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Smart port: a systematic literature review

Basma Belmoukari[1*], Jean-François Audy[2] and Pascal Forget[3]

Abstract

Considered an essential link in the logistics chain, the port has undergone various restructurings and evolutions throughout generations. Many economic, socioeconomic, political, and environmental factors require ports to move towards digitalization and sustainability. To this end, ports are required to change into smart ports that align with new Industry 4.0 practices to ensure their sustainability. This study proposes a systematic review of the literature on the emerging smart port concept to continue the work started by Buiza et al. and Molavi et al., aiming at a broader and comprehensive understanding of the smart port concept by business domain to fill this gap in literature. This research proposes 11 smart port characteristics grouped into 7 business domains. A definition is also proposed to update the concept.

Keywords Smart port, Port 4.0, Digital transformation, Maritime transport, Port of the future

1 Introduction

The seaport is a complex system [39] that plays a driving force role [55, 57] in the functioning of an open economy [28]. Ports play a crucial role in global supply chain performance [17, 55] as well as regional and national economic growth [7, 52, 56]. Approximately 90% of global trade is carried by sea [6, 46, 53, 56].

Today's global economy is characterized by rapid development and market liberalization [5, 49], which has led to competition between ports [9, 39, 49] and an awareness of environmental challenges [8, 39, 40]. These challenges have exacerbated and required ports to be increasingly modern [19] and strive for transformation [8, 39, 49]. The smart port concept solves these current and future challenges [20]. For this reason, many port authorities around the world are investing in smart ports [17, 23, 39].

*Correspondence:
Basma Belmoukari
basma.belmoukari@uqtr.ca
[1] Département de Management, Université du Québec À Trois-Rivières, 3351, Bd des Forges, Trois-Rivières, QC G8Z 4M3, Canada
[2] Interuniversity Research Center on Enterprise Networks, Logistics and Transportation (CIRRELT), 2325, rue de la Terrasse, Quebec City, QC G1V 0A6, Canada
[3] Département de Génie Industriel, Université du Québec À Trois-Rivières, 3351, Bd des Forges, Trois-Rivières, QC G8Z 4M3, Canada

Various authors believe that an effective, efficient [21, 40], safe, and sustainable port [21, 28, 40] creates added value [20] and places emphasis on customer satisfaction [5, 21, 28]. The intelligent port is an alternative for effective decision support [18, 39] through the mobilization of new information and communication technologies (ICT) and decision support systems [21].

Although there is a growing interest in the smart port concept in scientific and professional literature, no clear definition has been proposed until now. This article presents a comprehensive review of the scientific literature on the smart port concept to expand its understanding and propose a definition that is integrated into the various visions of the scientific community. The remainder of the paper is divided into four sections: a description of port evolution throughout generations; a description of the systematic review methodology; a proposal for a smart port definition by activity domain; and a conclusion.

2 The port in transformation

The port is an essential link in the logistics chain that has evolved throughout generations [8]. Each generation of ports has been created in response to many changes in the global economy [26]. Numerous authors describe these different generations of ports from the first to the fifth generation. However, only definitions of the first

three generations have a consensus in the literature. In 1992, the United Nations Conference on Trade and Development (UNCTAD) developed a conceptual model to characterize these three generations [4]. The first generation of ports covered the period before the 1950s [36] and represented basic port activities [43], i.e., the loading and unloading of ships, as well as the transport of goods and bulk cargo [36, 39, 52] to ensure a land-sea link [58]. For this generation, the port was independent and operated in isolation from the commercial activities, such as port promotion, and the interface activities between land and sea transport [4, 26]. In addition, there was a lack of coordination and connection between the many port services [26].

The second generation of ports appeared between the 1960s and 1980s [36] and was characterized by the start of computerization and industrialization by way of industrial facility construction that connected the port to its hinterland [4, 26]. The port became a service center providing different services with added value through the integration of the commercial and industrial function [26, 52]. However, the various port operations were not coordinated [26], though a close relationship had developed between the port and the transport and trade partners [4]. The industrialization era had negative consequences for the environment [26].

Driven by the containerization of goods and intermodal transport [4], a third generation appeared in the 1980s [26, 52]. Ports turned into logistics centers [36] characterized by international trade development and intermodal transport platforms, where the port and the terminal were integrated [4]. This generation made it possible to support and increase international trade [8, 52]. The services offered represented a very wide and diversified range of value-added services [4, 26] such as packaging, warehousing, handling, and distribution [43, 52, 58]. This period was also characterized by the rapid development of information technology and the appearance of electronic data interchange systems [4, 26], hence the beginning of bilateral electronic data exchange with customers. It was also at this time that environment protection measures in port operations began [4]. All these changes contributed to the increase in transported volumes [26]. This third generation has generated an increase in the volume of transport. The port needed additional road and rail links, connections to storage facilities, and resource optimization to absorb this additional volume and best meet the needs of users. The implementation of electronic data interchange systems has resulted in the need for Internet communication and regulations for secure operations. Finally, the port has established a relationship with the surrounding city to support its operations [26].

The fourth generation was the birth of the smart port, where the port has become a connected network [43, 58], as these various stakeholders have now been linked by a common port administration [52]. The port has also been described as a logistics platform that collects, stores, analyzes, and shares data in real time [36]. It also plays the role of a regional port, also called a port hub, that transports cargo to smaller peripheral ports by sea and acts as a gateway to manufacturers [26] through its digital interconnection with other ports [8, 45]. This new role requires private and public sector collaboration [26]. The fourth-generation port mobilizes smart technologies and innovative managerial practices [43]. In the same continuity, numerous authors link the fourth-generation port to the emergence of Industry 4.0 [45, 47], whereas some authors argue that the consideration of sustainable development sets this generation apart from previous ones [47]. This port development requires highly qualified personnel and safety and security device implementation to ensure port operations function properly [26].

According to some authors, the fourth-generation port model does not sufficiently reflect contemporary port functions and the latest port developments, hence the need for a new generation [32]. This fifth generation emerged in the 2000s. In this generation, ports are constantly innovating and using advanced technologies [36]. In 2011, Flynn et al. [16] provided the first definition of a fifth generation, describing it as a port focused on total customer satisfaction through port operations performance. Lee and Hu [33] supported the proposal of Flynn et al. [16] and explained that the port should be customer oriented and provide high-quality services to meet the needs of its customers. However, Wong et al. [52] criticized this definition, arguing that this change is not significant and strategic, but rather organizational. They described the fifth-generation port as the port that builds partnerships (customer port) through mutual planning and decision making, not a port that solely emphasizes customer satisfaction [52]. Lee and Lam [34] also made changes to the original proposal of Flynn et al. [16] in a case study examining major container ports in Asia, namely Busan, Hong Kong, Singapore, and Shanghai. Lee and Lam concluded that the fifth-generation port must be able to structurally manage and plan for local and regional community concerns beyond being customer-centric [32].

Other authors define the fifth-generation port as a smart port that not only places emphasis on its customers but also cares about the community [43, 58]. According to Kraszewski [26], the added value of the fifth generation is that the port is customer and local community oriented. In a similar vein, Lee et al. [32] applied a multi-criteria decision support method based on five key

aspects: service, technology, cluster, sustainable development, and transshipment centers. Each aspect contained criteria to evaluate and measure fifth-generation port performance, enabling the review of the fifth-generation port model and highlighting differences between the fourth and fifth generations. In the service aspect, the fifth generation emphasizes customer satisfaction and effective stakeholder management. In the technology aspect, system resilience and advanced infrastructures, such as SWS and RFID (radio frequency identification), become more important than in the fourth generation. The sustainability aspect must be aligned with new global regulations and requirements imposed on the maritime sector, as well as the interest of the community and the city surrounding the port [34]. Karas [27] defined the fifth-generation port as a logistics hub in the form of a platform that connects all stakeholders [26] to exchange data in real time to provide efficient handling services [27]. The fifth-generation port relies on smart and sustainable technologies and equipment [8, 27, 45, 58] to support data exchange and collaboration with many ports [58]. For Karas [27], only the ports of Rotterdam, Shanghai, and Singapore have reached the fifth generation to date, while other authors believe that only some ports in Asia have reached this generation [25].

Some authors have mentioned the possibility of a sixth generation. According to a predictive study by Notteboom and Rodrigue [26, 27], the sixth generation would be based on three characteristics: i) reaching a handling capacity of 50,000 twenty-foot equivalent units (TEU) of container ships, with a maximum draft of 20 m; ii) complete terminal automation; and iii) intermodal link management with the hinterland. Karas [27] added the increase in storage areas and yards to these characteristics with the help of new innovative technologies. To date, Karas [27] has said that no port has reached this generation.

It should be noted that each port is unique in its pace of transition and evolution from one generation to another [4] and that port development cannot be frozen in specific years. Currently, only about 60 fourth-generation ports are spotted, mainly in Europe and Asia, whereas another 200 ports have planned to migrate to a smart port in the next five years [41].

Although the model of the first three generations developed by UNCTAD is mature, it was criticized by the European Transport Commission in its review of the organization of work in ports in 1999 [26]. The authors considered the model to be incomplete because it did not consider work cultures, health, safety, environment, ownership, and governance, and the UNCTAD categorization of generations based on cargo type could not be a ranking attribute, as a port might handle different types of cargo [26].

In light of the context presented above, the fifth generation would be only a continuation of the fourth generation. Lee and Lam [34] conducted many studies with various methodological approaches to revise the Flynn et al. model [16] and better understand the fifth-generation concept. Lee and Lam [34] concluded that the fourth generation was insufficient because it did not reflect all port operations and services, and the fifth-generation literature was not yet well established and scarce.

According to a 2018 study by McKinsey & Company, 80% of new port projects in the next five years are aimed at creating smart ports [37]. Despite acquiring interest in the scientific community, few researchers have attempted to define the smart port [39]. There is no consensus to define this concept [39] nor a clear and precise definition [27] among researchers. Buiza et al. [7] present a smart port definition based on business domains. This definition was reviewed by Molavi et al. [39] in 2020, who defined a new framework of activity domains and asked researchers to conduct additional research to add new activity domains to the smart port concept for a complete and broad understanding. Based on this observation, this paper aims to propose a broad and comprehensive understanding of the smart port concept by researching new business domains and revisiting the work started by Buiza et al. [7] and Molavi et al. [39], and presenting a clear definition of smart port based on a comprehensive literature review.

3 Methodology

Two main methods are used to define a concept: a definition based on ad hoc interviews with stakeholders and a definition based on literature review and analysis [30]. This article has adopted the latter—a rigorous and structured systematic review of the scientific literature—that enables us to pinpoint articles and derive a clear definition []. The aim of this systematic review is to provide the scientific community with a complete understanding of the smart port concept.

The synthesis of this literature is presented in the form of classification according to port activity domains to revisit the work of Buiza et al. [7] and Molavi et al. [39]. This review is carried out following the methodology proposed by Denyer and Tranfield [11] in five steps: (1) review and formulation of the research question; (2) location of studies; (3) selection and evaluation of studies; (4) analysis and synthesis; and (5) results.

In the first step, we need to define a smart port. To establish a complete state of knowledge and provide a complete understanding of the smart port concept, all

names associated with the smart port will be considered, i.e., smart port, fifth-generation port, digital port, port 4.0, modern seaport, fourth-generation port, and port of the future.

The second step identifies previous studies, searching scientific databases using defined keywords. In this literature review, the following databases were used: Scopus, ABI, EBESCO, Emerald Insight, and Science Direct. These databases were chosen because of the number of accessible articles and peer review; the third step defines a set of inclusion criteria to ensure a transparent selection of identified studies (see Tables 1 and 2).

We analyzed the remaining 789 articles after removing the 233 duplicate articles. This analysis enabled us to select articles that aimed to provide an understanding of the smart port concept based on the title of the article and the abstract. As a result of this analysis, 70 articles were selected for this systematic review. Figure 1 shows the details of the article selection.

From these 70 selected papers between 2016 and 2020, there is a marked increase in scientific community interest in the smart port concept, as presented in Fig. 2.

The fourth step analyzes and synthesizes selected studies to highlight emerging smart port characteristics for an overall understanding of the concept, whereas the fifth and final step classifies characteristics defined in the literature by activity domain—in the fourth step—to revisit the preliminary concept definitions in the works of Buiza et al. [7] and Molavi et al. [39]. The objective is to present a clear and revised definition of the smart port by activity domain and propose new research questions that can be brought to the attention of researchers [3]. Steps 4 and 5 are presented in Sect. 2.

4 Literature review and synthesis of identified articles

The smart port concept is constantly evolving over time [27]. Consequently, the smart port definitions laid out in the literature are presented here in chronological order to note their evolution over time and identify the characteristics that emerge from one year to the next.

In 2011, Keceli [29] argued that smart ports, also called modern ports, have become transshipment centers (hub ports) that invest in infrastructure to compete and improve operations. This transition requires collaboration and buy-in from stakeholders to avoid delays, failures, and additional costs [24, 29].

In 2013, according to Wu et al. [53], the smart port is based on the computerization and digitization of documents (dematerialization). The port offers innovative services and solutions by sharing dynamic information in real time between stakeholders, thereby enabling efficient and sustainable decision-making. These authors also present two complementary definitions of the intelligent

Table 1 Inclusion criteria of the reviewed articles

Criteria	Definition of the criteria	Criteria included
Language	Aim for internationally published documents	English and French
Research period	Period of identifying articles	September 25 to 28, 2020
Type of items	Aim for quality of published articles	Peer-reviewed scientific articles
Publication period of the articles	This period represents the emergence of the intelligent port concept	From 2010 to September 2020

Table 2 Number of articles found by keywords used and database searched, applying the inclusion criteria

Keywords	Scopus	ABI	EBESCO	Science Direct	Emerald Insight	Total
"Maritime transport development" OR "smart port" OR "modern seaport" OR "port of the future" OR "port 4.0" OR "intelligent port" OR "port intelligent" OR "port de futur"	119	45	18	231	15	428
"Digital transformation" AND "maritime transport"	4	28	0	27	12	71
"Digital transformation" AND "seaport"	6	12	0	10	6	34
"Digital transformation" AND "port"	15	134	5	117	68	339
"Future advanced information and communication technologies" AND "port"	0	0	21	0	1	29
"Digital transformation" AND "maritime"	21	40	1	42	24	128
"Transformation numérique" AND "port"	0	0	0	1	0	1
Total						1022

The total review yielded a total of 1022 articles

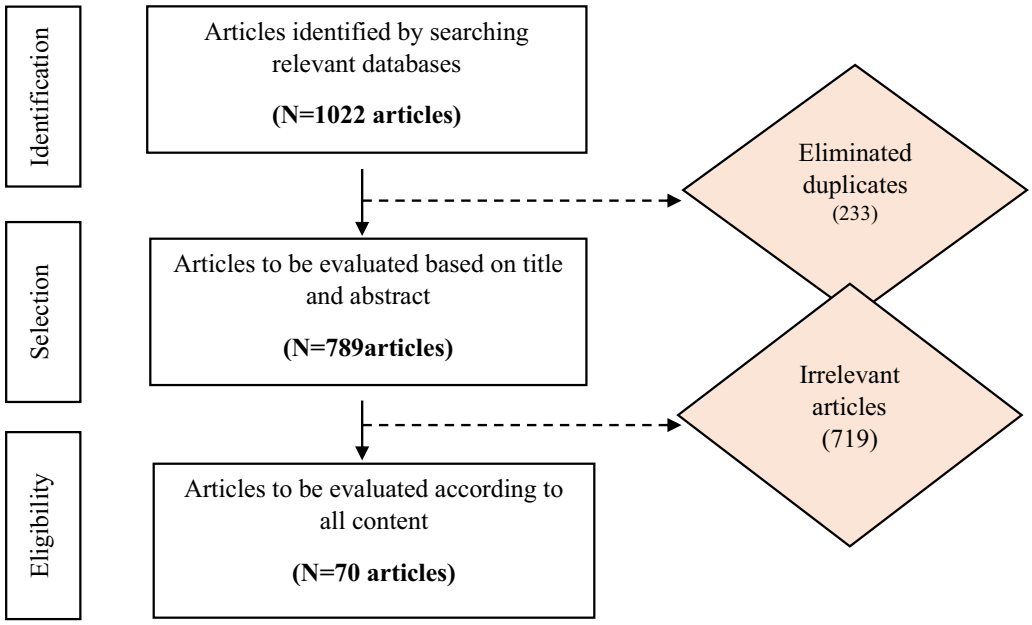

Fig. 1 Selection and evaluation of reviewed articles

port: a connected and automated port equipped with intelligent technologies that enable efficient traffic and information flow management, and a port based on computerization and dematerialization to provide efficient services at lower costs and seamless communication between ports. Other authors have linked the smart port concept to a comprehensive monitoring and visualization system that enables real-time information flow management, optimal production planning, and increased traceability and security [54].

However, in 2014, Duin et al. considered the smart port a fully automated container handling [13], whereas. Williams et al. [51] defined the port as a harbor offering new and efficient services in a platform shared among stakeholders in real time.

The literature review by Buiza et al. [7], proposed in 2015, highlighted the energetic, environmental, and operational characteristics that defined the smart port. Innovative technological configuration and automation were two characteristics added to the authors' article. Both characteristics will make it possible to improve productivity, data sharing, and port operation efficiency at lower costs. According to these authors, operational activities, technologies, and infrastructures are getting more attention from port authorities than energy and environmental aspects. In the same year, other authors described the smart port as a logistics information center enabling intelligent management of transport and traffic systems as well as real-time information sharing [49].

The smart port concept evolved as a logistics network in 2017, where all land and sea segments were connected and integrated [10]. Other researchers have defined the smart port as a modern port equipped with new information technologies that are part of a sustainable context. These researchers also considered citizens' quality of life, environmental protection, and local culture development as pillars of the smart port [42]. Heilig et al. [21] indicated that the intelligent port was based on NICT mobilization real-time data exchange, which is a competitive advantage. In the same vein, Fernandez et al. [15] presented the intelligent port as a system for visualizing and managing collected data that mobilizes technologies, computer architectures, and software for efficient and predictive decision making [12]. Heuermann et al. [22] described the smart port as connected, automated, and controlled by artificial intelligence. Finally, other authors [52] identified four pillars for smart port classification: (i) investment in new facilities and infrastructure; (ii) implementation of global security regulations, requirements, and initiatives such as port security enhancement programs initiated by the United States (for example, Customs-Trade Partnership Against Terrorism (C-TPAT) and Container Security Initiative (CSI); (iii) adoption of NICTs as a competitive advantage to enable information sharing and the design of customized applications to customers; and (iv) horizontal and vertical supply chain integration through innovative and collaborative strategies and partnerships in joint venture business development. To ensure that the smart port project and maritime

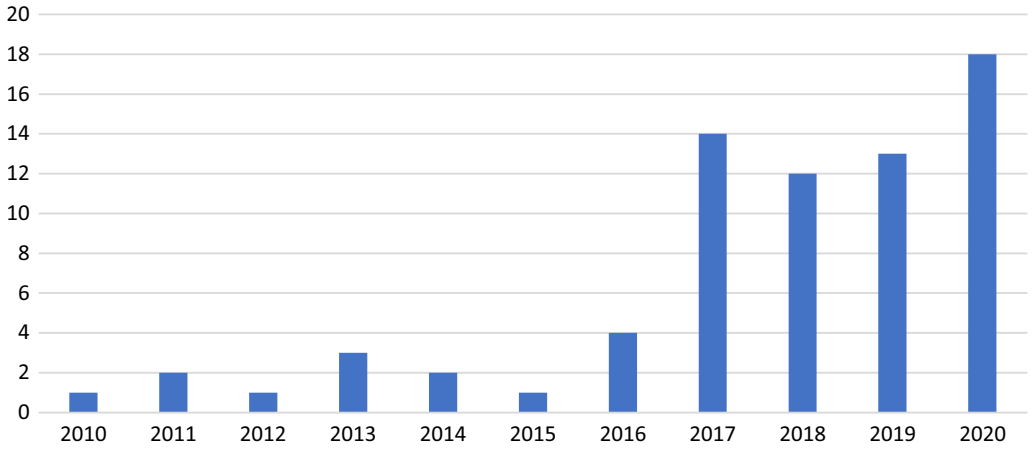

Fig. 2 Number of articles by year of publication

sector development are successful, a program of training, learning, and personal skill development must be developed [12].

The smart port became related to real-time data sharing and automation in 2018 by way of infrastructure mobilization, innovative technologies, and solutions [23]. According to Swuying et al. [36], the smart port was based on innovative ICT mobilization, cutting-edge technologies, artificial intelligence, and automation to make effective and predictive decisions. The smart port is also considered as a sustainable port to respond to naval gigantism, safety and security requirements and regulations, and cares about the citizen [38]. Other authors described the smart port as a connected port that protects the environment and mobilizes innovative technologies for business process and information flow management [43]. Finally, the smart port is made up of qualified personnel involved in the culture and strategy of innovation [28].

In 2019, the smart port was a sustainable port that complied with environmental regulations and standards and mobilized automation technologies designed to increase productivity and safety [47]. According to Lacalle et al. [31], the smart port adopts innovative technologies that enable predictive decision making and implements tools to measure and mitigate adverse environmental impacts. Other researchers defined the smart port as a sustainable port, where operations are connected and linked through ICT mobilization, process and equipment automation, and energy resource optimization [8]. Jovic et al. [25] considered the smart port as a connected and automated port that shared real-time data collected between stakeholders and developed port-port and port-stakeholder collaborations. According to Feja et al. [35], the smart port is a sustainable port that jointly invests with its stakeholders in innovative and sustainable infrastructure and equipment to get attention among the competition. The port provides a healthy and safe working environment, contributes to environmental protection, and guarantees security against cyber threats and vulnerabilities. According to these authors, pioneering smart ports are in Rotterdam, Singapore, and Antwerp. In the same vein, the smart port is a set of information and goods flows shared between port actors continually [14]. It is also an intelligent port equipped with NICTs and innovative infrastructures to promote transparency between stakeholders and environmental protection. Finally, it enables efficient intermodal integration that contributes to accident reduction with the help of scheduling planning and predictive decision making [17].

In 2020, the smart port became part of the smart city concept made up of a set of companies and ecosystems based on digitization and the mobilization of advanced and sustainable technologies. It made port operations effective and efficient, contributed to continuous improvement, and added value. Transformation towards a smart port was determined by a number of political, environmental, economic, and port-specific factors depending on its composition and stakeholders [27]. Adepoju [1] argues that the smart port requires significant public and private investments to make the transition. According to Yau [58], a smart and efficient port mobilizes ICT and innovative infrastructure to face global competition, provide value-added services, and increase nation competitiveness and sustainability. However, digitization and automation are smart port characteristics. The main objectives are to increase economic and sustainable performance and create a city-port synergy that offers a better quality of life to citizens [37]. Other researchers associated the smart port with

a sustainable, collaborative, and cooperative ecosystem through a skilled and creative workforce and the implementation of innovative technologies. The port sows trust between stakeholders, facilitates reliable and transparent information sharing, eliminates all non-value-added tasks [50], and offers interactive and dynamic services [45]. Still, other researchers defined the smart port as digital transformation, research, and development management, and an innovation culture imbued to reconfigure processes and flows [18, 45]. In a similar vein, Molavi et al. [39] defined the smart port as a connected, automated port designed to meet stakeholder demand. It adopts smart and strategic management practices, has a skilled and creative workforce, and deploys innovative infrastructure and technology solutions to solve maritime sector problems. It is based on four areas of activity that measure and evaluate the smart port: operations, environment, energy, and safety and security. According to the same authors, the intelligent port enables sustainable development and port operation security.

5 Results

5.1 Data presentation

The articles selected in this literature review present the characteristics associated with smart ports. In an effort to capture this concept, 17 features were identified to develop a broader understanding. Table 3 presents articles per publication year and the various characteristics identified. Of the 70 relevant articles selected for systematic review, 36 provided definitions of the smart port and assigned characteristics for understanding the new concept.

Various observations can be drawn from this synthesis. Firstly, the definition of a smart port evolves over time, where some characteristics emerge over the years and others are retained. In 2015, the energy and environmental domain was not part of port authority priorities, as these authorities paid more attention to the operational domain and smart technology implementation. New characteristics appeared in 2016: namely, good human resource management and citizens' quality of life. We also witnessed the emergence of the social dimension, characterized by creating closer connections with citizens to offer a better quality of life, all the while embodying local culture. Human resources management was characterized by recruiting a highly qualified workforce and providing continuous training to its personnel to align with the new needs of the smart port. As of 2017, researchers incorporated the sustainable port notion into the smart port concept and said that port authorities were moving towards sustainable managerial practices, green technology implementation, and renewable energy. Infrastructure, equipment, and innovative technologies were pointed out in 22 of the 36 articles (72%) and were the most cited feature, followed by sustainable environment, mentioned in 16 of the 36 articles (44%), and ""Operational efficiency" (15 of the 36 articles, approximately 42%).

A grouping was proposed for characteristics belonging to the same family to refine exploitation of the 17 characteristics selected from the literature. The "Monitoring and visualization system," "Real-time information sharing," and "Computerization and dematerialization" characteristics are thus grouped under the "Intelligent and innovative infrastructures, equipment, and technologies" characteristic, which includes all technologies and equipment as well as the expected result of their implementation. The "Horizontal and vertical integration of the supply chain" and "Intelligent traffic management and planning" characteristics are grouped under the "Operations efficiency" characteristic, and the "Smart Port-City Collaboration" is grouped under the "Concern for the Quality of Life of the Population" characteristic, which is the port's relationship with the citizens and the city.

Table 4 summarizes the 11 characteristics after grouping, with the respective number of authors mentioning each characteristic.

5.2 Intelligent port concept by business domain

Some authors define the intelligent port in relation to activity domains, which explains the many facets of the concept. The first facet was proposed by Buiza et al. [7] who defined five areas of activity: operational, innovative technological configuration, automation, energetic, and environmental. This definition was revisited by Molavi et al. [39] in 2020, where they proposed the addition of a new emerging activity domain, "safety and security," and grouped the "Innovative technological configuration" and "automation" domains, proposed by Buiza et al. [7], into a single activity domain called "operations." To this end, Molavi et al. [39] provided a definition of the intelligent port concept according to four activity domains: operations, environment, energy, and safety and security (Table 5).

Good governance and human resource management, concern for quality of life and population, and a skilled and creative workforce do not fit into any of the business domains. The "Infrastructure, equipment and intelligent and innovative technologies" area will also be presented separately since it is the most cited characteristic in literature and will include automation. Consequently, the intelligent port is comprised of seven areas of activity.

This business domain rearrangement and assignment of various characteristics results in a proposal of 7 business domains and 11 characteristics (Table 6). Thus, the smart infrastructure, technologies, and equipment

Table 3 Identified smart port features by publication year

Characteristics	2011	2013	2014	2015	2016	2017	2018	2019	2020	Total
Intelligent and innovative infrastructures, equipment, and technologies	[29]	[53, 54]		[7]		[15, 21, 42, 52]	[23, 36, 43]	[8, 14, 17, 31, 35, 47]	[18, 27, 39, 45, 58]	22
Stakeholder collaboration and involvement in port projects	[24, 29]							[28, 39]	[39, 50]	6
Environmental sustainability		[53]		[7]		[42]	[38, 43]	[8, 17, 31, 35, 47]	[27, 37, 39, 45, 50, 58]	16
Efficiency of operations		[53]	[13, 51]	[7]		[15, 52]	[38]	[17, 31, 47]	[27, 37, 45, 50, 58]	15
Real-time information sharing		[53, 54]	[51]	[7]	[49]	[21, 52]	[23, 43]	[14, 25]	[39, 50]	13
Automation		[53]	[13]	[7]		[22]	[23, 36]	[8, 25, 47]	[37, 44]	11
Connectivity		[53]				[10, 22]	[43]	[8, 25]	[39]	7
Safety and security		[54]				[52]	[38]	[17, 35, 47]	[39]	7
Intelligent traffic management and planning		[53, 54]			[48]		[43]	[17]		5
Communication and data exchange between ports		[53]				[52]		[25]		3
Monitoring and visualization system		[53]				[15]				2
Computerization and dematerialization		[53]								1
Energy efficiency				[7]				[8]	[39]	3
Good governance and human resource management (skilled and innovative workforce and training)						[12, 52]	[28]		[18, 39, 45]	6
Quality life of the population						[42]	[38]		[37]	3
Horizontal and vertical integration of the supply chain						[52]				1
Smart Port-City Collaboration									[27, 37]	2

Table 4 Summary of the grouped smart port characteristics

Characteristics	Authors	Total
Intelligent and innovative infrastructures, equipment, and technologies	[7, 8, 14, 15, 17, 18, 21, 23, 25, 27, 29, 31, 35, 36, 39, 42, 43, 45, 47, 49–54, 58]	26 (72%)
Efficiency of operations	[7, 13, 15, 17, 27, 31, 37, 38, 43, 45, 47, 48, 50–54, 58],	18 (50%)
Environmental sustainability	[7, 8, 17, 27, 31, 35, 37–39, 42, 43, 45, 47, 50, 53, 58]	16 (44%)
Automation	[7, 8, 13, 22, 23, 25, 36, 37, 44, 47, 53]	11 (30%)
Safety and security	[17, 35, 38, 39, 47, 52, 54]	7 (19%)
Connectivity	[8, 10, 22, 25, 39, 43, 53]	7 (19%)
Good governance and human resources management	[12, 18, 28, 39, 45, 52]	6 (16%)
Stakeholder collaboration and involvement in port projects	[24, 25, 29, 35, 39, 50]	6 (16%)
Quality life of the population	[27, 37, 38, 42]	4 (11%)
Energy efficiency	[7, 8, 39]	3 (8%)
Communication and data exchange between ports	[25, 52, 53]	3 (8%)

Table 5 Attribution of features grouped according to domains by Buiza et al. [7] and Molavi et al. [39]

Characteristics	Domains according to Buiza et al. [7]	Domains according to Molavi et al. [39]
Intelligent and innovative infrastructures, equipment, and technologies	Innovative technological configuration (infrastructure is not included)	Operations
Efficiency of operations	Operational	Operations
Environmental sustainability	Environmental	Environmental
Automation	Automation	Operations
Safety and security	–	Safety and security
Connectivity	Innovative technological configuration	Operations
Energy efficiency	Energetic	Energetic
Stakeholder collaboration and involvement in port projects	Operational	Operations
Good governance and human resources management	–	–
Communication and data exchange between ports	–	–
Quality life of the population	–	–

Table 6 Business areas and associated smart port characteristics

Field of activity	Characteristics
Infrastructures, equipment, and innovative technologies	Connectivity
	Intelligent and innovative infrastructures, equipment, and technologies
	Automation
Operations	Stakeholder collaboration and involvement in port projects
	Efficiency of operations
	Communication and data exchange between ports
	Intelligent traffic management and planning
	Real time information sharing
Energetic	Energy efficiency
Environmental	Environmental sustainability
Safety and security	Safety and security
Social	Quality life of the population
Human resources	Skilled and creative workforce
	Good governance and human resources management

domain includes the use of innovative state-of-the-art technologies, real-time data sharing among stakeholders, and port automation to improve overall port productivity and efficiency.

The operations domain reflects port operation efficiency and effectiveness at a lower cost [6, 53]. This domain includes customized services offered to customers with added value [58] and intelligent traffic management and planning [17, 54]. It also includes the implementation of smart business models [2, 43, 45] and strategies for horizontal and vertical integration of the supply chain [52], which will contribute to business development, good stakeholder management [2, 43, 45], and total customer satisfaction [18, 21, 28, 52].

The energy domain consists of implementing managerial solutions and practices. It provides an optimal energy consumption, takes an approach towards renewable energy consumption, and implements energy management systems [39].

The environmental domain contains all the implemented practices, technologies, and solutions to comply with international and national regulations and laws. The domain consists of protecting the environment against harmful impacts of port activities on human and animal welfare. To this end, the intelligent port implements an optimal environmental management (EMS) system and a reduction of atmospheric emissions. The domain also implements actions to reduce noise pollution, manage optimal waste, and develop techniques for evaluating and reducing wastewater [39].

The safety and security area consists of reducing work-related accidents and protecting employees and citizens against any external and internal threat. It complies with safety and security-related international and national regulations, laws, and standards and includes a safety management system according to International Maritime Organization (IMO) standards and requirements as well as an external and internal asset and threat identification. These measures increase security and improve the security system [39].

The business areas and associated characteristics make it possible for the following definition to be proposed for the smart port concept:

> *"The smart port is a connected, sustainable, safe and automated port, which relies on smart infrastructure and equipment, skilled personnel and smart managerial practices, to ensure customer satisfaction, environmental protection and a better quality of life for the citizen."*

By integrating new and emerging business areas and reviewing work started by Buiza et al. [7] and Molavi et al. [39], the aforementioned definition promotes a broad and extensive understanding of the smart port concept. This first clear definition of the smart port concept, based on a comprehensive literature review, addresses the gap in the literature.

6 Conclusion

The port is a major player in nation development. It has evolved through different generations—from the first to fifth generation until today. Globalization, worldwide environmental issues, demographic and climatic changes, and fierce competition between ports require port authorities to evolve towards a smart port.

Researchers have proposed definitions of the smart port by business domain, including Buiza et al. [7], and Molavi et al. [39]. Based on these works and a systematic review of the literature, this study proposes a new updated definition that includes seven activity domains (operations, social, environment, energy, human resources, safety and security, as well as smart infrastructure, equipment, and technologies) and characteristics related to each domain to propose a clear and comprehensive definition of the smart port concept.

The transition to an intelligent port requires port authorities to prioritize innovative technologies and management practices to be adopted according to their specific challenges and limited resources to face current and future challenges. Authorities would benefit from a guide or tool that would encourage them to make the right choices to make the transition to an intelligent port successfully.

This definition of an intelligent port may be the foundation for designing a decision-making tool or a roadmap for transitioning to an intelligent port for future research. Results may be applied to a case study to validate fields of activity.

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