




Article

# Use of End-to-End Tool for the Analysis of the Digital Governance of Ports

Nicoletta González-Cancelas , Alberto Camarero Orive \*, Alberto Rivas Vilarchao  and Javier Vaca-Cabrero 

Department of Transport, Territorial and Urban Planning Engineering, Technical University of Madrid, Madrid 28040, Spain; alberto.rivas.vilarchao@alumnos.upm.es (A.R.V.)

\* Correspondence: alberto.camarero@upm.es

**Abstract:** *Background:* Digital governance currently presents challenges in the context of ports, where efficiency and transparency are key elements for the success of operations. In ports, the effective adoption of digital governance can have a significant impact on optimizing operational processes and improving coordination between port authorities, logistics operators and customs. *Method:* In this context, the article proposes the use of an End-to-End Tool to analyze and evaluate digital governance in ports. This tool makes it possible to collect data from various sources, carry out a thorough analysis of the processes involved, and evaluate the satisfaction of end users. In addition, it provides an intuitive and easy-to-use interface to visualize results and make evidence-based decisions. The outcomes revealed areas of improvement in operational processes, identified bottlenecks, and presented proposals to optimize port efficiency. *Results:* The port currently exhibiting the best digital governance is Valencia, followed by Piraeus, Barcelona, and Algeciras, with very comparable management, and finally, Genoa. *Conclusions:* Efficient public–private collaboration in digital governance boosts port competitiveness. Regulatory frameworks for data security are crucial, and digital governance emerges as vital for global success.

**Keywords:** data management; digital governance; ports; digitalization; end-to-end tool



**Citation:** González-Cancelas, N.; Camarero Orive, A.; Vilarchao, A.R.; Vaca-Cabrero, J. Use of End-to-End Tool for the Analysis of the Digital Governance of Ports. *Logistics* **2024**, *8*, 58. <https://doi.org/10.3390/logistics8020058>

Academic Editor: Robert Handfield

Received: 25 March 2024

Revised: 22 May 2024

Accepted: 3 June 2024

Published: 6 June 2024



**Copyright:** © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

## 1. Introduction

In the last decade, the rapid evolution of information and communication technologies has fundamentally reshaped global port management. The emergence of digital governance within ports stands out as a pivotal strategy, aimed at enhancing operational efficiency, safety, and sustainability within these critical logistical frameworks [1].

Today, ports play a very important role in the industry, allowing the economic development of the countries in which they are located. Globally, ports engage in continual competition to provide superior services and ensure seamless cargo movement, while also prioritizing environmental sustainability through the modernization of their processes and technologies [2].

In Spain's case, its peripheral location within Europe, coupled with its extensive coastline spanning approximately 8000 km—the most among European countries—positions Spanish ports as pivotal drivers of economic growth and advancement. They not only serve as key hubs for logistics but also act as catalysts for regional prosperity, contributing significantly to the economic progress of the southern European continent [3].

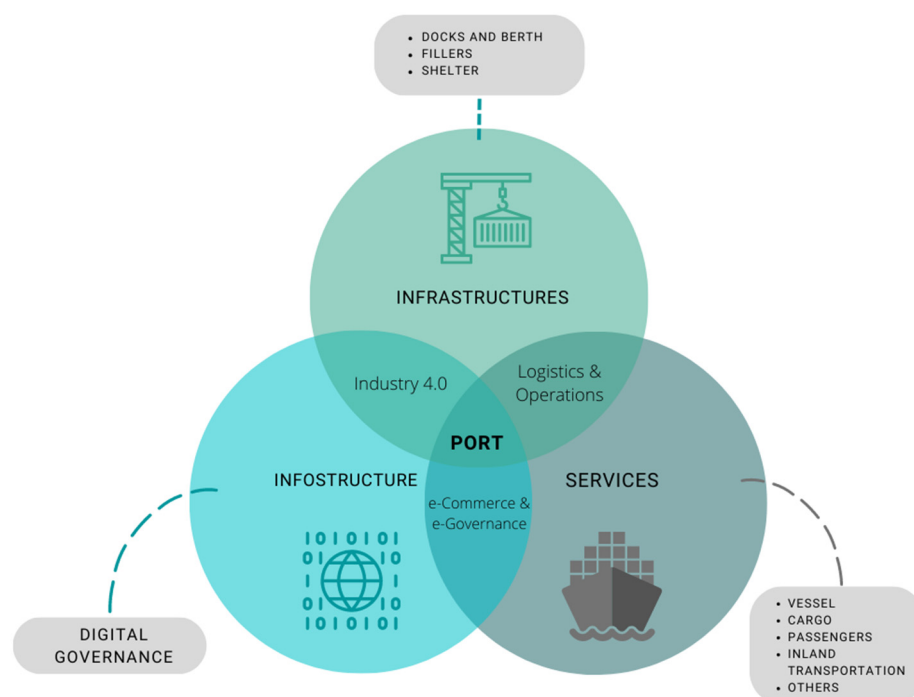
Due to the importance of ports as business hubs, digitalization is a crucial aspect to take into account [4]. The digital transition, the automation of practices and processes, and the implementation of other cutting-edge technologies are gaining strength in the global maritime-port field and methods are being sought to end the tedious and complicated traditional procedures that are carried out on paper, to give way to intelligent solutions based on the cloud, Big Data, Artificial Intelligence and the Internet of Things (IoT) [5].

Nevertheless, this industry lags behind others in terms of digitalization, due to the formidable challenge of achieving consensus and collaboration among all stakeholders

within the transport chain. Additionally, notable discrepancies exist in the pace of digital transformation across different countries [1].

Therefore, the original function of ports to connect sea and land has evolved into global logistics centers that manage the flow of goods and provide value-added logistics services in an efficient and environmentally friendly way [1].

These modern ports are based on three fundamental pillars (Figure 1), infrastructure, a classic element of civil engineering; the services offered by the port to the different participating agents and the infostructure or data management [6]. This final pillar underscores the essence of digital governance, which entails the utilization, processing, and management of data gathered through tools that have emerged with digital advancement to effectively administer a port. In essence, digital governance in the port administrative domain revolves around harnessing technological innovations to streamline operations and decision-making processes [7].



**Figure 1.** Fundamental pillars of a modern port. Source: own elaboration.

It is essential to recognize the current challenges in the digital governance of ports. The complexity of port operations, coupled with the need for coordination between multiple actors, poses significant challenges in terms of efficiency and transparency. The research, using the End-to-End tool, seeks to address these challenges by analyzing detailed digital governance in Mediterranean ports and identifying areas for improvement. By providing a comprehensive, evidence-based assessment, these contributions have the potential to inform and improve existing practices in this field, thereby contributing to the advancement of port management.

The rest of this article is organized as follows: Section 2 presents the state of the art of current port digital governance, highlighting the crucial collaboration between public and private sectors, which offers benefits such as operational optimization. The future entails automation and coordination between modes of transportation, requiring continuous evaluation and adaptation, as demonstrated by a detailed description of the proposed method using the End-to-End tool. Section 3 explains the End-to-End Tool methodology, followed by the presentation of our research results in Section 4, which provides an in-depth analysis and discussion of these findings. Finally, Section 5 concludes the article with a summary of our contributions and conclusions drawn from the study.

## 2. State of the Art

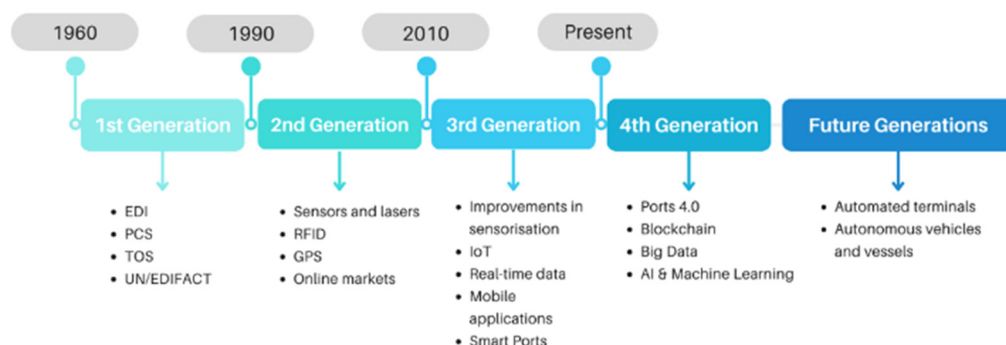
### 2.1. The Digital Governance of Ports: Evolution to the Present

Port governance influences numerous sectors, such as the logistics chain, economic, management, engineering, etc. [3]. Digital governance is no exception.

Port digitalization seeks to create, through the integration and use of new technologies, such as Blockchain, Artificial Intelligence or the Internet, a work environment where information is more accessible and its use more efficient and intelligent, in such a way that the processes involved in port management can interact with each other in a standardized and unique platform [7]. That is, digital evolution consists of the transformation towards a more digitally interconnected future.

The concept of digital governance is novel in the port system, but widely used by numerous authors in other fields. According to [7], the concept of digital governance has evolved from the simple use of digital technologies to govern, to a more comprehensive approach that includes the use of these technologies to improve the way governments interact with citizens and businesses. Reference [8] further emphasizes the importance of digital governance mechanisms and the principles that enable agile responses in dynamic competitive environments. This suggests that digital governance is not just about using technology for efficiency, but also about using it to be more responsive and adaptable to change.

In port history, four significant generations of digital evolution have emerged, each characterized by distinct processes that propel digitalization forward [9]. Figure 2 shows the milestones of the digital evolution of ports, from the beginning of this process to the present, and what is expected in the near future.



**Figure 2.** Milestones of port digitalization. Source: own elaboration.

Examining the macro-environment of the maritime-port sector, the emergence of digital governance stems from the industry's imperative to adapt to the evolving global landscape. This adaptation entails embracing new technologies and innovations that empower port authorities to optimize their operations, enhance market competitiveness, and demonstrate greater environmental responsibility [10].

The transition towards digital governance and the use of technologies is the basis of industry 4.0 and, therefore, of ports 4.0, enabling improvements in the speed and efficiency of transport. However, these solutions do not only cover the use of the Internet or Artificial Intelligence. They commenced with seemingly simpler yet equally innovative systems, such as containerization, which revolutionized the industry by standardizing cargo handling and transportation, leading to significant efficiencies and cost savings [10]. This was a maritime milestone that transformed the maritime and logistics industry and served as a basis for ports, today, to use the innovative technologies that are developed.

With the emergence of the Internet, new business formats began to emerge, such as social networks, electronic devices or data management in the cloud. These services were making their way to become an essential part of any industry, no different in the port, where as a result of this the landscape of maritime transport logistics began to change [11].

There are disruptive technologies that significantly impacted the governance of ports, such as the Internet, Big Data or Blockchain, and these technologies are frequent in the current situation of ports, while others, such as fleets or autonomous vessels, are expected to have a strong impact in the near future [12].

Digitalization began mainly in ports in Europe and Asia, particularly prominent in Singapore, Hamburg and Rotterdam. It is these ports that, by embarking on digital improvement, managed to take a big step forward in terms of efficiency, cost reduction and increased customer satisfaction [13].

As time progresses and technologies advance, ports worldwide have embarked on this transition, embracing digital solutions to enhance their operations. Latin America stands out in this regard, as digital governance is taking the lead, primarily due to the utilization of open data practices. This contrasts with other countries like Spain, where digital governance adoption may be comparatively slower [14].

Another important case was that of Ghana, in West Africa, where there are several examples of initiatives for the digital governance of its ports. In 2017, a Paperless Port System (PPS) was established to improve the competitiveness, efficiency, and transparency of the ports of this country; however, after a year numerous difficulties were denoted that have harmed this initiative [15]. This is an example indicating that the simple implementation of technology without correct adaptation to port development does not mean the success of digitalization.

However, the scope and speed of digitization differs greatly between countries and ports. This is due to a number of factors such as governance statutes, the business landscape, and technology investments [16].

The near future bases its advances on automation, not only of terminals, but also of ships, vehicles and port machinery, so it is important to know the process and history of maritime-port autonomy [17].

## *2.2. Digital Governance: Contributions and Benefits to Ports*

Port governance focuses on the use of large volumes of data generated by port systems to obtain valuable information and make strategic decisions, with the use of Big Data and data analysis. Data analytics plays a pivotal role in optimizing resource allocation, forecasting demand, detecting patterns and trends, and enhancing overall decision-making within the maritime-port sector [18].

A significant element of digital governance is citizen participation and transparency: this aspect refers to the use of digital tools to involve citizens in decision-making and improve transparency in port management. This may include citizen participation platforms, public information portals, and interactive communication channels [19].

In terms of benefits, recent studies have highlighted the improvement in operational efficiency through process automation, supply chain optimization and the reduction in waiting times for ships and goods [20].

In addition, digital governance in ports has proven to be an effective tool for strengthening port security, through the implementation of advanced surveillance systems, real-time information exchange and the detection of potential risks [21].

However, implementing digital governance strategies in ports also presents significant challenges [22]. Among them is the need to ensure the interoperability of information systems between the different port actors, the protection of sensitive data and cybersecurity, as well as the management of organizational change required to adopt new technologies and processes.

The challenges associated with digital governance in ports are of many types and must be taken into account.

One of the key challenges is to ensure interoperability between the different systems and platforms used by port actors, such as customs, container terminals, shipping companies and port authorities [23]. The lack of common standards and the heterogene-

ity of systems can hinder the exchange of information and the efficient coordination of port operations.

Digital governance at ports involves managing vast amounts of sensitive data, from cargo and route information to personal and financial data. Therefore, cybersecurity and data protection are critical challenges [24]. Ports must implement robust security measures to protect systems and information against cyber threats, ensuring the confidentiality, integrity and availability of data.

The adoption of digital governance solutions implies changes in the processes, technologies and organizational culture of ports. Resistance to change, lack of digital skills, and the need to train port staff in the use of new technologies are significant challenges [25]. Effective training programs and changes in management strategies are crucial to ensure a successful transition to digital governance.

Implementing digital governance solutions in ports can require significant investments in technology infrastructure, specialized software, and human resources [26]. It is critical to evaluate the return on investment (ROI) and financial viability of these projects. Challenges include identifying appropriate funding sources, accurately estimating costs and benefits, and efficiently managing financial resources.

Digital governance in ports involves collaboration between multiple actors, such as the port authorities, private companies, governance entities, and port communities [27]. The absence of clear governance and efficient coordination can indeed impede the implementation of digital solutions and hinder collaborative decision-making. Establishing robust governance frameworks and fostering collaboration among the various stakeholders involved are imperative steps to surmount these challenges and facilitate the effective adoption of digital innovations in the maritime-port sector.

There is a digital divide between ports that have access to advanced technologies and those that lack them [28]. This gap may be due to differences in terms of financial resources, technological infrastructure and technical capabilities. To achieve the equitable adoption of digital governance in ports, it is necessary to address the digital divide and ensure equitable access to the necessary technologies and resources.

These challenges need to be considered and addressed to achieve a successful implementation of digital governance in ports and make the most of its potential benefits.

In terms of best practices, several studies have highlighted the importance of establishing strong collaborations between public and private actors, encouraging the participation of all stakeholders in the design and implementation of digital solutions, and promoting the continuous training of port staff in digital skills.

Digital governance in ports has become an area of growing interest and relevance in the field of port management.

### *2.3. Digital Governance: Contributions and Benefits of End-to-End Tool*

Analyzing the current industry is necessary to be able to adapt to the growing and changing environment in which the world finds itself. Like the subject of this paper, the industry is immersed in a technological revolution marked by digitalization. This allows for an improvement in the operation and development of industrial processes, as well as an increase in productivity and a general reduction in costs and transaction times.

Understanding this, it is reasonable that the End-to-End tool has been used to analyze this area and is able to establish future strategic lines and action.

However, this tool is highly novel and has been created only recently, and that is why it has not yet been applied to industry analysis. So far in this area, analysis tools, such as affinity matrix, SWOT matrix, BOT [29], etc., have been used, but they are tools that have certain limitations and that is why the End-to-End has been created, as an analysis methodology that solves these problems. So, although it has not yet been used in the industry, it is expected that it will be in the coming years, when it becomes relevant in this sector [30].

Transport, like industry, has been subjected to the digitalization process, where the development of intelligent and synchromodal transport is currently being sought, thus allowing for greater coordination between all modes of transport.

The study tool, in the case of the port area, has been used in issues related to the modernization and improvement of efficiency, as well as in the field of sustainability. More specifically, it has been used to analyze the digital evolution of Spanish ports and, secondly, it has been used to analyze the conversion to green ports applied to a specific case study [4]. It is a study methodology that, although it does not yet have an established history, allows for an increasingly clear image of the ports to be drawn [30].

In the case of the study of digital evolution, this tool has enabled the taking of snapshots of the current state, medium–low, of Spanish ports in terms of digitalization, and has determined the guidelines to advance down this strategic path, covering the main theme in a national or microenvironment perspective and allowing for the advancement of the research on the global macroenvironment [4].

On the other hand, the study of green ports has managed to give more functionality to the tool by applying it to a specific scenario and setting the guidelines to follow it, to achieve the desired objective and, once that is fulfilled, extend it to the rest of ports with the same motivations and ambitions [30].

### 3. Methodology and Results

The scope and motivation of this work is to determine the short- and long-term future scenarios for the digital governance of Mediterranean ports through the use of the End-to-End tool. This system consists of a unique End-to-End management and analysis of information from the beginning of a project, offering a complete functional solution.

The End-to-End tool is a methodology that seeks to understand a system, analyzing its history from its creation to the present, and understanding the economic processes both on a small and large scale that have made the project evolve. It basically encompasses from origin to completion, managing the progress of the project by tracking each and every phase of its life.

In this case, the aim is to assess the environment and unique conditions prevalent within the maritime-port sector concerning its digital governance. Furthermore, this tool presents an opportunity to explore potential scenarios for the evolution of digitalization within ports, transcending the present circumstances.

The application of this analytical tool consists of the identification and review of several research factors in order to analyze and then respond strategically to the environment in which the port sector is located. That is, find out what will happen in the near future and use these forecasts as an advantage.

What it seeks is the successful development of a project, establishing the path to reach it and taking into consideration the changing environment in which it is situated (Figure 3).

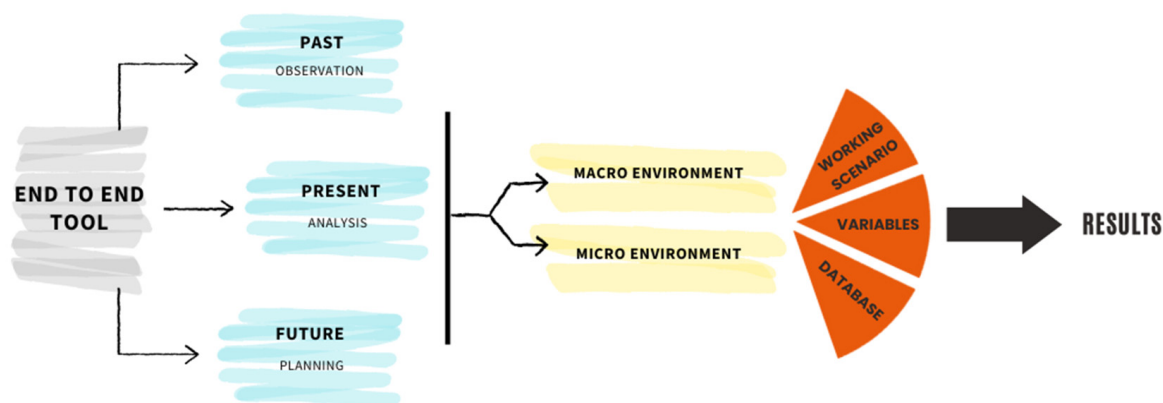


Figure 3. Operation End-to-End tool. Source: (Ramos Velasco et al., 2022 [30]).

### 3.1. Approach to the Application Case

With a comprehensive understanding of digital governance and digitalization in place, the next step is to select the application scenario for the End-to-End tool. This entails carefully choosing the specific context or situation where the tool will be deployed and applied to achieve its intended objectives.

The ports that have been chosen are: Valencia, Barcelona and Algeciras (Spain), Piraeus (Greece), and Genoa (Italy). Some ports of the Mediterranean Sea have been left out of this analysis due to the lack of information, and that is why these ones have been selected, since they will facilitate a coherent analysis with useful results. Figure 4 shows the situation of the selected ports in the Mediterranean.



Figure 4. Selected ports. Source: own elaboration.

### 3.2. Method: Applying End-to-End Tool

#### 3.2.1. Past

It begins with the results obtained from the observation of the past. It displays this in the form of a comparative table of the 5 case studies, on which the following indicators have been evaluated (Table 1):

1. Historical experience
2. Main activity
3. Strategy
4. International relations
5. Technological evolution

Table 1. Analysis of the past of the selected ports. Source: own elaboration.

INDICATORS	Port of Valencia	Port of Piraeus	Port of Barcelona	Port of Algeciras	Genoa Port
Historical experience	Middle Ages	S. V b.C.	Middle Ages	1894	Middle Ages
Principal activity					
Container					
Passengers					

Table 1. Cont.

INDICATORS	Port of Valencia	Port of Piraeus	Port of Barcelona	Port of Algeciras	Genoa Port
Bulk					
Strategy					
Efficiency					
Specialization					
Diversification					
Intermodality					
International relations	Italy, France, Morocco	Italy, Spain, Turkey	Italy, France, Morocco	Africa, Latin America, Mediterranean Sea, Northern Europe	Spain, France, Greece
Technological evolution	5 out of 5	2 out of 5	4 out of 5	3 out of 5	3 out of 5

Following this analysis, it becomes evident that historical trends have propelled the evolution and development of ports towards a more efficient, modern, and technologically advanced future. Embracing this evolution is crucial to avoid stagnation, which could result in market loss and company failure. Therefore, transitioning to digital governance aligns with the evolutionary trajectory that ports have historically followed since their inception.

3.2.2. Present

As already mentioned, to understand the present, a SWOT analysis of the port industry of the Mediterranean Sea has been carried out, studying its Strengths and Weaknesses, its internal characteristics, its Threats and Opportunities, and external characteristics (Figure 5).

<p><b>Strengths</b></p> <p>Strategic location. Modern and diversified infrastructure. Digital adaptation and digital governance Accesibility.</p>	<p><b>Weaknesses</b></p> <p>Competition. Limitations in depth. Capacity for expansion. Passenger traffic. Environmental impacts.</p>
<p><b>Threats</b></p> <p>Competition. Political uncertainty. Changing regulations and transport trends. Environmental impacts</p>	<p><b>Opportunities</b></p> <p>Increasing international demand. Cruise traffic. Infrastructure investments. Accessibility improvement.</p>

Figure 5. SWOT matrix. Source: own elaboration.

With this study, it has been possible to obtain, in a rational way, the ideas that allow us to have an image of the present of the Mediterranean maritime industry. These are:

1. Level of digitalization and digital governance.
2. Environmental impacts
3. Competitiveness and connectivity between ports
4. Infrastructure development

### 3.2.3. Macroenvironment

This section is developed by selecting data in each port based on their latest published reports, as well as articles and other scientific documentation based on their relationship with the environment in which they are currently located [31–33].

Finally, it is expected that the maritime industry of the Mediterranean will continue to grow and that these ports will continue to be key pieces in it, given that they are in a constant process of improvement and adaptation to changes in the environment, showing a proactive attitude towards technological innovation and its extension to administrative departments to achieve complete digital governance, requiring them to face present and future challenges in a transparent, efficient and connected way in real-time. In addition, they are working hard to try to reduce their environmental impacts and achieve demanding environmental standards, a promise that, today, seems difficult, but is necessary to generate the pressure that causes change. This is intended to ensure that ports continue to be an essential part of the development engine of the countries where they are located.

As an example, Table 2 is presented below, which shows the model of the database to be employed.

**Table 2.** Database. Source: own elaboration.

Category	Subcategory	ID	Indicator
Past		Pa_1	Historical experience
		Pa_2	Principal activity
		Pa_3	Strategy
		Pa_4	International relations
		Pa_5	Technological evolution
Present Macro Environment	Economic	MaE_1	Cargo volume
		MaE_2	Number of berths
		MaE_3	Infrastructure investment
	Institutional	MaE_4	Total traffic
		MaI_1	Government investment
		MaI_2	Political stability of a country
		MaI_3	Regional competitiveness
		MaI_4	Transparency
	Sociocultural	MaI_5	Protection of the national port brand
		MaSC_1	Employability
		MaSC_2	Employee training programmes
	Sustainability	MaSC_3	Gender Inclusiveness
		MaS_1	Greenhouse gas emissions
		MaS_2	Energy consumption
		MaS_3	Water consumption
		MaS_4	Biodiversity and habitat
	Technological	MaS_5	Reduction of water consumption (compared to 2019)
		MaS_6	Reduction in energy consumption (compared to 2019)
		MaT_1	Use of ICTs
		MaT_2	Use of AI
MaT_3		Use of Digital Twins	
MaT_4		Use of chatbots	
MaT_5		Metaverse	

Table 2. Cont.

Category	Subcategory	ID	Indicator
	Legal	MaT_6	Digital competitiveness
		MaT_7	Ports using GIS
		MaL_1	Code of Ethics for Port Agencies
		MaL_2	IMO Compendium Regulations
		MaL_3	Corruption Perception Index
Present Micro Environment	Customers	MiCu_1	Digital market
		MiCu_2	Hinterland
	Suppliers	MiS_1	Data management system
		MiS_2	Digital logistics
		MiS_3	Fleet
	Products	MiP_1	Traceability technologies
		MiP_2	Merchandise
	Competitors	MiCo_1	Port performance index
		MiCo_2	Port capacity

### 3.2.4. Microenvironment

The analysis of the microenvironment is composed of indicators whose results are qualitative, unlike many of the macroenvironment indicators, which could be defined by data and statistics. The results of this variable are shown in the following table (Table 3).

Table 3. Microenvironment. Source: own elaboration.

INDICATORS	Port of Valencia	Port of Piraeus	Port of Barcelona	Port of Algeciras	Genoa Port
<b>Customers</b>					
Digital market	3	2	3	3	3
Hinterland	3	3	3	3	3
<b>Providers</b>					
Data management systems	3	2	3	2	3
Digital logists	3	2	3	3	3
Fleet	3	2	3	3	2
<b>Product</b>					
Traceability technologies	3	2	3	2	2
Mercandise	3	3	3	3	3
<b>Competitors</b>					
Port performance index	2	3	4	4	1
Port capacity	4	4	2	3	2

Note: 4-Very high; 3-High; 2-Medium; 1-Limited.

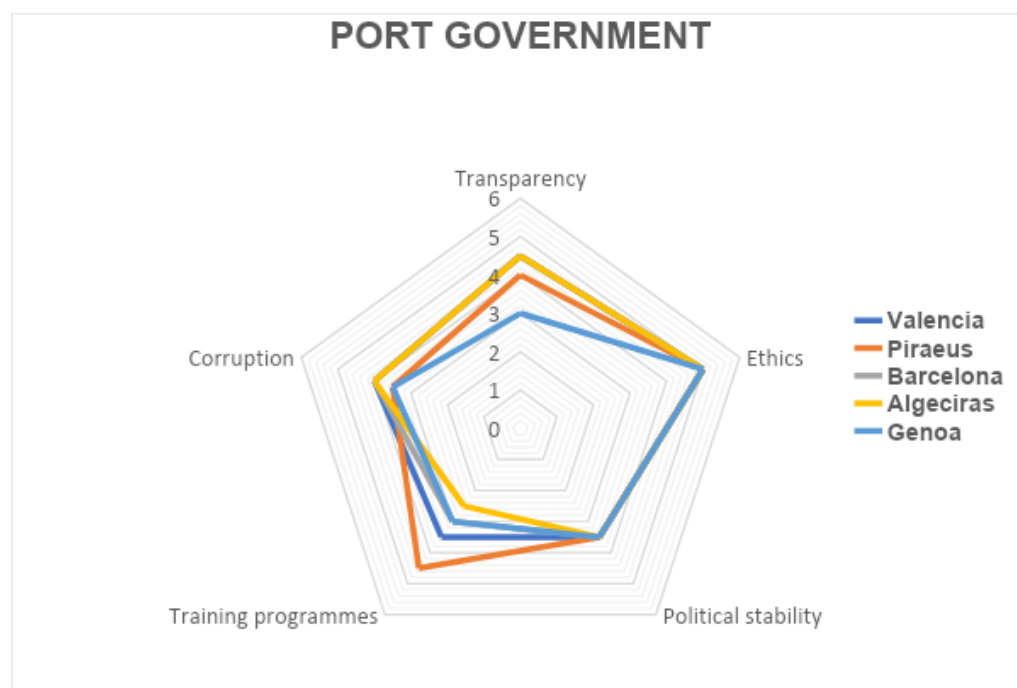
Based on the analysis conducted, it is evident that port development is indeed trending towards the increased digitalization and automation of container loading and unloading processes. Furthermore, there is a growing inclination towards the greater implementation of monitoring and data management technologies within port operations. These trends underscore the industry’s commitment to enhancing efficiency, optimizing resource utilization, and leveraging technology to meet evolving demands and challenges.

Ports are focusing on improving their efficiency and management capacity through technology and innovation. The inherent future of ports lies in continuous improvement and technological implementation, largely driven by competitive pressures. To optimize their operations and maintain a prominent position in the global maritime market, ports must transition to fully digitized governance processes. This shift is imperative to meet the evolving demands of the industry and ensure sustained competitiveness in the international arena.

#### 4. Analysis of Results

Firstly, the model has sought to analyze the port governance through the indicators studied, for which we have analyzed more specifically the level of transparency, its ethics, and the degree of training of employees, as well as the political stability and level of corruption of the countries where they are located, since they directly affect the form of governance of these.

Figure 6 shows that both in terms of transparency and ethics, the ports of the Mediterranean environment are very well positioned, and they have established effective port management systems that promote transparency and ethics in their operations. This is achieved through the implementation of clear policies and standardized procedures that ensure fairness in decision-making. In addition, Mediterranean ports have committed to maintaining high ethical standards in their business activities, including the fight against corruption and bribery. These practices have earned ports the trust of users and operators, solidifying their role as vital shipping and logistics hubs in the region. However, in relation to this it is difficult to understand what will happen in the future, because, although the great importance of ports in these issues is demonstrated, there is no force external to them that encourages or generates the pressure to continue developing.



**Figure 6.** Port governance analysis. Source: own elaboration.

From this analysis, the importance of the security and honesty of the business is deduced, as well as the need for protocols and constant training programs for workers or reskilling, to move from a traditional form of governance to a more innovative one focused on digitalization, which is becoming especially important as can be seen in the following figure, and it is indisputable that it will continue to develop in the coming years.

Figure 7 shows the degree of adoption of the main digitization technologies in the five case studies.

From this analysis, it is clear that the maritime industry is embracing new technologies, and fostering a culture of innovation by studying, developing, and implementing them within the sector. In addition, due to the current global hyperconnection, the fact that ports are advancing on common issues means that they are almost certainly struggling to break the biggest barrier that hinders the maritime industry, which is the disparity in process management elaborated upon in the already known and final point of this research. Digital governance is a process that with its future reach, will solve all the problems associated

with disinformation and lack of homogenization of processes, as well as everything that they entail. These differences and inefficiencies will disappear as technologies, and Artificial Intelligences begin to establish protocols and process standardization programs that facilitate an interoperable maritime industry worldwide.

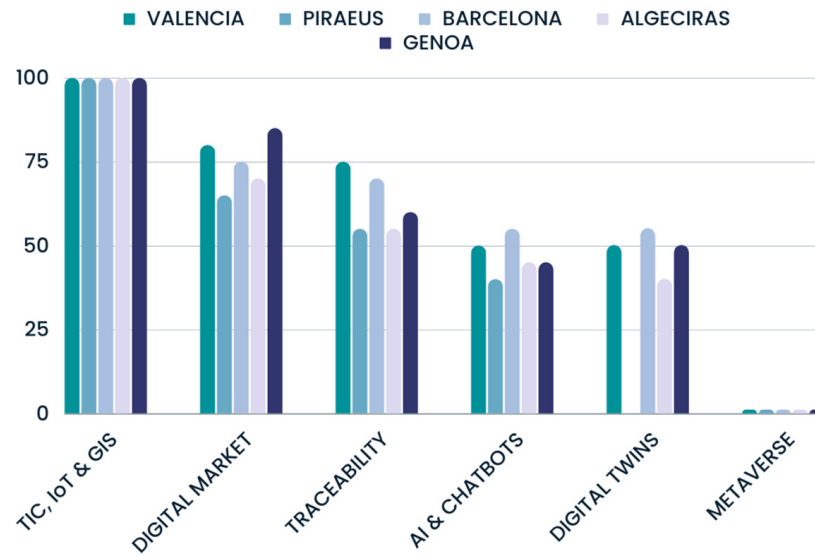


Figure 7. Digital analysis. Source: own elaboration.

Next, the information pertaining to investment in ports, as indicated by governance investment and infrastructure indicators, has been collected, revealing disparities between them (Figure 8). Nevertheless, it is evident that over the years, all the case studies have been striving to adapt to the expanding international trade and global logistics chains to maintain their competitiveness in the Mediterranean region. It is intuited that this practice will continue with the same growing trend due to the need to improve ports either physically or digitally, for which access to economic resources is necessary.

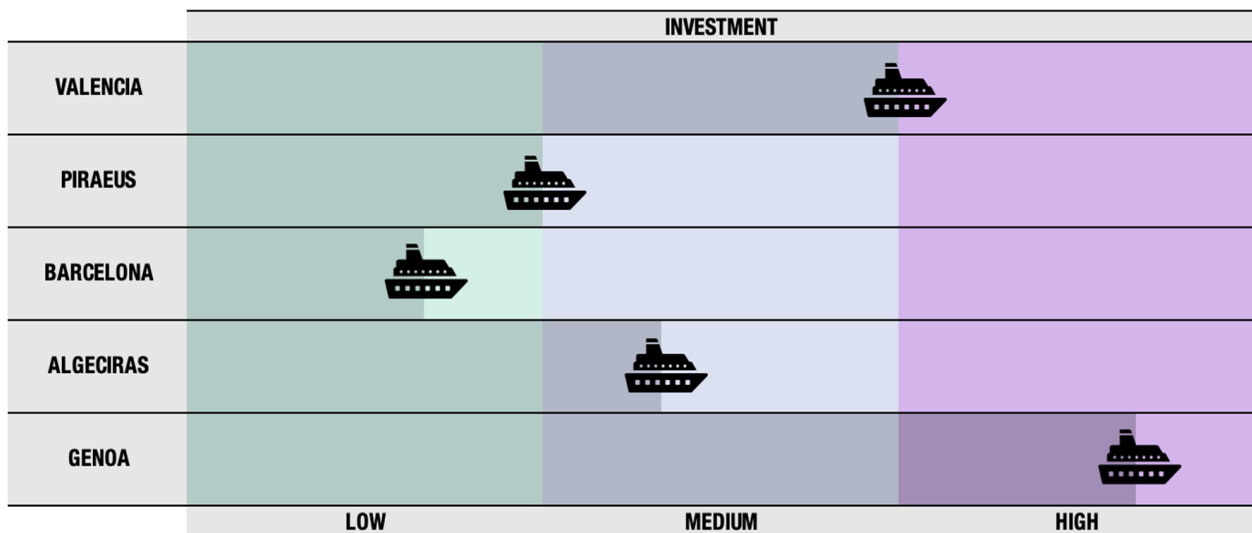


Figure 8. Investment analysis. Source: own elaboration.

This, added to the previous analyses, suggests that access to financing is essential to maintain a position in the market, adapting its work and governance methodologies to the digital world in which the current global panorama is immersed, and which will continue to develop in the coming years.

Another crucial aspect gleaned from the analysis via End-to-End is understanding the success of port businesses, and whether this trend will persist with the pursuit of full digitalization of their administrative departments (Figure 9), for which indicators have been addressed that have certain features in common, more specifically the adaptation to the environment, keeping business protection as a priority.

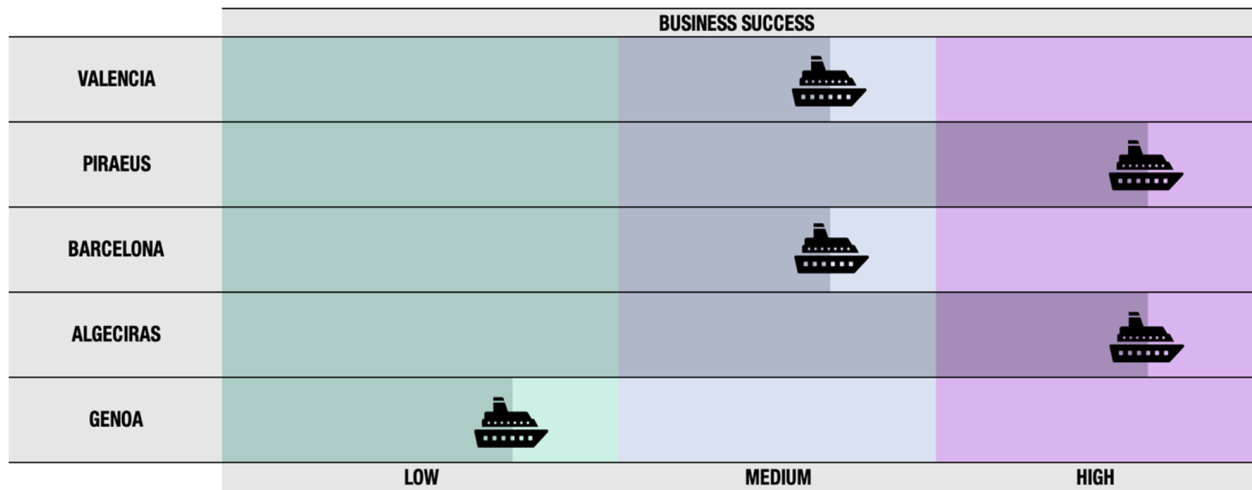


Figure 9. Business success analysis. Source: own elaboration.

The study is expected to continue designing and implementing public policies and promoting private initiatives for the adoption of digital governance, and thus improve the competitiveness of the sector with greater performance, support, and capacity of ports.

The overarching objective of this research is to analyze the present and future state of digital governance. All preceding diagrams have contextualized their data in relation to this parameter, which is logical given that the governance of a port serves as its central function. That is, without governance there is no port and therefore, its form of application must be constantly adapted to the environment and, hence, ports are committed to its digitalization.

Figure 10 shows the fundamental pillars of port digital governance.

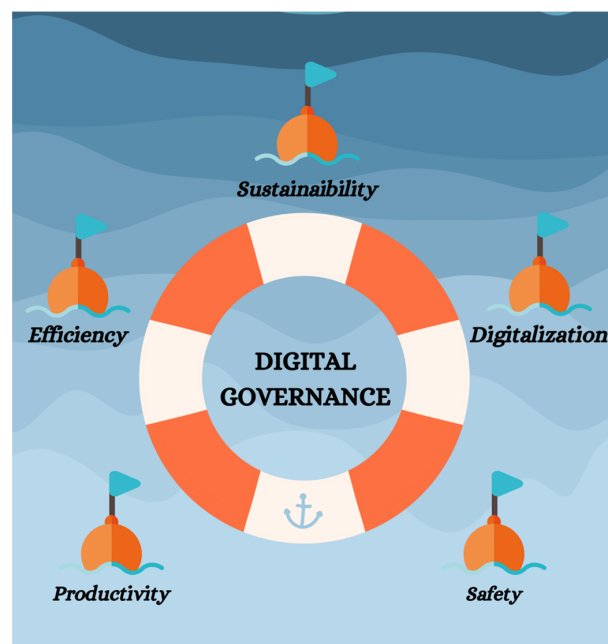


Figure 10. Fundamental pillar digital governance. Source: own elaboration.

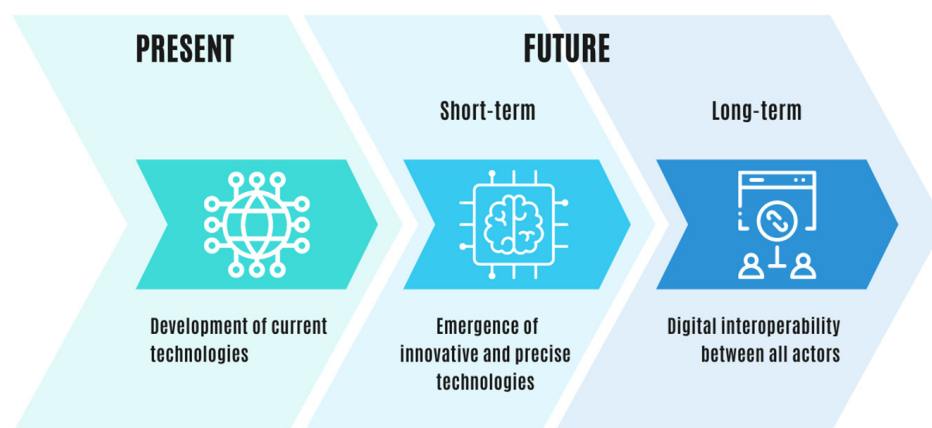
The evaluation has considered aspects such as transparency in management, the accessibility of information, data security, port operation and efficiency in the management of digital resources. Therefore, it has been determined that the port that currently has the best digital governance is Valencia, followed by Piraeus, Barcelona and Algeciras with a very comparable management and, finally, that of Genoa (Figure 11).



**Figure 11.** Ranking of ports. Source: own elaboration.

It is important to remark this classification is not static, but is anticipated to evolve as competition drives the endeavor to enhance digital governance in each port. Consequently, this assessment serves not only as a means to identify leaders in this domain but also as a catalyst to inspire and stimulate the continuous advancement and enhancement of digital governance within the global ports' market.

The success of digital governance in the future will depend on the commitment and collaboration between the agents involved, whether governances, port operators, shipping companies or technology providers. Its interoperability will make it possible to make the most of the opportunities offered by digital transformation, improving efficiency, competitiveness, security and trust in the port sector (Figure 12).



**Figure 12.** Future of digital governance. Source: own elaboration.

The future of digital governance looks exciting and promising, and is contingent on adaptability and strategic vision to address developments and manage them effectively for the benefit of all stakeholders.

Finally, the internal analysis of the port environment reveals common characteristics among the studied ports. All of them have their own digital platforms for electronic

information exchange among maritime agents. Although the ports are connected by European rail corridors, each has unique features in its area of influence, with access to diverse markets and customers.

Regarding suppliers, the ports have implemented advanced data management and digital logistics systems, such as the Navis terminal management system, to optimize container loading and unloading processes. Additionally, they have a wide variety of shipping service providers, including globally recognized companies like Maersk, MSC, and CMA CGM.

In terms of products, the ports are highly competitive and adopt innovative cargo and container monitoring technologies, with Valencia and Barcelona leading in this aspect.

Regarding competition, port performance is assessed in categories such as operational efficiency, infrastructure, capacity, and service quality. The best-performing ports in these areas are Algeciras and Barcelona, followed by Piraeus, Valencia, and Genoa.

In summary, port development focuses on the digitization and automation of processes, as well as the implementation of monitoring and data management technologies. This requires internal process adaptation and high modernization to maintain competitiveness. Ports aim to enhance efficiency and management capacity through technology and innovation, responding to competitive pressures in the international maritime market. The transition to fully digitized port governance processes is crucial to maintain a relevant position in the market.

## 5. Conclusions

Firstly, there has been a clear need to implement e-governance policies and transparency in port management, in order to increase efficiency and improve the quality of services offered to users. Likewise, it has been proven that there is a significant disparity between the different ports in terms of the implementation of management, cybersecurity, and data protection measures, which puts at risk the integrity of the logistics chain, systems and user privacy.

In addition, it has been observed that ports that have implemented advanced technological solutions and efficient digital management have managed to improve competitiveness and increase their attractiveness as a tourist destination and as a place for the development of economic activities related to the transport of goods. On the other hand, the need to establish clear and updated regulatory frameworks has been identified to guarantee the efficient and secure management of data and computer systems in ports.

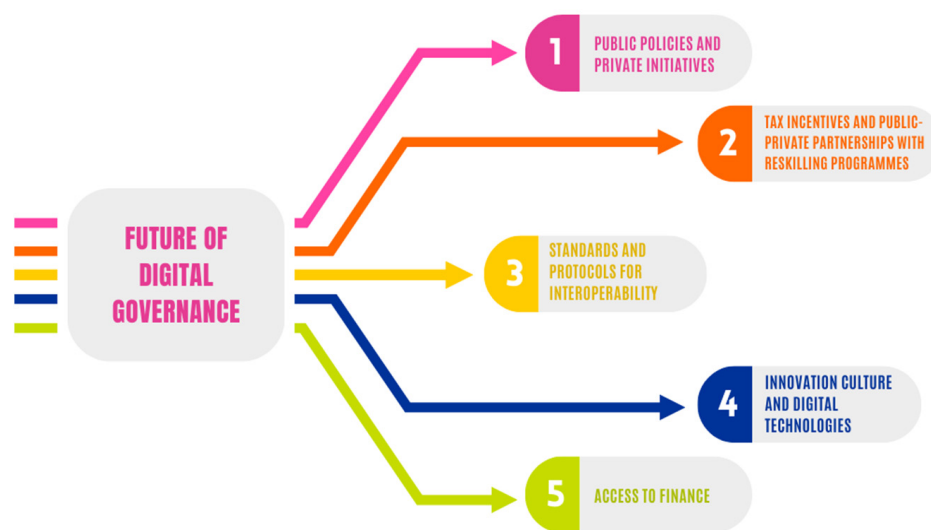
With this, the following ideas have been clarified that have become statements for the future development of digital governance:

- Public policies and private initiatives are essential to foster the adoption of digital governance and enhance the competitiveness of the sector.
- The receipt by the ports of fiscal incentives and the promotion of public–private collaborations with continuous training and reskilling programs.
- The proclamation and adoption of standards and protocols for the interoperability of port management systems.
- The promotion of a business culture that promotes the innovation and adoption of digital technologies for the correct management of data or infostructure.
- Access to necessary financing due to the presence of high costs associated with the implementation of the measures in question.

The ultimate goal of digital governance should be none other than to achieve maximum efficiency and productivity, based on sustainable measures to respect the environment and maintain a level of security in accordance with the highly established standards of information management: the most critical and strategic resource today, indispensable for the development of any sector.

The development of these premises will lead to the future success of digital governance that will depend on the commitment and collaboration of agents, taking advantage of the opportunities offered by digital transformation, improving the efficiency, competi-

tiveness and confidence of the port sector. This indicates a promising future, as long as the adaptation and strategic vision are managed properly, and without forgetting the premises necessary for a correct development, as shown in Figure 13.



**Figure 13.** Keys to the future development of digital governance. Source: own elaboration.

In the future, it is probable that we will want to delve deeper to a broader level in order to continue with the study trend. It is hoped that the tool will soon be used again to analyze an even more international environment, consistent with the present importance of globalization. To execute this, it will be necessary to look for ways and tools to overcome the limitations that, today, restrict the available information, such as the increasingly developed Artificial Intelligence, or other types of tools that allow for greater communication and transparency with the world's port authorities.

Finally, as the conclusion of the research of the study ports, it has been determined that the level of development of digital governance is higher in Valencia, followed by Piraeus, Barcelona and Algeciras, practically on par with each other, and finally that of Genoa. All of them are ports that are still classified as having state-of-the-art and admirable digitized administrative systems worldwide, which reflect that the classification is dynamic and will change as ports incorporate new and innovative management systems. After this, it is concluded that digital governance will continue to develop as a key piece, not only in these ports, but in all those who want to remain part of the current changing global landscape.

**Author Contributions:** Conceptualization, A.R.V. and N.G.-C.; methodology, A.R.V., N.G.-C. and J.V.-C.; software, A.R.V.; validation, A.C.O. and N.G.-C.; formal analysis, A.R.V. and J.V.-C.; investigation, A.R.V. and N.G.-C.; resources, N.G.-C.; data curation, A.R.V. and A.C.O.; writing—original draft preparation, A.R.V.; writing—review and editing, J.V.-C.; visualization, A.R.V.; supervision, N.G.-C. and A.C.O. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Data Availability Statement:** The data is found, according to protocols established by the university, in the department in which the professors are part. If any reader is interested in expanding their knowledge, please do not hesitate to contact the authors.

**Conflicts of Interest:** The authors declare no conflict of interest.

### Abbreviation

EDI	Electronic data interchange
PCS	Port community system
TOS	Terminal Operator system
ONU/EDIFACT	Electronic Data Interchange for Administration, Trade and Transport.

RFID	Radio Frequency Identification
GPS	geographic position system
IoT	Internet of things

## References

- Gómez Díaz, C.; González-Cancelas, N.; Camarero Orive, A.; Soler Flores, F. Digital Governance Approach to the Spanish Port System: Proposal for a Port. *J. Mar. Sci. Eng.* **2023**, *11*, 311. [CrossRef]
- Camarero, A.; Cancelas, N.G.; Verdesoto, V. Impact of COVID-19 on the cost of technical services in European ports. In Proceedings of the Institution of Civil Engineers-Maritime Engineering, Online, 24 March 2022; Thomas Telford Ltd.: London, UK, 2022; pp. 3–13.
- Port Economics, Management and Policy. Routledge & CRC Press: London, UK. Available online: <https://www.routledge.com/Port-Economics-Management-and-Policy/Notteboom-Notteboom-Pallis-Pallis-Rodrigue-Rodrigue/p/book/9780367331559> (accessed on 29 April 2024).
- González-Cancelas, N.; Serrano, B.M.; Flores, F.S.; C-Majolero, N. Diagnosis of the digitalization of the Spanish ports: End to End tool. *World Sci. News* **2021**, *155*, 47–64.
- Clemente, D.; Cabral, T.; Rosa-Santos, P.; Taveira-Pinto, F. Blue Seaports: The Smart, Sustainable and Electrified Ports of the Future. *Smart Cities* **2023**, *6*, 74. [CrossRef]
- Cancelas, N.G.; Cabrero, J.V.; Orive, A.C. Metaverse in Spanish ports as a high impact solution. *World Sci. News* **2023**, *181*, 145–163.
- Cancelas, N.G.; Serrano, B.M.; Flores, F.S. Federated Learning for Spanish Ports as an Aid to Digitization. *J. KONBiN* **2021**, *51*, 1–17. [CrossRef]
- Vaia, G.; Arkhipova, D.; DeLone, W. Digital governance mechanisms and principles that enable agile responses in dynamic competitive environments. *Eur. J. Inf. Syst.* **2022**, *31*, 662–680. [CrossRef]
- Belmoukari, B.; Audy, J.-F.; Forget, P. Smart port: A systematic literature review. *Eur. Transp. Res. Rev.* **2023**, *15*, 4. [CrossRef]
- Tijan, E.; Jović, M.; Aksentijević, S.; Pucihar, A. Digital transformation in the maritime transport sector. *Technol. Forecast. Soc. Chang.* **2021**, *170*, 120879. [CrossRef]
- Min, H. Developing a smart port architecture and essential elements in the era of Industry 4.0. *Marit. Econ. Logist.* **2022**, *24*, 189–207. [CrossRef]
- Lun, Y.V.; Lai, K.; Cheng, T.E.; Yang, D. New Technology Development in the Shipping Industry. In *Shipping and Logistics Management*; Springer: Berlin/Heidelberg, Germany, 2023; pp. 257–279.
- Notteboom, T.; Pallis, T.; Rodrigue, J.-P. Disruptions and resilience in global container shipping and ports: The COVID-19 pandemic versus the 2008–2009 financial crisis. *Marit. Econ. Logist.* **2021**, *23*, 179–210. [CrossRef]
- Acciaro, M.; Renken, K.; El Khadiri, N. Technological change and logistics development in European ports. In *European Port Cities in Transition*; Springer: Berlin/Heidelberg, Germany, 2020; pp. 73–88.
- Senyo, P.K.; Effah, J.; Osabutey, E.L.C. Digital platformisation as public sector transformation strategy: A case of Ghana’s paperless port. *Technol. Forecast. Soc. Chang.* **2021**, *162*, 120387. [CrossRef]
- Othman, A.; El-gazzar, S.; Knez, M. A framework for adopting a sustainable smart sea port index. *Sustainability* **2022**, *14*, 4551. [CrossRef]
- Kapkaeva, N.; Gurzhiy, A.; Maydanova, S.; Levina, A. Digital Platform for Maritime Port Ecosystem: Port of Hamburg Case. *Transp. Res. Procedia* **2021**, *54*, 909–917. [CrossRef]
- Yang, D.; Wu, L.; Wang, S.; Jia, H.; Li, K.X. How big data enriches maritime research—A critical review of Automatic Identification System (AIS) data applications. *Transp. Rev.* **2019**, *39*, 755–773. [CrossRef]
- Secinaro, S.; Brescia, V.; Iannaci, D.; Jonathan, G.M. Does Citizen Involvement Feed on Digital Platforms? *Int. J. Public Adm.* **2022**, *45*, 708–725. [CrossRef]
- Dev, N.K.; Shankar, R.; Qaiser, F.H. Industry 4.0 and circular economy: Operational excellence for sustainable reverse supply chain performance. *Resour. Conserv. Recycl.* **2020**, *153*, 104583. [CrossRef]
- Attaran, M. Digital technology enablers and their implications for supply chain management. *Supply Chain Forum. Int. J.* **2020**, *21*, 158–172. [CrossRef]
- Gerlitz, L.; Meyer, C. Small and Medium-Sized Ports in the TEN-T Network and Nexus of Europe’s Twin Transition: The Way towards Sustainable and Digital Port Service Ecosystems. *Sustainability* **2021**, *13*, 4386. [CrossRef]
- Ahmad, R.W.; Hasan, H.; Jayaraman, R.; Salah, K.; Omar, M. Blockchain applications and architectures for port operations and logistics management. *Res. Transp. Bus. Manag.* **2021**, *41*, 100620. [CrossRef]
- Inkinen, T.; Helminen, R.; Saarikoski, J. Port Digitalization with Open Data: Challenges, Opportunities, and Integrations. *J. Open Innov. Technol. Mark. Complex.* **2019**, *5*, 30. [CrossRef]
- Raza, Z.; Woxenius, J.; Vural, C.A.; Lind, M. Digital transformation of maritime logistics: Exploring trends in the liner shipping segment. *Comput. Ind.* **2023**, *145*, 103811. [CrossRef]
- Inkinen, T.; Helminen, R.; Saarikoski, J. Technological trajectories and scenarios in seaport digitalization. *Res. Transp. Bus. Manag.* **2021**, *41*, 100633. [CrossRef]
- 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. [CrossRef]

28. Lappalainen, A.; Rosenberg, C. Bridging the digital divide: Success depends on content provider and application developer involvement [point of view]. *Proc. IEEE* **2021**, *109*, 2–10. [[CrossRef](#)]
29. Orive, A.C.; Santiago, J.I.P.; Corral, M.M.E.-I.; González-Cancelas, N. Strategic Analysis of the Automation of Container Port Terminals through BOT (Business Observation Tool). *Logistics* **2020**, *4*, 3. [[CrossRef](#)]
30. Velasco, E.R.; González-Cancelas, N.; Orive, A.C.; Díaz-Gutiérrez, D. Green Ports Analysis Using an End-to-End Tool Application in the Fishing Port of Vigo. *J. Mar. Sci. Eng.* **2022**, *10*, 1959. [[CrossRef](#)]
31. Barcelona es el Principal Puerto de Cruceros del Mediterráneo y de Europa con 2.68 Millones de Cruceristas y 758 Escalas en 2016 | Red Social de Cruceros | Nudoss.com. Available online: <http://nudoss.com/barcelona-principal-puerto-de-cruceros-del-mediterraneo-y-de-europa/> (accessed on 13 May 2024).
32. Amministrazione Trasparente Autorita' Di Sistema Portuale Del Mar Ligure Occidentale—Gazzetta Amministrativa. Available online: [https://ww2.gazzettaamministrativa.it/opencms/opencms/\\_gazzetta\\_amministrativa/amministrazione\\_trasparente/\\_liguria/\\_autorita\\_\\_di\\_sistema\\_portuale\\_del\\_mar\\_ligure\\_occidentale/](https://ww2.gazzettaamministrativa.it/opencms/opencms/_gazzetta_amministrativa/amministrazione_trasparente/_liguria/_autorita__di_sistema_portuale_del_mar_ligure_occidentale/) (accessed on 13 May 2024).
33. Platias, C.; Spyrou, D. EU-Funded Energy-Related Projects for Sustainable Ports: Evidence from the Port of Piraeus. *Sustainability* **2023**, *15*, 4363. [[CrossRef](#)]

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.