Port Infolink in Rotterdam and PortNET in Amsterdam. Although the implementation of a PCS indeed facilitates the collaboration between all involved stakeholders, it increasingly affects the port authorities themselves. It enables them to organize port activities more efficiently, track port operators’ activities and manage port operations more easily.

Since supply chains are becoming more integrated, the port authorities are focused not only on the port community, but also on relations with other transport nodes in the hinterland, through the interoperability of the PCS with other systems such as the Circulation Integrated Platform for the railway system. It will result in facilitating electronic communication and paperwork, also positively affecting business sustainability.

Port authorities play an important role in PCS implementation. However, it is necessary to note that other stakeholders have individual preferences, therefore, various PCS business models may be developed. In the future research, different models of introducing an integrated Port Community System in seaports should be analyzed because it will determine the specific financial model and goals that PCS as a project aspires to. In their future research, the authors will focus towards investigating the role of port authorities in financing and maintaining the PCS.

This paper (when compared to previously published papers dealing with this topic) provides a clearer insight into two research objects: the role of the port authority in governing and managing the seaport, and the role of the port authority in PCS implementation. This research is based on the literature review (which also presents the main limitation of the research), and as such offers an initial overview of the role of port authority in port governance, and the role of port authority in PCS implementation.

Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest.

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G. Digital Information Services Needed for a Sustainable Inland Waterway Transportation Business

Abstract: Inland waterway transportation (IWT) is highly efficient in terms of greenhouse gas emissions but lacks economic competitiveness when compared to other modes of transport. Digital information services that foster efficiency and sustainability of IWT are considered important elements for improving its attractiveness and thereby reducing greenhouse gas emissions of the transportation sector as a whole. Therefore, this paper addresses the question of what kind of digital information services are actually needed and should be provided, e.g., by port and waterway authorities, to stimulate a modal shift in favour of IWT. Though the concept of river information services (RIS) already provides a harmonised approach to information services in the sector, the current political and scientific discourse still lacks insight into what degree the currently available information services actually meet industry needs. Equally, possibilities to provide practical recommendations are limited. Therefore, this contribution fills this knowledge gap by providing data from the field gathered through a combination of qualitative and quantitative research methods. After elaborating on the underlying problem as well as the current state of research and practice, we will lay out observed information-relevant challenges to business actors and their respective needs. Based on this, practical recommendations for improvements of digital services and further avenues for research are derived.

Keywords: digital information services; inland waterway transport; digitalization; IWT operators; sustainable transportation

1. Introduction

Inland waterway transportation plays an important role in transforming the transportation sector by providing large transport capacities, reduced costs, energy-efficiency, and, consequently, lower greenhouse gas (GHG) emissions compared to other transport modes [1,2]. Indeed, with IWT in its present state consuming just a fifth of energy per tonne-kilometre as compared to road transport and only half of the rail transport, resultingly being the most energy-efficient mode of transport, the exploitation of IWT's full potential that comes with a modal shift in its favour can be regarded as a pre-requisite to meet the European Commission's targets in terms of reducing GHG emissions [3,4]. Inland ports located along rivers and canals constitute potent distribution hubs regulating various freight flows [5] to cities, particularly those linked to global transport via seaport gateways [6]. IWT thus has the potential of providing environmentally friendly sustainable solutions whilst fuelling economic development.

High reliability of services in combination with low costs are crucial factors for modal shift [7]. Yet, to provide efficient and competitive transport services, stakeholders involved in IWT need to carry out a set of complex navigational and planning decisions [8]. For this, the provision of relevant digital information services is of high importance as it ultimately affects decision quality [9] and the efficiency and sustainability of transport operations. Sustainability in this context refers to the ability to mitigate the negative impacts of business activity by providing socially inclusive working conditions, economic performance, and environmentally friendly transport services [10].

While the concept of river information services (RISs) already provides a common framework for digital information services operated by port and waterway authorities, practitioners and industry experts claim that current implementations and functionalities do not sufficiently allow the full exploitation of the potential of digitalisation [11]. Thus, “to ensure the competitiveness of the inland waterway system in the medium and long term, a significantly more intensive orientation of inland navigation towards digital trends will be indispensable in the future.” [12].

The potential impact of digitalisation and information and communications technology (ICT) on the inland waterway transport business has been acknowledged in the research community [8,13,14,15,16,17,18,19]. However, a lack of scientific contributions that focus on the needs of IWT operators regarding digital services still clearly prevails. To overcome this research gap and to provide a better understanding of digital information services needed by IWT stakeholders for sustainable inland waterway transportation operations, the authors propose a user-centric research approach that combines qualitative and quantitative methods. This work, carried out within the scope of the EU Horizon 2020 project IW-NET [20], aimed to identify digital information services that are required for improved planning decisions by operational IWT stakeholders, such as crew members and transport planners. This goal, to further align and structure the research process, imposes a set of further inquiries on:

- The challenges that IWT operators face when making planning decisions before and during transport operations;
- The importance of specific information to carry out the respective planning tasks;
- Digital service functionalities to address the existing planning challenges;
- Ways for stakeholders to access those digital services.

The remainder of this article is organised as follows: First, the practical and scientific background of the relevant field of study is given in Section 2 by outlining current legislation of information services in European IWT and by providing a literature review on digital services in the IWT domain. Section 3 elaborates on the methodological approach that was used to answer our research questions while the results of the study are described in Section 4. Finally, a discussion along with the respective conclusions follows in Section 5.

2. European Legislative and Scientific Background

2.1. The RIS Directive as a Framework for Information Services in European IWT

At the European level, the need for information in the inland navigation domain has been addressed by the Directive 2005/44/EC on harmonised RISs on inland waterways in the community (commonly referred to as the “RIS Directive”). As a result of the harmonised action, the EU has required its member states to implement a set of information technologies that support traffic and transport management, including interfaces with other modes of transport. As such, RISs are intended to improve safety, efficiency, and environmental friendliness [21] and sustainability of inland navigation. The EU has taken a holistic approach that encompasses policy development, support for research and development, a legal framework (see Figure 1), and monitoring of the implementation of the legislation.

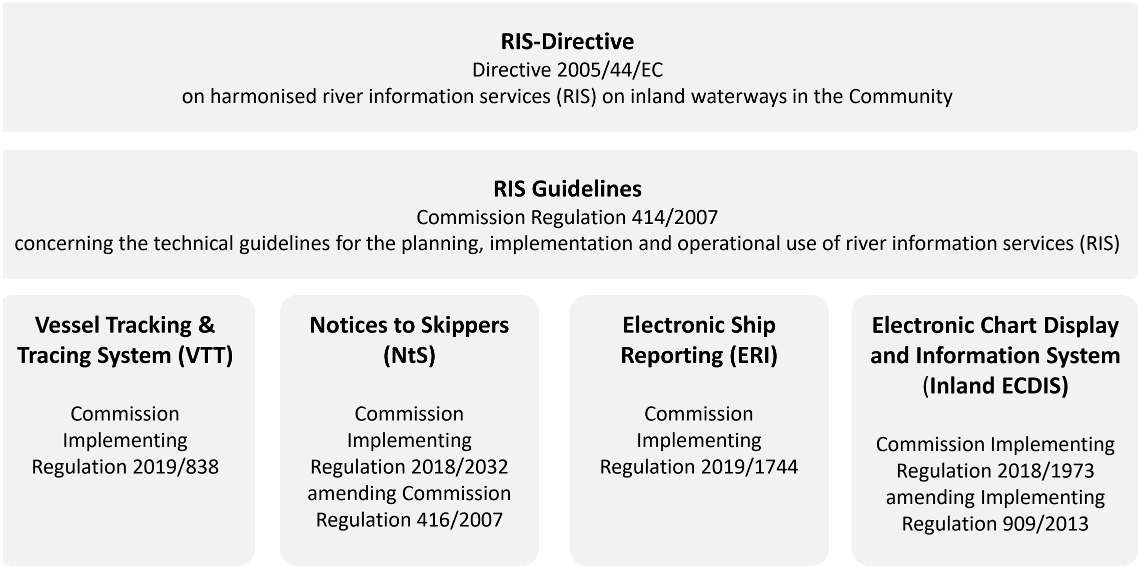

Figure 1. RIS legal framework based on [17]

The RIS Directive defines four key technologies that are subject to common and continuous specification. This includes:

- Vessel tracking and tracing (VTT);
- Notices to skippers (NtS);
- Electronic reporting international (ERI);
- Inland electronic chart display and information system (inland ECDIS).

The technical specifications to these key technologies have been developed by the European RIS expert groups and adopted by the European Commission into a set of directives and regulations [23]. These efforts are now continued under the umbrella of the information technologies working group of CESNI (Comité européen pour l'élaboration de standards dans le domaine de la navigation intérieure), which is the European Committee for proposing standards in the field of inland shipping. The activities of this working group regarding RISs comprise the drafting of proposals for the development and revision of technical standards in the field of RISs, including proposals for the European regulations, the promotion of the proper implementation of standards in the field of RIS, as well as the support of policy initiatives on digitalisation in inland navigation [24]. Ultimately, the implementation of RIS is handled by the designated "competent authorities" within the EU member states [21].

As the DINA (Digital Inland Waterway Area) study commissioned by the European Union has revealed, significant shortcomings of the current RIS standards and related digital services include limited functionalities for continuous and controlled data sharing (especially in a machine-to-machine manner) and a lack of up-to-date information on traffic conditions (bridges, locks, berth allocation) as well as limited system integration between barge operators and logistics stakeholders. The study concludes that the current situation represents a significant impediment towards achieving better competitiveness of IWT [11]. Hence, to allow for more effective digitalisation efforts, it is necessary to define and analyse the needs and requirements of the industry.

2.2. Literature Review on Digital Services in the IWT Domain

In the past, several academic authors analysed the impact of digitalisation in inland waterway transportation. However, the overall body of publications available on the matter is rather limited.

A rather conceptual note is given by Wang and Sun [14]. They outline an intelligent waterway management system based on the use of cutting-edge ICT technologies incorporating advanced sensors and internet of things (IoT), cloud computing capabilities, big data, and artificial intelligence, as well as wireless communication. According to them, an "intelligent waterway" could enable sharing and exchange of waterway-related business data and change the current "'information isolated island situation' through unified data resource planning and standardized data center". Furthermore, the authors claim that waterway planning lacks effective data analysis, while maintenance is lacking fast-tracked feedback. In the context of an "intelligent information service platform", Di et al. [15] carried out an evaluation of inland waterway information service demands in China. They highlight that the design of inland information services requires a stronger user perspective due to changing needs as well as missing capabilities of technical providers to anticipate the user's requirements.

Other contributions specifically focus on the role of the European river information services for inland waterway transportation. For example, Schilk and Seemann [16] emphasise the role of

RISs in the context of transport logistics services. According to them, river information services have extended and will further expand their scope from a primarily navigational function to the whole transportation process lifecycle and will become the backbone of an intelligent transport system (ITS) for inland waterways. As such, they claim, logistics-driven RISs will foster the integration of IWT in multimodal transport chains. In the same context, Niedzielski et al. [8] see great potential of RISs to improve the efficiency and achieve sustainability of inland waterway transport companies. They argued that the immediate impacts of the technology are "intangible and incalculable" but will ultimately contribute to a better financial performance of the sector, affecting the economic aspect of sustainability. This observation is in line with the findings of Verberght et al. [17] who analysed the impact of the RIS Directive on IWT performance in the Antwerp-Rotterdam-Amsterdam-Rhine region, with a special focus on the dry and liquid bulk market. Even though they concluded that the introduction of the RIS Directive had no significant effect on IWT performance in their statistical experiments, they pointed out methodological difficulties in quantifying the effects of RISs. However, they pointed out that even if RISs had no measurable economic effect and do not meet the economic objective, they still serve as core infrastructure for smart shipping solutions.

Other authors specifically focus on new business uses cases that are enabled by RISs. For example, Koralova-Nozharova [18] assessed the impact of digitalisation on cargo flows for forestry products on the Danube waterway and further identified impediments that prevent digitalisation of transportation services. The contribution pointed out a lack of harmonisation with regard to information and communication applications, as well as national legislation of countries that limit sharing of traffic information with third parties, which may prevent sustainable business development. Durajczyk and Drop [19] considered the role of well-established RISs for enabling and supporting the development of IWT business models for urban and interurban freight transport. Among others, they claimed that river information services improve the conditions for IWT operations in urban areas by providing capabilities for optimised route planning, improved coordination and consolidation of cargo flows, and better supervision and control, as well as reduced administrative barriers, ultimately affecting economic (decreased costs, waiting time etc.) and social (efficient use of human resources, etc.) aspects of sustainability.

Analysing the above-mentioned literature, it can be concluded that even though the importance of digitalisation for increased competitiveness and efficiency of inland waterway transport operations is broadly acknowledged, the literature seemingly gives little attention to the functional requirements of the IWT business. However, in order to take full advantage of digitalisation and digital transformation, it seems necessary to apply a user-centric approach [15] and to analyse what digital information services are perceived as important to IWT business stakeholders in detail, in order to achieve sustainable business.

3. Methodology

To understand what digital services are required for improved planning decisions (as perceived by operational IWT decision makers, such as crew members and transport planners) that can, in turn, improve efficiency and lead to a more sustainable IWT business, our research design and course of action in the field was based both on an inductive and qualitative approach as well as a deductive and quantitative approach, thus making up a mixed-method approach [25].

As shown in Figure 2, the course of action started with initial desk research using the existing scientific literature as well as an investigation of other secondary data, such as the RIS regulations and guidelines (see Section 2.1), websites of the competent waterway authorities, or related projects, such as "RIS COMEX" [26].

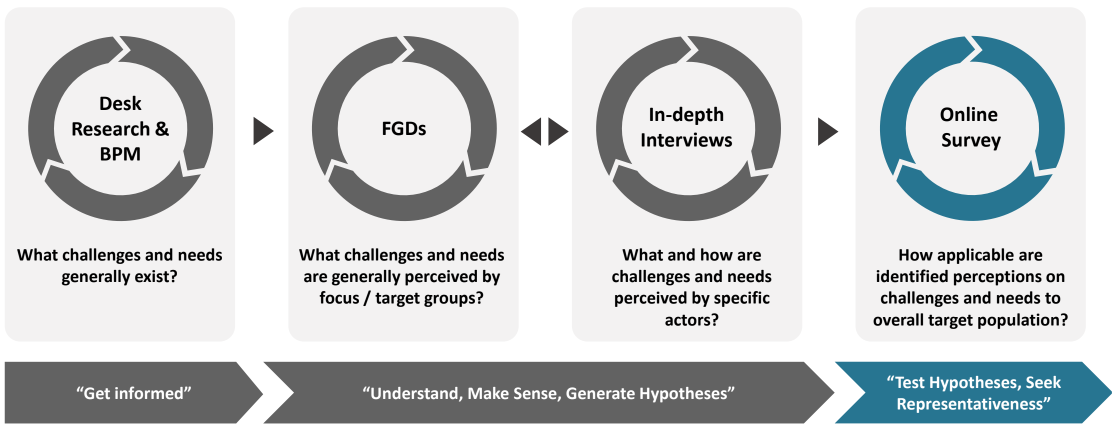

Figure 2. Overall research design and course of action (own figure, 2021).

It was accompanied by modelling and analysis of IWT business processes using the Business Process Model and Notation 2.0 (BPMN) [27] to acquire general information on structural outlines, to get a general understanding of challenges and needs, and to further familiarise with the topic. Next, qualitative research followed through the use of focus group discussion (FDGs) with relevant stakeholder and target groups to deepen understanding, make sense of challenges and needs, and generate initial hypotheses. In-depth, individual interviews were carried out afterwards to lay out hypotheses in more detail, according to specific actors. To then test the generated hypotheses and indicatively understand how far these were applicable to the overall target population, an online survey finalised data collection in the field.

3.1. Qualitative Data Collection: Focus Group Discussions and In-Depth Interviews

Based on previous desk research, expert FGDs (focus group discussions) were used to collect first-hand general information on the perceptions of target groups and identify issues of concern to generate intermediate hypotheses as well as to establish further contact with the participants and to build rapport for the following individual in-depth expert interviews. Furthermore, in-depth interviews provided more detailed information on the individual stakeholders' perceptions and interdependency of problems, thus giving more room for interpretation. The qualitative interviews conducted covered a total of 25 participants and took place from January 2021 to May 2021.

Geographically, for both FGDs and in-depth interviews, the sample of participants was drawn from IWT actors that operate on and along the River Weser, which represents the main waterway hinterland link of the ports Bremerhaven and Bremen in Northern Germany. The set of participants covered actors engaged in infrastructure management, port authorities and public bodies, crew members (skippers, helmsmen, and boatsmen), and administrative staff of IWT operators, hinterland logistics experts, and software developers active in the sector. An interviewee or actor bias had been set consciously. As shown in Table 1, the focus was on infrastructure managers, port authorities, and public officials to maximise compliance with organisational needs, public policies, and regulations, which would, if not thoroughly considered, inhibit implementation of innovations to be developed.

Table 1. Target groups approached for qualitative research.

Target Sub-Group	**Interviewees (n)**
Infrastructure managers	9
Port authority / public officials	7
IWT operators	3
Others (software developers, IT experts)	6

Sum	**25**

IWT operators were used to assure a transport operational view of developments. The underrepresentation of this actor group was indirectly accounted for by further surveying it in the course of the quantitative online survey. Others, such as software developers and IT experts, were consulted for further inspiration and to inquire about the various IT systems used in the domain since they were aware of the latest developments in the realm of digital services.

3.2. Quantitative Data Collection: Online Survey

What followed and finalised the gathering of primary data was a quantitative online survey, as a deductive method, to obtain information from a larger sample of the population [28], mostly IWT operators (onboard and land personnel). Furthermore, hypotheses and identified perceptions in terms of representativeness were checked to see if initial, qualitative findings could be supported quantitatively and explore their applicability at a European scale.

The first part of survey results allows an outlining of basic characteristics of the panel, including general information on respondents, such as mother tongue, professional background, routes frequently travelled, and types of cargo they would transport.

Aside from these general classification questions, the second part of the survey was designed to yield quantitative insights. As such, the hypotheses related to perceptions of the importance of stakeholders' needs in terms of digital service functionalities, the appearance of common challenges faced during transport, the importance of information to carry out respective planning tasks, and preferences with regards to access to digital services were translated into closed questions using 4-point Likert-type rating scales. Assuming an equidistant scale, the answers have been coded numerically such that the arithmetic mean ("mean rating") of the perceived responses could be calculated. As the condition of equidistance is not without doubt [29], the presentation of the mean serves illustrative purposes only and is not to be used for parametric statistical analyses.

The survey was carried out from May 2021 to June 2021 using the survey platform "SoSci Survey". Given that the largest IWT volumes in the European Union go to or come from the Netherlands, Germany, Belgium, and France [30], the survey has been conducted in all respective languages of these countries. Participants were gathered through advertisement in selected mailing lists, press releases and the use of social media of partnering IWT associations, corporations and political actors. While this non-probabilistic "convenience sampling" comes with advantages in terms of a good balance of acquisition costs and response rate, it also entails methodological disadvantages. As such, the chosen selection criteria may foster selection bias [31]. It can be assumed, for example, that exclusive use of an online survey will tend to be answered by people who have an affinity for digital information services. Similarly, the selection of available languages will exclude some potential respondents of the respective population.

4. Results of the Online Survey

4.1. General Information on Respondents

The survey attracted a total of 84 respondents, among which the vast majority answered in Dutch (50%), followed by German (26%), English (20%), and French (4%). Most of the respondents indicated a professional background as skippers (whereas 55% are self-employed barge operators and 11% traditionally employed), transport planners (14%), managing directors (15%), or crew members on inland vessels (2%). Around 12% of the respondents did not fit into the predefined role descriptions. In this context, it should be noted that the respondents could select one or more answers. Accounting for this, around 62% of the respondents can be considered to be crew members, 32% landside staff, and 6% stated to be involved in onboard as well as landside activities.

Corridors frequently used by respondents were the Rhine route (57%), followed by the north-south route (France–Belgium–Netherlands; 44%), the east-west route (North Sea ports–Northern Germany–Eastern Europe; 26%), and the Main-Danube route (24%). Respondents transported various cargo types, mostly bulk material (61%) and/or containers (44%), general cargo (40%), liquid bulk (19%), vehicles (4%), swap bodies (2%), or other cargo (13%).

4.2. Challenges for IWT Operations

To get an understanding of the operational environment of IWT, reasons, and considerations behind digital service needs, the respondents were asked to provide an indication of frequency of commonly faced challenges in the context of their operational activities. The results indicate that most respondents face a lack of available or suitable berths, time-consuming pre-announcement and reporting obligations, lack of information on available services at these berths (e.g., fresh water supply, waste disposal), and a lack of available shore power facilities at these berths. The only situation not observed frequently by more than half of the respondents was a lack of information on local nautical conditions (e.g., depths, currents, dangers), as shown in Table 2.

Table 2. Overall frequency of challenges for IWT operations (own survey, 2021, n=84).

Challenges	“never” (1)		To	“always” (4)	mean rating
Delays due to unavailable or malfunctioning infrastructure (e.g., locks, signals)	8%	35%	44%	13%	2.62
Lack of available or suitable berths	7%	21%	44%	27%	2.92
Lack of available shore power facilities at berths	13%	24%	36%	27%	2.77
Lack of information on local nautical conditions (e.g., depths, currents, dangers)	21%	50%	24%	5%	2.12
Lack of information on available services at allocated berth (e.g., water supply, waste disposal)	8%	25%	43%	24%	2.82
Lack of information on local points of interest (e.g., health services, shops, post boxes)	21%	26%	25%	27%	2.58
Pre-announcement and reporting obligations are too time-consuming	10%	25%	32%	33%	2.89
Pre-announcement and reporting obligations are too complex or complicated	12%	36%	21%	31%	2.71
Pre-announcement and reporting obligations are not clear	12%	31%	30%	27%	2.73
Too many different means of communication with authorities	11%	32%	30%	27%	2.74

Percentages may not total 100% due to rounding.

The comparison between respondents having stated a position onboard and those working in landside positions indicates that the challenges laid out in the survey are generally more relevant for operations onboard vessels. Most significant differences can be found regarding the "lack of available or suitable berths" (mean rating for onboard = 3.13; onshore = 2.50) as well as the "lack of information on available services at allocated berth" (mean rating for onboard = 3.02; onshore = 2.43). Almost equal importance by both groups is given to the challenge of lacking shore power facilities and too many different means of communication with authorities.

Since the respondents had the possibility to state additional challenges they face (which were not mentioned in the survey), one of them mentioned language issues in VHF communications. Furthermore, two of them stated that the increasing number of incompatible electronic announcement procedures results in extra administrative burden.

4.3. Importance of Information to Carry out the Respective Planning Tasks

Assuming that the operational planning challenges induce a need for certain information from decision makers, additional emphasis was given to gain further insight into the importance of the respective information types. Based on the expert interviews, different information types were clustered into "berth-related", "lock-related", "waterway-related" and "destination-related" information types (see Table 3, Table 4, Table 5 and Table 6).

Table 3. Importance of berth-related information to carry out planning tasks (own survey, 2021, n = 84).

Information	"Unimportant" (1)		to	"important" (4)	Mean Rating
Availability of berths	8%	4%	12%	76%	3.56
Availability of shore power facilities	13%	15%	31%	40%	2.99
Availability of fresh water supply	6%	14%	24%	56%	3.30
Availability of waste disposal	8%	5%	29%	58%	3.37
Possibility to unload own vehicle	10%	12%	15%	63%	3.32

Landside access Information	5%	15%	21%	58%	3.33

Percentages may not total 100% due to rounding.

Table 4. Importance of lock related information to carry out planning tasks (own survey, 2021, n=84).

Information	"Unimportant" (1)	to		"important" (4)	Mean Rating
Opening hours	6%	11%	20%	63%	3.40
Expected lockage time	7%	13%	29%	51%	3.24
Average waiting times	11%	11%	29%	50%	3.18
Contact information	10%	19%	21%	50%	3.12

Percentages may not total 100% due to rounding.

Table 5. Importance of waterway related information to carry out planning tasks (own survey, 2021, n=84).

Information	"Unimportant" (1)	to		"important" (4)	Mean Rating
Water levels	4%	8%	18%	70%	3.55
Bridge clearance heights	4%	4%	12%	81%	3.70
Bridge status (open/closed)	6%	15%	18%	61%	3.33
Malfunctions and infrastructure maintenance works	4%	6%	7%	83%	3.70

Percentages may not total 100% due to rounding.

Table 6. Importance of location related information to carry out planning tasks (own survey, 2021, n=84).

Information	"Unimportant" (1)	to		"important" (4)	Mean Rating
Shopping facilities	24%	29%	24%	24%	2.48
Public transport / taxicabs	32%	29%	23%	17%	2.24
Delivery services (e.g., groceries or food)	26%	31%	21%	21%	2.38
Repair services	19%	15%	36%	30%	2.76
Health services	19%	15%	21%	44%	2.90
Post offices	35%	38%	21%	6%	1.99
Public facilities	29%	32%	27%	12%	2.23
Sports facilities	52%	32%	12%	4%	1.67
ATMs	32%	26%	25%	17%	2.26
Bunker services	13%	17%	31%	39%	2.96

Percentages may not total 100% due to rounding.

As can be seen, waterway related information which can also be described as nautical information is of high significance to the full panel, especially for onboard personnel. Unlike in road transportation, IW networks do not allow for spontaneous detours or turns, which make route planning especially critical. Information on bridge clearance heights as well as on malfunctions or ongoing and future maintenance works have received the highest ratings of all information types for the whole panel as well as for the single user groups. However, the individual preferences may differ along the corridors due to different nautical conditions. As an example, the data shows that water level information are perceived as comparably lower significant by respondents that operate in the north-south-route which is predominantly covered by water regulated canals. Also, the need for information on bridge clearance heights has been stated as especially important by respondents operating in the east-west-route which is known for low vertical clearance while oftentimes possessing high water levels (e.g., River Weser).

Also associated with voyage planning decisions are information about berths, which represent opportunities for the crew to rest and revictual. Of most importance in this regard are information on the availability of berths. Remarkable is the different view on information on the “possibility to unload own vehicle” (mean rating for onboard = 3.59; onshore = 2.79) as well as “landside access information” (mean rating for onboard = 3.5; onshore = 3.00) which have received fairly high importance ratings by onboard staff, while perceived as the least important berth-related information type by the other group. Whether shore power facilities are available at berth is rated comparatively low which can be assumed to be the case due to the fact that the adoption of shore power in inland navigation is still low in most European corridors and ports. With respect to locks, which may represent bottlenecks along the journey, participants would most likely need to receive information on opening hours. In this category, East-West-Corridor spanning from the North Sea Ports to East-Europe shows a significantly high demand for information on “average waiting times” for locks, while the Main-Danube subgroup states a need for information on “opening hours” of locks. A weak link between operational planning and the group of location related information can be deducted by comparatively low importance ratings for the respective items. Information on bunker and health services are of highest significance.

Over all information categories, onboard personal has stated higher importance on the selected items.

4.4. Needs in Terms of Digital Service Functionalities

Since digital services represent a means to cope with existing operational challenges and provide relevant and necessary information for planning decisions in IWT, respondents were asked to indicate how important they perceive certain functionalities that were suggested in the qualitive research phase to be made available to IWT operators.

As shown in Table 8, the results show that the survey panel generally supported the predefined functionalities to be important. On average, all proposed functionalities receive higher importance ratings by landside personnel (mean rating onboard = 2.83; landside = 3.24). High importance, especially by crew members, is given to the provision of real time information on bridge clearance heights (mean rating onboard = 3.45; landside = 3.41), while as the possibility to announce port visits electronically receives the highest importance ratings by landside staff (mean rating onboard = 3; landside = 3.57). Concerning lockages, the respondents, especially the landside group, see the importance to allow for lockage synchronization in the case where a number of locks in a row need to be passed over the possibility to book slots for single locks (mean rating onboard = 2.98; landside = 3.44). The largest gap between onboard and landside respondents can be found with respect to chat functionalities to allow for communication with port offices (mean rating onboard = 2.38; landside = 2.96) as well as "ETA predictions" (mean rating onboard = 2.71; landside = 3.22). A functionality to access news feeds can be found to be rather not important for both groups (mean rating onboard = 2.38; landside = 2.74).

Table 7. Overall perceived importance of potential functionalities of digital services (own survey, 2021, n=84).

Functionalities	"Unimportant" (1)	to		"important" (4)	Mean Rating
Electronic port announcement	11%	11%	27%	51%	3.19
Online port customer services (e.g., billing)	7%	23%	32%	38%	3.01
Booking of specific berths	10%	24%	23%	44%	3.01
Lockage slot booking	17%	24%	20%	39%	2.82
Lockage synchronization ("green wave")	11%	17%	20%	51%	3.13
ETA predictions	13%	21%	29%	36%	2.88
Push notifications for notices to skippers (NtS)	11%	14%	30%	44%	3.08
Chat functionalities with port office	17%	36%	23%	24%	2.54
Real time bridge clearance view	4%	12%	21%	62%	3.43
News feed	23%	27%	26%	23%	2.49

Percentages may not total 100% due to rounding.

4.5. Preference for Access to Digital Services

Studies on technology acceptance indicate that the end-user's "intention to use" digital services on adequate channels/devices to the user may represent an important success factor. Therefore, the respondents were asked about their preference to access digital services.

As shown in Table 9, most respondents would primarily like to access information using a web browser on their laptop or desktop computer. A significant acceptance can be assumed when providing services by integration into existing navigation systems on board or via mobile apps on smartphones or tablets. However, in the qualitative stage as well as in the comment section of the survey, respondents commented that they see inflation of different native apps to be installed as a serious problem. This can be approached by offering mobile applications within a mobile browser without having the need for installation. The comparison of user groups within the panel shows that personnel onboard vessels rank access via mobile devices more favorable than landside staff (mean rating onboard = 3.3; landside staff = 2.96).

Comparatively few respondents seek for integration into existing systems such as Transport Management Systems. This might be due to the fact that the share of landside personnel made up less than half of the panel.

Table 8. Preference for access to digital services (own survey, 2021, n=84)

Access to digital services	“Strongly oppose”	(1)	to	“Strongly favor” (4)	Mean Rating
Mobile app (smartphone/tablet)	10%	13%	26%	51%	3.19
Web browser (laptop/desktop computer)	6%	7%	35%	52%	3.33
Integration into existing software (e.g., Transport Management System)	20%	23%	26%	31%	2.68
Integration into navigation systems on board	7%	18%	24%	51%	3.19

Percentages may not total 100% due to rounding.

Comparatively few respondents seek integration into existing systems, such as transport management systems. This might be due to the fact that the share of landside personnel made up less than half of the panel.

5. Discussion and Conclusions

The purpose of our research was to gain insight into what digital services are required for improved planning decisions by IWT operators, to allow for a more sustainable IWT business. After reviewing the existing literature, it can be concluded that the importance of digitalisation in IWT is recognised, especially with respect to the competitiveness and efficiency of inland waterway transport. However, a deeper understanding of the challenges and functional requirements of the IWT business, which is vital to take full advantage of digitalisation and digital transformation and enable sustainable business, is missing. The results of the study fill this research gap and extend the body of knowledge in the field of digital services in European IWT.

While the RIS Directive represents an elaborate framework for legislation of harmonised IWT information services in Europe, studies show some conceptual shortcomings. The results of our investigation support this notion by highlighting digital service functionalities that go beyond the scope of the current RIS framework.

Our findings elucidate that the IWT community faces a number of various planning and decision challenges that can be improved by better supply with information. As such, it has been confirmed that a lack of available or suitable berths as well as time-consuming preannouncement and reporting obligations are apparently common. Additionally, IWT operators do not have sufficient insight into the extent of information on available services at these berths (e.g., fresh water supply, waste disposal) as well as a lack of available shore power facilities. In our panel, those challenges seem more apparent to persons working onboard rather than those on land.

With regard to the importance of specific information for planning purposes, our results show a high relevance of information by onboard as well as landside respondents that can be used for decisions related to voyage planning. This includes waterway-related information, such as bridge clearance heights or water levels and lock-related information as well as berth-related information. In comparison, the proposed location-related information types are of little demand and received lower importance ratings, which may reflect a weak interdependency with operational planning.

Most of the proposed functionalities that address these planning issues receive strong support by the respondents, while the provision of real-time bridge clearance information as well as electronic port announcements have been stated as most important. Surprisingly, even though the demand for information was found to be generally higher by onboard personnel, the proposed functionalities have been more appreciated by landside personnel. This may refer to the notion that some onboard respondents want to keep their focus on navigation and vessel operation rather than engaging with administrative activities. Therefore, we conclude that user centricity, which includes ease of use and orientation on functional needs, is key when offering new digital information services.

This also incorporates the use of suitable access channels to those services. Our results show no clear preference on single access types. Mobile devices such as smartphones and tablets as well as laptops and desktop computers are generally perceived to be equally appropriate, while crew members' demonstrate a higher attraction to mobile use. However, to avoid an inflation of installable apps and being able to equally support onboard and landside personnel, responsive web applications may become the most adopted choice. In addition, the integration into navigational systems was evaluated as favourable.

Limitations of the study arise from the low number of survey participants. To put this in perspective, in Germany alone, 6805 people worked as skippers for inland waterway transports in 2017 [32]. Assuming a somewhat similar number for the year 2021, confidence levels and ranges reached in analysis do not at all meet scientific criteria commonly applied for representativeness [33]. Further shortcomings arise from the characteristics of the participant panel. With the survey having taken place online only, a certain degree of familiarisation with the use of digital services must be attested. Additionally, the research is focused only on the European level, which does not allow a direct inference to other important IWT areas in the world. Additionally, a language barrier may have partly existed, as the survey was not translated into all languages spoken in the European Union. It can therefore be concluded that the results give a profound initial insight into the requirements and demands for digital services for sustainable inland waterway transport but must be treated with caution for the limitations imposed by the applied methods. Nevertheless, we believe that the survey, together with the previous qualitative research phase, still gives a good indication and summary of perceptions in terms of information needs with regards to digital services for a sustainable IWT business. From a managerial standpoint, the results of this research can contribute to future adaptions of the RIS standards and guidelines by the CESNI working groups but may also serve as a benchmark for competent waterway authorities that seek to provide additional digital services to the IWT community. A possible way to prioritise the results and derive future avenues is given in Figure 3. As such, it could be claimed that future digital services for inland waterway transport should put a stronger focus on the "integration of port processes" as well as on "real-time data sharing and coordination".

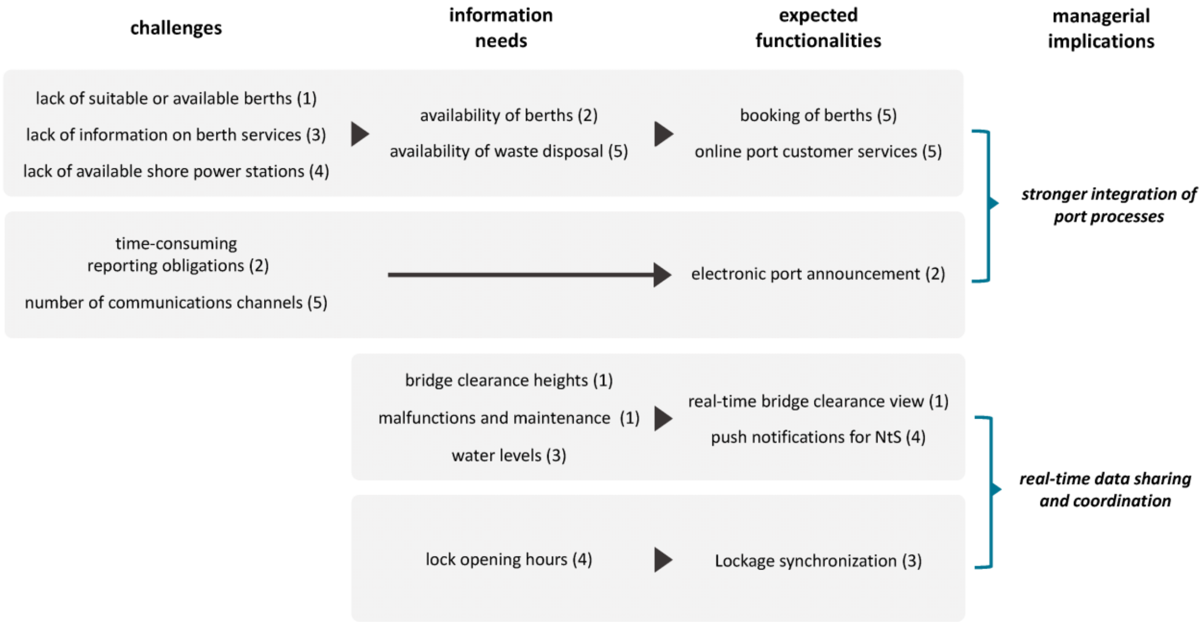

Figure 3. Model to derive managerial implications based on the top 5 rated challenges, information needs, and expected functionalities of IWT operators (own figure, 2021).

Further research should also continue to analyse these directions and thereby support legislative steps. Furthermore, our approach should be applied to other important IWT corridors in the world, to allow for comparative analyses. In addition, this study does not allow for an evaluation of the usefulness of currently implemented and available digital services from an IWT operator perspective, such as the core RIS technologies provided by the competent authorities in the European Union. Further research would be useful in this context as well. It would also be necessary to further investigate concepts on how to integrate the set of useful functionalities into user workflows, such as voyage planning or the process of managing a whole port call lifecycle.

Author Contributions

Conceptualization, P.S., J.-N.B. and M.J.; methodology, P.S. and J.-N.B.; validation, M.J. and N.M.-L.; formal analysis, P.S.; investigation, J.-N.B.; writing—original draft preparation, M.J.; writing—review and editing, P.S., J.-N.B., M.J. and N.M.-L.; visualization, J.-N.B. and P.S. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Not applicable.

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Conflicts of Interest

The authors declare no conflict of interest.

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H. Factors of Digital Transformation in Maritime Transport Sector

Abstract: This paper aims to present the model of factors which influence the digital transformation in maritime transport sector. The preliminary model is based on a literature review and interviews conducted to identify the relevant factors influencing the digital transformation of stakeholders operating in the maritime transport sector. In order to test the model, the survey was conducted on the sample of Croatian administrative (port authorities, ministry, harbormaster's offices, etc.) and commercial stakeholders (freight forwarders, agents, terminal operators, etc.) operating in maritime transport sector. The collected data was analyzed using the partial least squares structural equation modeling (PLS-SEM) approach. The research has shown that organizational, technological, and environmental (TOE) factors affect the digitalization of the organizations in the maritime transport sector. As a result of digitalization, changes in business models are visible: organizations in maritime transport sector generate additional revenue from new sources, provide new services, and introduce new sales channels.

Keywords: digital transformation; maritime transport sector; seaports; TOE factors; PLS-SEM

1. Introduction

An increasing number of practitioners and scholars are exploring the possibilities offered by digital technologies and digital transformation [1,2,3,4,5,6,7,8]. Digital transformation has increased consumer expectations and disrupted markets while at the same time putting pressure on traditional companies and traditional business models [9]. Digital transformation refers not only to the implementation of new technologies but also to shaping digital strategies and digital culture and creating a new business model [10,11,12,13].

The carriers, seaports, and shippers involved in maritime transport chains [14] have become increasingly dependent on information and communication technologies [15]. Digital transformation may positively affect the maritime transport chain in terms of optimized cargo handling, improved business processes, and minimized environmental impacts [16]. Furthermore, the digitalization of seaport business processes may enhance sea–land supply chain performance [17,18]. Despite numerous benefits, digital transformation in the maritime transport sector lags other transport sectors [19].

The research problem can be observed as follows: A significant number of heterogeneous stakeholders operate in the maritime transport sector, often using incompatible information systems [20,21], the costs of establishing information interoperability are very high [3,22,23], there is a lack of awareness of the positive effects of digital technologies [24], laws and regulations often allow only paper data exchange [25], and cooperation among stakeholders operating in the maritime transport sector is at an insufficient level [23]. Despite these obstacles, there is an urgent need to move ahead and seize the opportunities of digital transformation in the maritime transport sector. Therefore, it is important to understand the current role and situation of digitalization, as well as factors that influence organizations in the maritime transport sector on their digital transformation journey.

This research follows up on the literature review "Digital transformation in the maritime transport sector" [26], in which drivers, success factors, and barriers related to digital transformation were identified. Based on that, we developed the preliminary research model and designed a survey that we administered among 94 enterprises in the maritime transport sector in Croatia. We used PLS-SEM statistical analyses to identify the reliability of the factors of digital transformation in the maritime transport sector. Influencing factors were grouped into technological, organizational, and environmental factors (TOE factors) and factors related to changes in a business model. The latter are included in the research as numerous authors connect digital transformation with reshaping business models. This research aimed to develop and validate a model of the influencing factors on digital transformation in the maritime transport sector, which will help stakeholders to better understand the digital transformation phenomenon and shape more successful digital transformation strategies. In this respect, the results can be used to support decision makers in their digital transformation endeavors.

2. Literature Review

Digitalization refers to the implementation of digital technologies [27] or business process automation [28] to enhance business productivity and sustainability [29]. Digital technologies are only one aspect of digital transformation. It refers to the implementation of digital technologies in order to innovate business models, the success of which depends on actively reshaping business strategies [29,30], adequate digital skills [31], digital culture, etc. [3,13].

Fruth and Teuteberg [32] established that automation and digitalization in maritime logistics are constantly progressing and affecting changes in business models. Bălan (2020) [33] recognized the disruptive impact of advanced information and communications technologies

(ICTs) on maritime transport and supply chains. The importance of digitalization has been also recognized by the European Union, which encourages paperless procedures regarding custom processes, freight documents, and documents between cargo owners and contract carriers [34].

Heilig et al. [35] identified three generations of digital transformation in seaports, namely, transformation to paperless procedures, transformation to automated procedures, and transformation to smart procedures. Heilig et al. [29] analyzed the development and the state of the art of digital transformation at the seaport level and identified current opportunities and barriers related to digital transformation.

El Hilali et al. [36] analysed digital transformation in a sustainability context, using a PLS approach. According to the results, "customers, data and innovation", as drivers that companies should work on during a digital transformation, significantly affect companies' efforts to reach sustainability.

As already mentioned, the preliminary research model is based on the literature review "Digital transformation in the maritime transport sector" [26]. In that study, factors were grouped according to the technology organization environment (TOE) framework [37,38]. Technology refers to the acceptance and implementation of modern digital technologies and innovations, along with their safety and interoperability. Organization refers to organizational resources, organizational structure, and communication among employees within an organization. The external environment affects the activities of the organization and its growth. The TOE framework is frequently used in this kind of research, and according to [37], the adoption of innovations is clearly affected by the technological, organizational, and environmental contexts within an organization. In order to adapt the findings and conclusions of the aforementioned paper to this research, we made several changes; for example, success factors and barriers were converted into influencing factors.

Furthermore, to enhance the preliminary research model, the authors identified the scope of changes caused by digitalization and digital transformation, which were defined as changes in a business model. It is important to design a business model to capture value from innovation [39].

In order to validate the preliminary research model as a next step, the authors interviewed six experts in the maritime transport sector. Regarding the interviews with experts, the authors considered different types of stakeholders (administrative and commercial) in order to make the results more relevant. To conduct the quantitative analysis, the authors defined the constructs. The constructs and respective measurement items (factors) are presented in Table 1. The abbreviation ST stands for success technological factors, SO for success organizational factors, and SE for success environmental factors. The abbreviation D stands for digitalization and BM for changes in a business model.

Table 1. Constructs and items.

Constructs	Items	Sources
Technological factors	ST1: The organization implements measures to improve information security	[21,26,32,40,41-47]
	ST2: ICT systems within the organization are interconnected	
	ST3: The organization has connected its own ICT systems with systems operated by other commercial or administrative stakeholders	[21,26,48-51]
	ST4: The organization uses standards for electronic data interchange (e.g., EDIFACT, XML, etc.)	[21,26,48]
	ST5: The organization has available funds for the implementation of new digital technologies	[3,23,26,43,45,52,53]
	ST6: The organization systematically manages the risks of the implementation of new digital technologies (for example, risks related to the quality of project implementation by the contractor)	[26,45,52]
	ST7: The organization has hired new IT experts, i.e., expanded IT departments in order to accelerate the digital transformation	[26,54] + Interview
	ST8: The existing technology in the organization allows the upgrade of modern digital technologies	[55]
	ST9: The use of modern digital technologies opens up new business opportunities	[55]
	ST10: The organization regularly invests in modern technologies to develop its business and services	[3,26,43,52,55]
	ST11: The organization has provided prerequisites for interoperability with external information systems, i.e., with systems managed by other stakeholders (for example, by sharing the interface specification to which external systems can be connected)	Interview
Organizational factors	SO1: The organization has a clearly communicated vision toward all employees in the context of digital transformation	[26,31,53,56-68]
	SO2: Managers are motivated when it comes to the digital transformation of the organization (for example, encouraging the adoption of digital technologies)	[26,69-72]
	SO3: The organization has sufficient financial resources to introduce new digital technologies	[3,26,43,52] + Interview
	SO4: The organization has enough human resources to introduce new digital technologies	
	SO5: Managers possess sufficient digital skills needed to digitally transform an organization	[26,45,52,53,55,69,72-75] + Interview
	SO6: Employees possess sufficient digital skills needed for the digital transformation of the organization	
	SO7: The organization invests in employee knowledge in the context of digitalization and digital transformation	[24,26,30,40,44,46,53,54,56,58,61,63, 64,66,71,76-85]
	SO8: The organization conducts continuous training of employees in the field of digitalization and digital transformation	Interview
	SO9: There is an awareness in the organization of how digital transformation can affect the business of the organization	[24,26,81,86,87]

	SO10: Employees actively share knowledge and information among themselves within the organization as a result of digitization and digital transformation	Interview
	SO11: The organization has introduced new leadership roles to improve digitalization and digital transformation (for example, business process manager)	[26,54] + Interview
	SO12: The organization is actively developing digital transformation strategies	[9,12,26,29,30,35,42,46,47,49,52-54,56-58,60-65,68,70-74,76,77,81,82,84,85,87-100]
	SO13: Employees in the organization have the opportunity to participate in the development or adaptation of digital technologies	Interview
Environmental factors	SE1: The organization feels the pressure of competition on business due to digitalization and digital transformation of competition (digital transformation can significantly disrupt existing markets, and recombine existing products and services)	[3,9,12,23,24,26,32,35,42,47,49,54,55,57,64,65,70-72,74,79,81,84,87,89,90,92,93,95,96,99,101-106]
	SE2: The organization feels the pressure of business partners and other relevant stakeholders on the business (due to the emergence of new technologies, the expectations of business partners may increase)	[9,12,23,24,26,40,42,45,51,52,54-57,61-66,69-72,74,79,84,86,89,101,103-105,107,108]
	SE3: The business of the organization is tightly regulated or subject to special legal regulations	[3,21,26,55,89,109]
	SE4: The organization cooperates with research institutions in the development of new digital solutions (for example, startups, faculties, etc.)	Interview
	SE5: There is the compliance of the organization with standards (for example, ISO standards) and conventions	[55]
	SE6: The organization conducts socially responsible business with the help of digitalization and digital transformation	Interview
Digitalization	D1: The organization cooperates with new partners with the aim of developing new digital solutions	[55,101]
	D2: The organization has digitalized internal business processes	[3,55]
	D3: The organization has digitalized external business processes	[29,30,35,36,110-115]
Changes in business model	BM1: The organization generates additional revenue from new sources as a result of the implementation of digital technologies	[30,55,114,116]
	BM2: The organization has entered new markets as a result of digitalization and digital transformation	[55,101]
	BM3: The organization provides new services as a result of digitalization and digital transformation	[11,12,30,35,36,55,80,101,110-112,114,115,117-120]
	BM4: The organization has introduced new sales channels as a result of digitalization and digital transformation	Interview
	BM5: The organization has introduced new ways of charging for services as a result of digitalization and digital transformation	[30,55,114,116]

3. Methodology

The methodology combines qualitative and quantitative approaches [55,116,121]. Based on an extensive literature review [26], digital transformation influencing factors were identified and clustered using the TOE framework. These factors influence the level of digitalization in enterprises and are reflected in business models changes. To confirm the relevance of the influencing factors, interviews with six experts from different organizations were conducted, and a preliminary research model was designed. The authors interviewed the managers of the following organizations: the ministry of transport, shipping and logistic companies, a port authority and the enterprise that focuses on digitalization of stakeholders operating in maritime transport sector. After that, the authors designed the questionnaire and conducted a survey of 262 Croatian stakeholders to validate the research model. Figure 1 shows the research steps and outcomes.

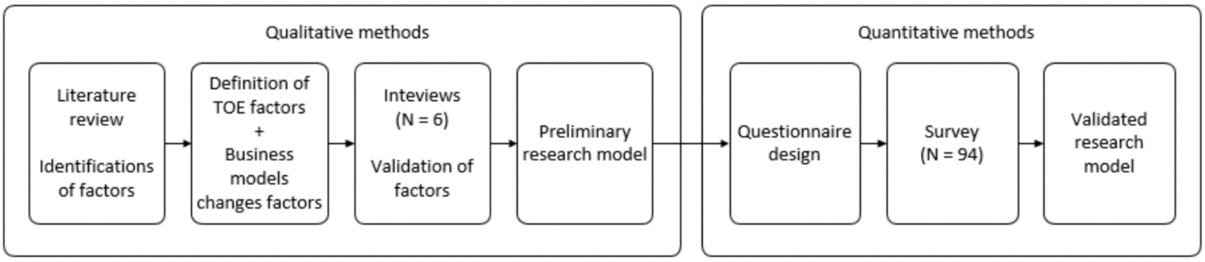

Figure 1. The research steps.

Based on the extensive literature review and interviews with experts, the following hypotheses were formulated:

Hypothesis 1 (H1). Organizational factors have a positive impact on technological factors.
Hypothesis 2 (H2). Technological factors have a positive impact on digitalization.
Hypothesis 3 (H3). Environmental factors have a positive impact on digitalization.
Hypothesis 4 (H4). Digitalization has a positive impact on changes in a business model.

The preliminary research model of digital transformation in the maritime transport sector is shown in Figure 2.

The authors designed a questionnaire and collected quantitative data on factors influencing the digital transformation of stakeholders operating in the maritime transport sector through an online survey. A five-point Likert type scale (1—totally disagree, 5—totally agree) was used to measure the level of agreement with given statements on the questionnaire. For data analyses, the partial least squares structural equation modeling (PLS–SEM) method was used to test the model, using SmartPLS 3.3.9 (SmartPLS GmbH, Bönningstedt, Germany).

The authors contacted 262 Croatian stakeholders listed in relevant national databases, both commercial (freight forwarders, agents, terminal operators, etc.) and administrative (port authorities, harbour master offices, and the relevant ministries). Since seaports are an important link in the transport chain [122], and the connection of the seaport with the hinterland contributes to the competitiveness of the seaport and influences its development [123,124], the authors also considered rail and road carriers that are involved in the maritime transport chain. Experts who had leading positions within the organization and who had experience in the field of digital transformation responded to the surveys (one person from each organization). The complete set of data was collected in 2022 from 94 organizations in Croatia.

4. Results

4.1. Descriptive Statistics

Out of the total of 262 invited enterprises, we received 122 responses. We took into account only fully completed surveys, 94 of them. Out of 94 respondents, 35.11% were administrative stakeholders, and 64.89% were commercial stakeholders. Table 2 shows the types and percentages of the different stakeholders.

Table 2. Types and percentages of stakeholders.

Group of stakeholders	**Type of stakeholders**	**Percentage**
Administrative stakeholders	Public bodies and administrative stakeholders	35.11%
Commercial stakeholders	Shipping companies	17.02%
	Freight forwarders and logistics operators	14.89%
	Maritime brokers	11.70%
	Port operators and terminal operators	7.45%
	Other	7.45%
	Maritime port agents	3.19%
	Road carriers	2.12%
	Railway carriers	1.06%

Among the commercial stakeholders, we received the largest number of responses from shipping companies, followed by freight forwarders and logistics operators. The category “other” includes: crewing (manning) agencies, the maritime training center for maritime education, and vessel management

4.2. Measurement Model Evaluation

In the first part of the PLS–SEM analysis, we tested the measurement model. We evaluated composite reliability and convergent validity and the reliability of measurement model indicators, and then we assessed discriminant validity and evaluated the composite model.

4.2.1. Evaluating Composite Reliability and Convergent Validity of Measurement Model

First, to measure the composite reliability of the measurement model, we calculated Cronbach's alpha, Dijkstra–Henseler rho_A, and composite reliability as shown in Table 3.

Table 3. Construct Reliability and Validity.

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Changes in business model	0.883	0.900	0.927	0.809
Digitalization	0.802	0.807	0.884	0.719
Environmental factors_	0.766	0.841	0.863	0.679
Organizational factors	0.842	0.847	0.894	0.678
Technological factors	0.816	0.820	0.879	0.646

All composite reliability values are measured in the interval from 0 to 1, where 1 means a complete reliability estimate. The measure of composite reliability (rho) is higher than Cronbach's alpha, which is recommended because rho estimates are usually closer to true reliability. Cronbach's alpha as rho has an acceptance limit of 0.7, and a match above 0.8 means good composite reliability. Table 3 shows that Cronbach's alphas for the latent variables are between 0.766 and 0.883, and rho is between 0.807 and 0.900. In recent years, Dijkstra–Henseler rho_A [121] has become increasingly popular. Dijkstra–Henseler rho_a above 0.707 is considered appropriate, meaning that the latent variable explains more than 50% of the variance in a construct [121]. Table 3 shows that all rho_A are above 0.707, indicating a reliable construct.

"Convergent validity is the extent to which the indicators belonging to one latent variable actually measure the same construct" and is estimated based on average variance extracted

(AVE) [121]. As a composite reliability metric, AVE is between 0 and 1, where 1 represents a complete convergence estimate [125]. "An AVE larger than 0.5 has been suggested to provide empirical evidence for convergent validity, as the corresponding latent variable explains more than half of the variance in the belonging indicators" [121]. As shown in Table 3, the AVEs for all latent variables are between 0.646 and 0.809, which is appropriate and indicates convergent validity.

4.2.2. Evaluating the Reliability of Measurement Model Indicators

An assessment of the reliability of the indicator can be given based on factor loadings, where a factor loading above 0.707 is considered acceptable.

In the original measurement model, there were 38 indicators that we gradually eliminated. In each iteration, we eliminated one factor with the lowest factor loading. We continued this process until we came up with indicators with factor loadings above 0.707. It means that "more than 50% of the variance in a single indicator can be explained by the corresponding latent variable" [121].

4.2.3. Assessment of Discriminant Validity of a Measurement Model

"Discriminant validity entails that, two latent variables that are meant to represent two different theoretical concepts are statistically sufficiently different." To obtain empirical evidence for discriminant validity, the heterotrait–monotrait (HTMT) ratio should be considered [121]. The HTMT should be lower than 0.85 (stricter threshold) or 0.90 (more lenient threshold) or significantly smaller than 1". The HTMTs for the latent variables are shown in Table 4. No HTMT is higher than the strict criterion, 0.85, so HTMT indicates the discriminant validity of the measurement model.

Table 4. HTMT values.

	Changes in business model	Digitalization	Environmental factors_	Organizational factors	Technological factors
Changes in business model					
Digitalization	0.581				

Environmental factors_	0.190	0.786			
Organizational factors	0.366	0.580	0.523		
Technological factors	0.369	0.781	0.705	0.713	

4.2.4. Evaluating Composite Model

To provide an estimate of the composite model, we focus on estimating multicollinearity, weights, and composite loadings [121]. Multicollinearity occurs when two independent variables have a high correlation, which increases standard errors and test unreliability, and when there are difficulties in assessing the importance of variables depending on each other [125]. As a rule, problems with multicollinearity occur when the variance inflation factor (VIF) is above 4.0, or above 5.0 following the less stringent criterion [121,125].

Problems with multicollinearity can occur at both the measurement level and the structural model level [125], so SmartPLS separates VIF into inner VIFs for the measurement model and outer VIFs for the structural model. Table 5 shows the inner VIFs for the measurement model.

Table 5. The inner VIFs.

	Changes in business model	Digita-lization	Environmental factors_	Organizational factors	Technological factors
Changes in business model					
Digitalization	1.000				
Environmental factors_		1.482			
Organizational factors					1.000
Technological factors		1.482			

All values are much lower than 4 (the maximum inner VIF is 1.482), which is why we do not expect problems related to multicollinearity. Table 6 shows the outer VIFs for the measurement model as well as the weights and loadings.

Table 6. The outer VIFs, weights, and loadings.

Constructs	VIF	Weight	Loading
BM1	2.905	0.366	0.917
BM3	2.461	0.424	0.912
BM4	2.292	0.319	0.869
D1	1.387	0.371	0.769
D2	2.315	0.415	0.889
D3	2.291	0.393	0.880
SE3	1.444	0.287	0.730
SE5	1.610	0.383	0.820
SE6	1.892	0.523	0.911
SO4	1.743	0.295	0.793
SO7	2.157	0.337	0.856
SO8	2.158	0.306	0.841
SO9	1.851	0.275	0.803
ST10	1.927	0.341	0.829
ST2	1.638	0.294	0.787
ST6	1.486	0.299	0.746
ST8	2.107	0.310	0.848

All VIFs are lower than 4 (the maximum outer VIF is 2.905), which is why we do not expect problems related to multicollinearity in the structural model.

"While weights show the relative contribution of an indicator to its construct, composite loadings represent the correlation between the indicator and the corresponding emergent variable; a loading shows the absolute contribution of an indicator to its construct" [121]. If there is an indicator of a latent variable with a significantly smaller loading than other indicators, then it is necessary to assess whether it is appropriate to exclude that indicator. The validity of the indicator must also be taken into account. In the event of a change in the validity, we may choose to keep an indicator with a lower weight. As can be seen from Table 6, within the structural model, indicators of latent variables are similarly weighted/loaded.

4.3. Structural Model Evaluation

After completing evaluations of the measurement and composite models, according to which we consider the measured properties of the research model to be appropriate, we can proceed with the assessment of the structural model [121,125]. In the assessment of structural models, we focus on estimates of model fit as well as estimates of path coefficients, their importance, effect sizes (f^2), and coefficients of determination (R^2) [121].

First, it was necessary "to evaluate the overall fit of the estimated model through the bootstrap-based test of overall model fit and the Standardized Root Mean Square Residual (SRMR) as a measure of approximate fit to obtain empirical evidence for the proposed theory" [121]. For each iteration of the following steps, we used SRMR, the squared Euclidean distance (d_{ULS}), and geodesic distance (d_G) to verify that the model corresponds to a saturated structural model [121] (see Table 7).

Table 7. Model fit.

	Saturated model	**Estimated model**
SRMR	0.080	0.106
d_{ULS}	0.972	1.725
d_G	0.508	0.571

An SRMR below 0.08 (or in a more conservative version below 0.10) indicates acceptable model fit [121,126]. Based on the considered data, the SRMR coefficient is 0.08, which is still acceptable.

The values of d_{ULS} and d_G by themselves have no value for assessing the suitability of the model. The adjusted Bollen–Stine bootstrap should be implemented to estimate d_{ULS} and d_G, which in SmartPLS is marked as double, or perfect, bootstrapping. This procedure creates samples based on the distribution of confidence intervals for SRMR, d_{ULS}, and d_G. If d_{ULS} and d_G are within the 95% confidence interval, the model is considered appropriate [126]. The analysis of the research model showed that both values are within the 95% confidence interval.

The structural or internal model consists of latent variables and the relationships (arrows) between them. The weight written on the arrow that directly connects the two latent variables is the standardized regression coefficient. The statistical characteristics of individual paths are checked using a double, or complete, bootstrapping, and for a path to be statistically significant, it must have a p value lower than 0.05 [121]. The results of the bootstrapping analysis are shown in Table 8.

Table 8. Path coefficients (bootstrapping).

Relationship	**Original Coefficient**	**Sample Mean**	**Standard Deviations**	**T statistics**	**P Values**
Digitalization -> Changes in business model	0.491	0.497	0.106	4.653	0.000
Environmental factors -> Digitalization	0.414	0.429	0.105	3.939	0.000
Organizational factors -> Technological factors	0.597	0.611	0.094	6.376	0.000
Technological factors -> Digitalization	0.399	0.386	0.119	3.354	0.001

All p values are lower than 0.05, which means that the relationships between the variables are statistically significant. Furthermore, as can be seen from Table 8, all path coefficients are positive. It can be concluded that the hypotheses have been confirmed.

Table 9 shows the explained variance of a dependent construct (R^2) and the magnitude of an effect that is independent of sample size (f^2).

Table 9. Structural model evaluation.

Endogenous Variable	R^2
Changes in business model	0.258
Digitalization	0.535
Technological factors	0.383
Effect Size	f^2
Digitalization -> Changes in business model	0.375

Environmental factors -> Digitalization	0.272
Organizational factors -> Technological factors	0.675
Technological factors -> Digitalization	0.250

When phenomena are already quite well understood, one expects a high R^2. When the phenomena are not yet well understood, a lower R^2 is acceptable [121]. These results including the path coefficient and R^2 are presented in Figure 3.

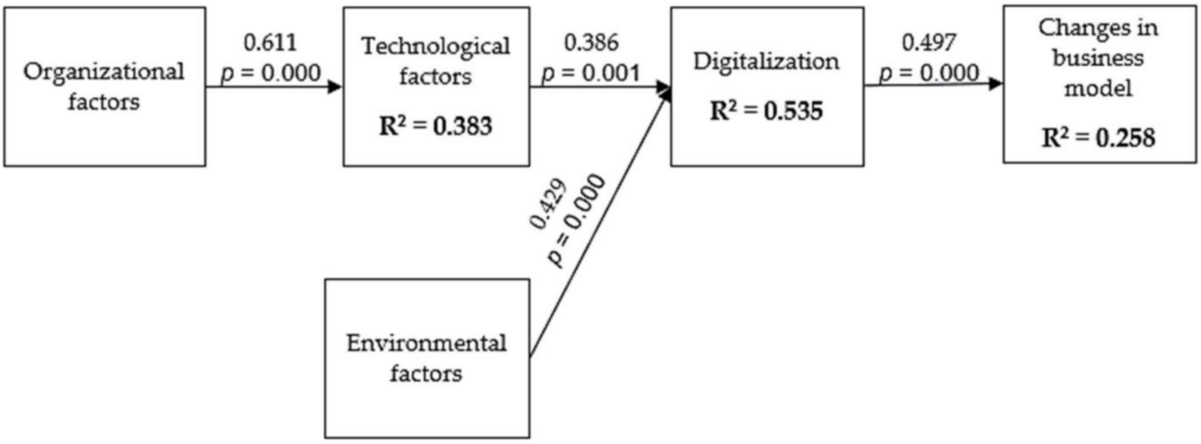

Figure 3. PLS analysis of the research model.

Given that, in our opinion, this is the first such study that evaluates the impacts of factors of digitalization on changes in business models, it is estimated that $R^2 = 0.258$ is an acceptable value.

Table 9 shows f^2, which indicates the practical relevance of an effect. The magnitude of the effect f^2 is independent of the magnitude of the sample value, and the effect size is considered weak for f^2 between 0.02 and 0.15, medium for f^2 between 0.15 and 0.35, and large for f^2 equal to or larger than 0.35 [121]. Table 9 shows that the structural model contains both medium and large effect sizes. Namely, in the structural model, the effect size of linking technological factors and digitalization is the weakest in the whole model ($f^2 = 0.250$). On the other hand, the effect size of linking organizational factors and technological factors is the strongest ($f^2 = 0.675$).

5. Discussion and Findings

Based on an assessment of the indicators, several organizational factors were assessed as the most reliable. One of the important organizational factors is the existence of awareness in the organization of how digital transformation can affect the business of the organization. If there is no awareness, the need for investment in employees, new digital technology, etc. will not be recognized, which will ultimately slow down or prevent digital transformation [24]. For this reason, organizational factors represent the base or first step towards digital transformation. Another factor is "the organization has enough human resources to introduce new digital technologies". In order to ensure a sufficient number of human resources, cooperation between the university and the private sector is needed (e.g., by investing in knowledge), which would facilitate the further development and implementation of digital technologies in maritime transport sector [26,127].

One of the factors is "The organization invests in employee knowledge in the context of digitalization and digital transformation". In this respect, changes in the structure as well as the culture of the organization lead employees to take on roles that have traditionally been outside their functions [26]. Therefore, employees in the maritime transport sector should be encouraged by managers to upgrade their knowledge through intern or extern workshops, seminars, etc., which consequently affects organizational agility [128]. However, it is equally important that employee education take place regularly. Therefore, one of the factors the importance of which was recognized by the respondents related to the continuity of training: "The organization conducts continuous training of employees in the field of digitalization and digital transformation (for example, the development of an internal academy with online training and training modules in individual departments)".

Regarding technological factors, three of them were assessed as the most reliable, two of which were "The organization regularly invests in modern technologies to develop its business and services" and "The existing technology in the organization allows the upgrade of modern digital technologies". In this respect, "necessary technical modifications depend on the state of existing technologies used in an organization and must be adapted according to the needs of the organization" [26]. The last technological factor is "The organization systematically manages the risks of the implementation of new digital technologies", which is related to risks regarding, e.g., the quality of project implementation by the contractor.

The external environment may influence the activities of the organization and its growth. In terms of environmental factors, three of them were assessed as the most reliable. One of them is “The business of the organization is tightly regulated or subject to special legal regulations”, which is usually related to green transport technologies or technologies that are applied for efficient and safe operation [109]. Another environmental factor is “There is a compliance of the organization with standards (for example, ISO standards) and conventions”. For example, “ISO/IEC 38500:2015 provides guiding principles for members of governing bodies of organizations on improved, and acceptable use of information technology within their organizations” [129]. The last environmental factor assessed as most reliable is “the organization conducts socially responsible business with the help of digitalization and digital transformation”. For example, in maritime transport, the United Nations 2030 Agenda and Sustainable Development Goal 17 refer to significant regulatory development that triggered a diffusion of corporate social responsibility [130].

In addition to assessing the factors of digital transformation, the stakeholders who participated in our research were asked if their organizations had a formulated digital transformation strategy, and only 27% of organizations provided a positive response. Furthermore, in 47% of organizations, general managers are responsible for leading the digital transformation. In other organizations, IT department managers, project managers, or digital transformation managers are responsible for digital transformation.

Stakeholders were also asked in which business area the digitalization has brought the most benefits, and the following areas were mentioned: sales, accounting, finance, cost management, procurement, reporting, the official procedures of arrivals and departures of ships, customs formalities, human resource management, and analytics. Furthermore, organizations use the following information technologies (in descending order, based on the number of responses): office programs, e.g., MS Office (93%); information systems for business support (69%); applications for communication with clients (48%); social networks, e.g., LinkedIn (48%); software solutions for business analytics (36%); online sales (14%); blockchain (1%); and other, e.g., geographic information systems (5%). The majority of organizations (60%) answered that they had increased productivity by introducing digitalization and digital transformation.

In addition, stakeholders pointed out the importance of digital transformation when it comes to sustainable business, especially the ecological aspect of sustainability. In this respect, some of them increasingly use green sources and have implemented various solutions in order to lower the harmful impacts of their business (such as fuel flow measuring systems to optimize fuel consumption). One of the stakeholders has also developed a research center that is focused exclusively on development of zero-carbon technologies and solutions.

Our research has shown that organizational, technological, and environmental factors affect the digitalization of organizations in the maritime transport sector. Digitalization includes cooperation between an organization and new partners to develop new digital solutions (including through participation in projects related to digitalization and/or digital transformation) and digitalized internal and external business processes. As a result of digitalization, organizations in the maritime transport sector generate additional revenue from new sources, provide new services, and have introduced new sales channels.

The contribution of this study is twofold. First, the results of the study enrich the body of knowledge in the field of digitalization and digital transformation in the maritime transport sector. The validated model of digital transformation offers other researchers an introduction to the investigated field and may provide a baseline towards future research designs. In this respect, this research offers a better understanding of the influencing factors (technological, organizational, and environmental) that affect the digitalization of organizations operating in the maritime transport sector and how these changes result in changes in business models (the way an organization operates and conducts business). Second, the model with identified influencing factors can help practitioners and decision makers in shaping their digital transformation and digitalization strategies.

6. Conclusions

In the maritime transport sector, stakeholders are at different stages regarding the digital transformation of their business. The motivation for this research stems from the lack of existing research focused on digital transformation in the maritime transport sector. The existing studies do not provide a comprehensive overview of digital transformation in the maritime transport or seaports. In this respect, this research presents a model of influencing factors on digital transformation in the maritime transport sector. For that purpose, the authors, as a first step, conducted a literature review and carried out interviews with six organizations. Based on that, the authors identified 11 technological factors, 13 organizational factors, and 6 environmental factors and defined digitalization through 3 items and changes in business models through 5 items. Furthermore, the authors collected quantitative data on factors influencing the digital transformation of stakeholders operating in the maritime transport sector through a survey methodology. In the first part of the PLS–SEM analysis, testing of the measurement model was performed. The authors evaluated composite reliability and convergent validity and the reliability of measurement model indicators and then assessed discriminant validity and evaluated the composite model. In the assessment of structural models, the authors focused on estimates of model fit, estimates of path coefficients, their importance, effect size (f2), and coefficient of determination (R2).

The research has several limitations, which may also serve as future research directions. First, the research findings were based only on a sample of 94 organizations in Croatia. The comparison of these findings with other countries (e.g., countries in which digital transformation leaders operate such as Holland at the Port of Rotterdam) could provide further insights regarding digital transformation in the maritime transport sector. Furthermore, the authors analyzed both commercial and administrative stakeholders. In this respect, further research could include only one group. In order to broaden the scope of the research, additional analysis of the impact of digitalization on the business model may be conducted, for example at the supply chain level. In this respect, virtualization of product supply may be included, which means selling items that are not even owned by the company through the digital integration of inventories (digital marketplaces). Furthermore, traceability and product safety can change the business model based on the securitization of food, etc. This study offers only partial insights into digital transformation, which is a complex and fast-evolving phenomenon.

Author Contributions

Conceptualization, M.J., D.V., E.T., and A.P.; methodology, M.J., D.V., and A.P.; software, M.J., D.V., and A.P.; validation, M.J., D.V., E.T., and A.P.; formal analysis, M.J., D.V., E.T., and A.P.; investigation, M.J.; resources, M.J., D.V., E.T., and A.P.; data curation, M.J., D.V., E.T., and A.P.; writing—original draft preparation, M.J.; writing—review and editing, E.T. and A.P; visualization, E.T. and A.P.; supervision, E.T. and A.P.; project administration, E.T. and A.P.; funding acquisition, E.T. and A.P. All authors have read and agreed to the published version of the manuscript.

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The authors declare no conflict of interest.

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