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A Framework for Adopting a Sustainable Smart Sea Port Index

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Abstract: The new business environment, and the new era of digital transformation put pressure on the global supply chain and accordingly on ports to cope with such changes; these require ports to be smarter and adapt to the new technological approaches. Smart ports SP express the prevailing trend for the transformation strategies. Although many previous studies discuss smart ports requirements there is no integrated vision provided before to capture different comprehensive elements of smart port and show its impact on sustainably. Therefore, this research aims at developing an integrated smart port index SPI, capturing different elements of SP and linking them to port sustainability performance. The research conducted a systematic literature review to identify all pillars that are required for the smart port adaptation and showed its impact on sustainability with a full-text reading stage that resulted in 48 articles. The paper indicated that few studies of the SPI have been proposed before to improve SP activity in different domains: operations, environment, energy, safety, and security; however, there is a need to address the several key issues related to port operations, and to consider human resources factor as part of the smart port requirement, particularly an integrated index that captures different pillars in SP elements and shows its effect on sustainable performance. The study reveals that SP initiatives around the world have different integration levels. According to this, the smart port index can be considered as the first integrated index linked to sustainability and including human resources; however, there are some limitations that could be an open issue to future researchers and practitioners to foster new practical research initiatives that can rely on this index to adapt the smart port practices in different ports, taking into consideration the human resources aspect and testing their impact on port sustainability.

Keywords: smart port index; maritime transport; key performance indicators and sustainability

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1. Introduction

Mobility and transport play a crucial role in worldwide logistics chains and facilitate economic growth between countries and nations [1]. With the increase of cargo volumes, more than 80 percent of the world's merchandise trade transport are carried out by vessel [2]. Consequently, seaport cargo handling processes need to be accomplished in a quicker and more efficient manner [3].

The seaport is a multidisciplinary system combined among economical function, infrastructure system, geographical space and trade [4]. Due to modernization, and rapid growing demand for the maritime transport and logistics services, sustainability and the importance of sustainable development have gained an increasing concern from academics, industry, society and the business community [5].

Sustainable development is becoming gradually more important in the development of business strategies. Over the last decade, sustainability and the importance of sustainable development have gained an increasing concern from academics, industry, society and the business community [5]. Sustainable transport enhances the environment (green transport), society (inclusive transport) and the economic dimension (efficient and competitive transport) of any sector in an integrated manner to assure synergies, complementarities and coherence; even though, it is not intended as an exhaustive list [6].

Maritime vessels are combined systems that produce and require the utilization of vast amounts of data for maximum efficiency, therefore the size of the network that maritime logistics companies operate widely increase, and they encounter huge scale planning difficulties at the strategic, tactical and operational level [7], which will entail a forward-thinking procedure to leverage the advantages of Industry 4.0 in a more comprehensive manner [8].

The occupancy of the Fourth Industrial Revolution (4IR) is infinite, directed by full force emergence of technologies that make biological, physical, and digital worlds edgeless [9]. Thanks to 4IR, the future of seaports is experiencing bold changes; the competitive industry of shipping and port logistics are pursuing several efforts to achieve competitive advantage through the 4th IR and extend into a new business area [10].

The effect of the fourth industrial revolution on marine transport would almost absolutely be an introduction of smart ships [10]; therefore, it is expected to have a huge effect on maritime transport and shipping sectors in which smart ships and autonomous vessels will be part of a new and fully interconnected maritime ecosystem [1].

An increasingly competitive environment is arising. New and current players are discovering ways by utilizing digital technology and developing new business models. The transport and logistics industry has been slower to present digital innovations than many other industries which is setting many of the industry's established players' business models at significant risk [11].

Geographical area, infrastructures, services, and the recently identified pillar which is emerging technology are considered as primary consolidated domains of a port with regard to its capability to compete and collaborate with different ports. Ports' problems were initially fixed with individual Information Communication Technology ICT solutions adopted by each decision-maker, which developed efficiencies in the three major port flows: cargo, information, and financial. However, new advantages and barriers are associated with the initiation of shared emerging ICT between decision-makers within ports [12].

Ports and harbors are suffering from severe competition for market share and achieving a higher efficient and secure flow of goods worldwide. High performing ports are performing smart technologies to properly manage operations, meeting new challenges in maintaining sustained, secure, and energy-efficient facilities that relieve environmental consequences. In this regard, a new concept has arisen called smart port. [13].

The smart seaport can be defined as "all parts of the port terminal operations, warehousing, logistics, yard and port transportation are closely connected through the wireless network or special network, providing all kinds of information for daily production supervision, related government departments and port shipping enterprises" [14].

As long as seaports are vital transportation links in the chain, and global trade is dominantly carried by sea, ports should be an important concern for developing countries [15]. Ports in developing countries should also consider changes in global trade. As also, they need to invest in human, institutional and technological dimensions in order that their traders and service providers can take advantage of new business opportunities to capture growth opportunities, remain competitive and gain from the enhancements that can be achieved by digitalization [2].

The concentration of researchers on current technology selection frameworks in literature is on the manufacturing industries in developed countries while they focus on energy and infrastructure projects in developing countries, with little attention on the selection technology for smart seaport in developing countries [16].

The focus of this paper is on the seaport, since sea port function and stages capture the majority of port activities that can be then adapted to other ports. The expansion of any sea ports can be classified into four stages: its first stage is associated with establishing seaports while its last stage include the linkage among ports and inland waterway [17], so capturing the index of seaport will allow further research to adapt this on inland as well.

Despite the recent increasing interest in the topic, efforts and research studies are needed to identify benchmarks at the international level, and to obtain advancement opportunities in ports. Smart port is a broad concept that contains several aspects of port activities. Although many previous studies discuss smart ports requirements there is limited availability of literature and research from academic researchers that tackle these requirements in integrated vision and show their impact on sustainability aspects to enhance the economic, social, and environmental factors of ports. Therefore, we aim to develop an integrated smart port index capturing different elements of SP and linking them to port sustainability performance through a systematic review of the limited work on smart ports pillars, with a focus on the role of sustainability. In addition, this timely article investigates some limitations that can propose different open issues to future researchers and practitioners to foster new practical research initiatives using those pillars in their port transformation procedure and testing their impact on port sustainability.

In this scenario of limited empirical evidence and cases on smart ports [13], the research have developed Smart Port Index as the convex combination of the sub-indices by identifying four key activity domains of a smart port: operations, environment, energy, and safety & security, and the related sub-domains of a smart port are recognized based on smart port best practices.

Based on a literature review, the research gap will be identified in a way that clarifies how this research will contribute to knowledge. Also, based on this review, the foundation of the research framework will be created and the best suited data collection techniques for this research will be selected. The remainder of this paper is organized as follows. Section 2 provides an overview of the literature on smart ports, sustainability, and the relationship between the smart port index and sustainable performance. Section 3 illustrates the method applied to conduct the research. Section 4 presents the results and analysis of this paper based on the study aims. Section 5 of this paper proposes the theoretical framework and discusses the obtained findings and results. Section 6 provides the conclusion and Section 7 addresses the limitations of this study and suggestions for future papers.

2. Literature Review

Ports are the backbone of the country's foreign trade and its gates to the outside world. They are the main link in the multimodal transport chain, in addition to their vital role in advancing the economic development process. Ambitious strategic plans have been made for the development of seaports and the transformation into a global logistics center which contributes to providing attractiveness for investment that enhances the position of any country on the map of global logistics centers to reach its ports to the ranks of the world's advanced ports which are classified as green ports, and to create a new generation of Ports. It is the generation of Smart Ports [18].

The Industrial Revolution 4.0 is a permanent economic transformation which means that the usual technological limits are being deleted. It is relying on combining the physical infrastructure with software, sensors, nanotechnology, or digital intelligence technology. Transformation of port's digitalization increases the connection between logistics chain, raises the automation of port operations, and facilitates emergencies [19]. In addition, increase the ability to better-taking decisions which is based on data, by the use of smart and collaborative platforms [20].

2.1. Smart Port

Given the major importance of the port sector in today's society and as a result of the large volume of business involved, this sector is of vital importance which is discussed by Rodrigo González et al. (2020) in his research, and they stressed that a minor improvement in profitability in this sector will have major consequences. It is the outcome of the large number of port operations that occur. Consequently, the application of the smart concept in the port sector is particularly important. Hence, the term "smart port" was born. It has generated great attention in all the active ports as it is the basis for the development and continuation of any future port [21].

The concept of "Smart Port" is derived from the concept of "Smart City" and is totally integrated with it including the study presented by Molavi et al. As stated by some researchers, a smart port should be designed for citizens and by citizens, and placed in the heart of the port of the future [21]. Therefore, the port must be sustainably integrated with the environment, ensuring a space that can be used by residents, strengthening its relationship with the sea and making it possible to benefit from it.

Botti, Monda [22] defined the smart port by way of a port with automation, great productivity and greening services such as a port operation structure, port logistics equipment and port logistics infrastructure. Meanwhile, according to Buiza-Camacho-Camacho, del Mar Cerbán-Jiménez [23], the smart port is specified in the areas of operation, energy and environment.

Smart ports have also been named intelligent ports, robotic ports, and autonomous ports in numerous studies. The smart port is relying on the application of innovative technologies to convert port services into interactive and dynamic services that are more effective and apparent. Its aim is to achieve the customers' needs and wants of needs. Furthermore, from environmental protection perspective [24], the sustainable development of the port establishes its main pillar as well as its orientation concerning the city and its citizens in order to guarantee the high quality of space and facilities. New technologies being considered contain Artificial Intelligence (AI), Block chain, and Internet of Things (IoT) [25].

Moreover, the usage of new technologies will increase the possibility of the port in the future, or Smart Port. Therefore, the port system will go hand in hand with data transmission systems and big data; the implementation of which will allow a complete transformation in many areas [21].

Figure 1 displays the structure of APCs. Relying on standard exchangeable messages (EDIFACT and XML), information relating to shipment and logistics; customs processes during import, export, and transit is transferred, besides, accessible software applications like eDesk, APICS, Cubix, and BTS can be obtained easily through any platform.

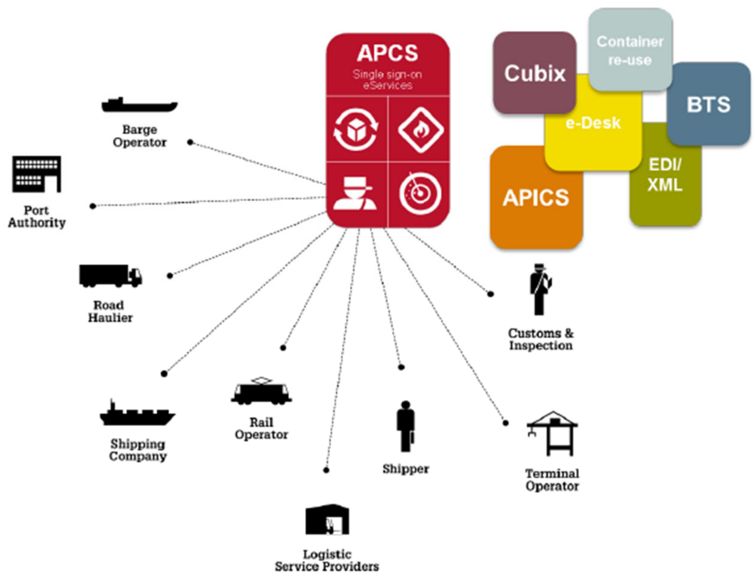

Figure 1. Functional Design of APCS. Source: [26].

To develop an operation mode for the smart port, researchers have conducted a ton of investigations on port optimization including enhancing logistics supply efficiency, improving port service functions, lessening environmental pollution at ports, and decreasing the energy consumption of equipment. These studies have presented practical and effective steps to port organizations and improved their shortcomings [27].

Yau, Peng [28] explained that the smart port aims to take advantage of technological innovations to improve port activities and services, and provide a social and economic boost to cities and regions through improving international trade competitiveness. The smart port system reduces power consumption and traffic. Ports have grown over five generations [29]. The first generation served as the contract point for land and sea transportation and provided essential operations, such as logistics, transportation, cruises, fishing and emergency rescue. Deployment of second-generation equipment and infrastructure reduces the dependence on manpower. The third generation, which acts as a cargo handling hub, provides value-added services such as warehousing, packaging and distribution. The fourth generation links physically discrete ports to act as a networked port. Fifth-generation ports which developed as a consequence of the dynamic growth of containerization, characterized by various approaches to the transport, environmental, and city-forming function. This generation provides deep IT integration with different stakeholders [30]. The fifth generation of ports is the newest and recent version, which is a customer- and community-focused smart port with five key features [31]:

- Smart port services and applications such as ship and container management; technologies such as data center, networking, communications, and automation;
- Using sustainable technology to enhance energy efficiency and decrease greenhouse gas emissions;
- Managing groups such as a shipping group consisting of companies and stakeholders who are geographically close with their main activity in shipping;
- Developing hub infrastructures to enhance cooperation between the different ports.
- Equipped with these five features, Smart Ports adapts to the dynamic and unforeseeable circumstances of ports to enrich port activities and services [28].

From the above, Szaruga, Kłos-Adamkiewicz [24] determine the relationship between the economic cycles of the gross domestic product and the volume of shipments of crude oil and petroleum products. The correlation is significant and positive between crude oil and petroleum product shipping volume cycles and GDP cycles. Thus, it can be said that the volumes of shipments of crude oil and petroleum products may be a measure of the economic situation and an initial warning tool in economic management. Based on the volumes of shipments of crude oil and petroleum products from the main Polish seaports, it is possible to get acquainted with the trends of the phases of the economic cycle of the main measure of economic growth, i.e., GDP.

2.2. Smart Port Index

The port's major function is to load and unload vessels which has a significant impact on the country's productivity. A port's productivity could be measured in seven areas (berth productivity, infrastructure productivity, land productivity, capacity for receiving large vessels, size and use of maximum capacity, the level of intra-modality and lines calling at the port) to determine how productive it is [32].

The concept of a smart port was highlighted by Buiza, Cepolina [33], relying on a project named "action plan for the smart port concept in the Mediterranean region" which concentrates on three main domains: operation, energy usage, and environment; furthermore, the study of Molavi, Lim [13] identified four activity domains of a smart port by analyzing the smart port initiatives, and Philipp [34] proposed on a theoretical framework a digital readiness index for ports and applied this to five selected seaports.

According to Molavi, Lim [13] study, smart port projects around the world vary in their comprehensiveness, and smart port penetration into port activities varies from port to port. The results reveal that government policies and region-specific variables can influence the value of the smart port index. Ports can gain a substantial competitive advantage in terms of service quality by completing this operation at the lowest possible cost and at the fastest possible pace. By merging technology and new ideas, smart ports gain an advantage in operational efficiency and cost reduction, the port will be completely linked via a communications system and totally integrated with its environment [35]. Smart ports increase their competitiveness by combining productivity, automation, and smart infrastructure upgrades [28].

Szaruga, Kłos-Adamkiewicz [24] showed that studies adopted by Molavi et al. to research the smart port concept, and its indicators identify the smart port concept and provide a quantitative evaluator which is the smart port index. Smart port is a concept that is attracting recent researchers to study as well as public power, smart infrastructure and automation in order to facilitate development and exchange of knowledge, improve port operations, increase port resilience, ensure sustainable development, security and secure operations.

Chen, Huang [36] identified that smart port in a wide-ranging sense is the consequence of digital technologies, business model innovation and resource value innovation. According to Rodrigo González, González-Cancelas [21], a trend study was used in the implementation of smart port measures implemented in Spain. The study focuses on investigating smart ports in relation to the following five main pillars: economic, operational, social, political and institutional and the environmental ones. Looking at the specific results in each of the five pillars analyzed, it is found that port investments should be higher in the development of operational and environmental scopes, relying on digitization and automation procedures for the purpose of advancing the arrangement and attaining a better degree of adaptation to the concept of the smart port.

In addition, the smart port depends on the interconnection among stakeholders in the port logistics chain, the automated equipment and the port terminal operations in order to strengthen liquidity, reliability, security of information exchange and real-time decision-making [20]. These practices also enhance the productivity of the smart port and increase its energy efficiency. Douaioui, Fri [37], in his study, detected the basic pillars of a smart port, which would be appropriate to apply this concept in different ports to evaluate its benefits quantitatively and qualitatively. Nevertheless, so far, the author highlighted that the smart port is a huge reveal of future developments in the port area, and it is rarely addressed.

2.2.1. Smart Ports Index Pillars

Referring to the previous studies in port and related fields, many researchers singles out specific evaluation indicators for the smart port mainly in four areas, namely operations, environment, energy, safety and security in order to develop their smart port strategies and identify the strengths and weaknesses of their current operations in order to continuous improvement [38].

Operations requirements refer to port productivity, such as berth productivity and berth efficiency to speed up the flow of goods, reduce cargo handling and prevent shipments from being damaged or lost [39]. The majority of port operations involve loading and unloading vessels, transferring goods to warehouses, and transporting freight by road or rail [13]. Much attention has been drawn to evaluating port's production and operation indicators. Chen, Huang [36] indicated that the systems contain the application of emerging information technologies, such as port production dispatching automation, Internet of Things and cloud computing, and emergency response capabilities. Chen, Xue [27] confirmed that the smart port is characterized by excellent port operation, an open ecosystem, and an active enlargement of sustainable innovative businesses. Smart ports are trying to apply advanced information technology in addition to automated and smart mechanical equipment for day-to-day production and port operation management, realizing port production and operation automation, the full process of port logistics supply chain services, and facilitating port financial operations. Smart ports enable seamless and synergistic communication among different vehicles, ships, people, cargo and port systems, improving its daily operational efficiency and increasing its advantages. As a result, smart ports use this indicator to systematize production scheduling, decrease manual work, and improve the handling capacity of port emergency events.

Environmental requirements refer to various environmental performance indicators, including soil waste management, air pollution and water pollution. Waste management is also a much-needed philosophy in this new direction for smart outlets in the future [39]. Ports have a bad image for pollution since they are responsible for a large portion of the pollution in the seas. The smart port key features with a sustainable goal are to lessen ports' negative environmental impacts while also contributing to the emergence of preventive initiatives by focusing on decreasing the environmental pollution, soil pollution, air pollution, and water pollution as well as recycling waste [25].

The increased volume of international trade also adds to the port's operating workload. This circumstance exacerbates environmental issues related to the port [39]. The ports, which connect diverse modes of transportation and handle a large amount of cargo, have serious environmental issues [40]. Smart ports stand out because they provide solutions to these issues [13]. Environmental management systems, trash management and water management are all aspects of the smart port's environment [41]. Several studies agree that the effectiveness and efficiency of seaports depend on new energy models which are based on low environmental impacts, drive innovations in both processes and technologies, and invest in new technology that aims to have environmentally friendly transportation systems and provide smart transportation services, as well as improving services for passengers, and enhancing safety, traffic and making the flow of traffic smoother, this is what is called smart ports. Also, Douaioui, Fri [37] confirmed that the smart port must simultaneously respond to a global environmental challenge by continuously improving its energy efficiency. The smart port anticipates reducing the environmental impact as long as it uses renewable energy in all its processes. Besides, efficient systems and automated port equipment increase the ability of reducing energy costs for motorized vehicles and improve roads leading to an improvement in the number of energy-consuming vehicles used at the port terminal.

Energy requirements are considered a prerequisite for improving the performance of the smart port, such as wind technology, photovoltaic technology and modern marine technologies [39]. Chen, Xue [27] indicated that trade and rationalization of energy savings in ports are in lessening of emissions. The evaluation indicators of the port energy protection and emission reduction capacities are considering the ability of using intelligent technology to achieve energy reduction and emission reduction, the ability to build and develop green ports that will achieve environmental health, energy consumption reduction, pollution reduction throughout intelligent technologies and emission reduction measures [42]. Energy is commonly used to provide energy services of all sorts. These contain electricity, transportation, lighting, heating, cooling, industrial operations. The full life process of energy is complicated and contains acquiring energy sources, transforming them into valuable forms, transporting, allocating, accumulating energy, and using energy [43].

Direct attacks by terrorists, utilization of ports as a channel for the movement of weapons, natural hazards, and natural risks in the port movements associated with safety and security are the outstanding issues in this area [39]. Ports began to pay attention to smart solutions to improve operations, enhance efficiency and sustainability, and avoid safety and security incidents [44]. Ports began to turn to the presence of technological solutions to solve the problems faced by the ports, and the transition to smart ports was made.

2.2.2. Ranking Stages

In the interest of attaining a ranking of the main Spanish ports according to the degree of their adaptation to the Smart Port concept, the study of Rodrigo González, González-Cancelas [21] prepared an indicator that collects all the features related to this concept in order to future apply it to ports, and this indicator consists of three stages:

- Work stage definition,
- Smart port indicator development,
- Ranking obtained

First, a work stage definition consists of conducting a comprehensive study of the entire smart port environment and its effects in order to ascertain the main areas that have an important impact. To this end, both the current state of development in adapting to the ideal smart port and the prediction of the concept's approach in the future must be studied.

Secondly, smart port indicator development; this indicator consists of defining and developing a global indicator capable of measuring and comparing the adaptation of a port with the concept of a smart port. To obtain it, those steps should be followed: first, define the indicators, measurement variables, and scoring rules that are most appropriate for the case study, using the Delphi panel methodology. Then weighting the indicators, determining the importance of each of them by assigning a certain weight to each of them. This process, in turn, is divided into two stages: An overall weighting of each of the identified pillars is determined in an effort to control and limit their importance within the Smart Port Index. The weighting depends mainly on the theoretical significance of the pillar itself and not on the indicators associated with it. And the significance of each index is obtained within the substrate being contained so that the sum total is the total weight assigned to the column.

Third, the ranking stage, the development of the Spanish smart port ranking consists of applying the index to the ports under consideration. To do this, the ports under study must first be identified, so as to provide a complete and multiple vision for the development of the Spanish port system in this area. Thus, the selection criteria are the importance of the port as a key point of value creation and the degree of development and implementation of smart port measures.

The indicator must then be applied to the selected ports in which it is necessary to carry out research and data collection work in order to check the correctness of the obtained data. Thus, a final score is assigned to each of the indicators for each port by developing the following two steps: Assign scores to each indicator, using specific measurement rules to assign an objective and justified score to each of the indicators for each port [45]. And apply weights to the scores of each indicator, multiply the score of each indicator by its associated weight on the total Smart Port index, and obtain the quantitative contribution of a given indicator in a particular port in representing its degree of adaptation to the concept of a smart port. The scores, once weighted, associated with each pillar are added to reflect the degree to which a particular pillar is adapted to the ideal smart port [40].

Thus, once the overall score for each column is known, a weighted aggregate sum of all the selected pillars in the study is performed to determine the overall score of the Smart Port Index in each port, and to obtain the final rating of the selected ports in terms of Smart Port. The scoring system used has been adapted to a score total of over 100 points so that the results are more visible and can be easily analyzed, along with the scores for each pillar.

Chen, Huang [36] illustrated that intelligent operation is an inevitable development trend of advanced ports in the future. Securing comprehensive and sustainable development is the crucial point to enhance the competitiveness of ports. Accordingly, it is more important from a practical point of view to study and analyze the assessment of the smart port. The study presents an initiative to assess the development of smart ports in the world. Furthermore, it provides an effective method for the evaluation system of the ports.

2.3. Sustainable Transport

Sustainability in maritime transport has been an important consideration over the last few years. The significant rise of international trade carried by sea has led to an increase in air emissions and their harmful impacts on human health and environmental change [46]. The global economic system is witnessing a set of recent developments that have led to the emergence of technological and operational concepts and applications that have affected the development of transport in general and the maritime transport industry in particular [47]. Therefore, stakeholders in the maritime transport sector at the global level seek to build a strategic development plan that aims to develop the maritime transport system and provide global logistics services through which it can keep pace with the development plans targeted by many countries of the world to bring about a comprehensive and sustainable development that affects all sectors in the country [48]. Based on this, a strategic role is played by keeping pace with global developments and providing development programs and plans at all levels, as well as through its role in supporting national development plans, supporting logistical activities [21]. See in Figure 2.

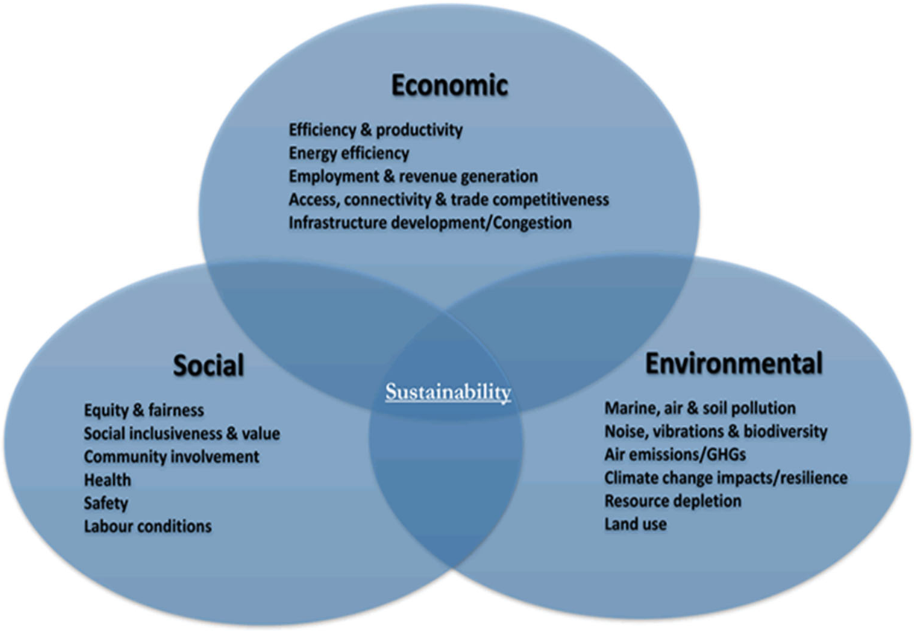

Figure 2. The three pillars of sustainable transport. Source: [49].

Fusco Girard [50] study also emphasized the intelligent development of port areas on circular processes at three main levels:

- Economic: the cooperation between companies to create value, facilitate synergies and stimulate circles among the company and the prosperity of society
- Social: capable of renewing interpersonal relations through relationships with 'places';
- Environment: All living systems are characterized by procedures that are circular and capable of self-sustaining and reproducing. Circular processes arise from reuse, recycling, and renewal of materials and energy while diminishing negative externalities.

Over the years, different maritime stakeholders have taken action the reduction of maritime air emissions, with the International Maritime Organization (IMO) and the European Union (EU). A significant initiative of the IMO has been included in the MARPOL Convention to reduce shipping air emissions by designation of Sulphur Emission Control Areas (SECAs) for vessels and deciding to establish a global sulfur limit from January 2020 forwards, short sea shipping (SSS) is explained as maritime transport that does not cross oceans. The sustainability performance of the SSS covers topics associated with the usage of alternative fuels in shipping, slow steaming, investments in advanced technologies, and the function of ports in sustainable maritime operations [46].

Comi and Polimeni [51] defined Short sea shipping (SSS) as maritime transport of goods between ports in the EU on the one hand, and ports located in the Mediterranean, and the Black Sea on the other, the European Commission prepared 30 priority axes and schemes involving land to sea transport networks and the performance of SSS lines and services. The performance of sustainable transport planning faces many barriers that prevent the appearance of sustainable transitions in terms of financial Barriers, legislative and Regulatory Barriers, government/institutional and organization barriers, political acceptance barriers, and social/public acceptance barriers.

However, one of the most important barriers related to sustainable transition is technical barriers in terms of the administration and cost, implementation, and organizational problems, technical barriers are key issues. In the context of infrastructure management, information systems, engineering design, and the availability of technology, technical barriers can restrict sustainable progress. Concerning human capital, a lack of skills and expertise is considered a huge obstacle to progress and is increased by the rapid changes in the type of policies relating to the emergence of new technologies [51]:

Most developed and developing countries today use energy in a way that is not sustainable [43]. As discussed by Yigit and Acarkan [52], a large proportion of the population lives in cities today. About 66% of the total population is expected to live in cities by 2050. Sustainability challenges such as air pollution, resource shortages and human health problems will increase with rapid urbanization. As a result, the concept of smart cities has emerged to provide sustainable urban expansion. Researchers have become interested in using alternative energies such as renewable energy, storage and coastal energy on ships to provide sustainable transportation, port areas and cities. Knez, Zevnik [53] claim that decreasing carbon dioxide emissions is a motive power for replacing standard internal combustion engines based on fossil fuels with "greener" and more efficient recourses. Christodoulou and Woxenius [46] highlighted the importance of adopting effective approaches and providing economic incentives which will encourage the investment in maritime technologies and the usage of alternative fuels, the study also clarified the significance of cooperation and shared planning across the maritime chain stakeholders in order to achieve sustainable maritime growth.

2.4. Smart Port and Sustainable Performance

Sustainability relies on a rational connection of the triple bottom line (people, profit, and planet); Effective control of people, trained to see the workforce not as a cost to be decreased or sidestepped, can achieve a sustainable competitive advantage [54].

The study of Berlin and Eriksson [39] has shown that there is a shift towards smart ports which entails supply chain sustainability, which refers to environmental, social and economic management with the aim of achieving long-term environmental, social and economic growth for all stakeholders involved in bringing products and services to market.

In the case of economic areas, the greater the efficiency in shipping logistics and the better the trade and cargo synchronization management, the greater the effect on the final price of the product [55]. Several previous studies analyzed the economic impacts of the shipping and port industry on the national economy [56]. It translates to greater commercial profitability. Comi and Polimeni [51] proposes a methodology for evaluating freight transport scenarios considering the essential function of SSS, regarding the changes in infrastructures, services and technology. The proposed analysis supports the decisions of maritime transport operators, analyzes maritime penetration of such services in other sea basins, and contributes to providing quantitative support to transport planning activities in progress at the EU-Mediterranean level. The study concentrates on improvements in terms of external costs attained from increasing the usage of SSS and comparisons among various intermodal transport chains. In the institutional sphere, ICTs will allow facilitation, increase efficiency and security in port management as well as improve relationships and information transfer between entities. Moreover, it will be possible to increase control over incoming and outgoing goods assuming an improvement in the customs security of countries [57]. The second dimensions of sustainability, the social dimension is becoming a main point of policy attention. Weather change represents a critical and potentially permanent threat to human communities and the globe. It is essential to expedite the reduction in global greenhouse gas emissions and pollutant emissions [51]; because some ports' boundaries have been affected by ships' exhaust fumes such as SOx, NOx, and PMs as well as the other ship emissions from port-related activities that can be the source lung cancer and heart-related diseases. The Smart Port should be designed for and by the inhabitant, making it the center of the port of the future. Thus, the port must be sustainably integrated with the environment, supplying spaces for the use of citizens, enhancing its relationship with the sea and allowing its enjoyment [58].

Lastly, the environmental sphere is closely related to the social field as the port must perform its activities and try to diminish the harmful influences on the lives of citizens and on the port's environments area at the same time. Comi and Polimeni [51] identified that the transport sector's total emissions represent 72% of greenhouse emissions, 66% of NOx, 21% of CO, 14% of PM10, and 20% of PM2.5 emissions. Previous studies have investigated the development of the operational energy efficiency of vessels and environmental regulations regarding environmental issues by involving technology changes. Consequently, technologies will be available to control port activities, such as handling hazardous or dusty materials, subject to the highest possible safety standards. Simultaneously, there should be periodic examines or controls to monitor pollution or the discharge of hazardous materials into the port. They assess the quality of the water or the potential pollution that could be caused by ships that wish to use it. In additions, technology will have a significant role in detecting and controlling probable hazards in shipping [21].

Zhao, Wang [59] discussed that there is a link between the smart port and improving port productivity and efficiency by adopting an automated system using technologies. The re-engineering of smart technology-driven business processes must be strategically planned by port operators with the participation of port stakeholders. Due to the significant environmental and social impact of port operations, increased attention has been drawn to port sustainability from academia. Smart ports seek to find innovative ways to decrease costs and reduce waste. The results determined that the higher the efficiency of the operations inside the port through the smart transactions, the greater the port's ranking index, the higher the circulation rate in the port and the growth in its productivity through smart transactions, as well as the shorter the waiting time for ships in the port, the lower the percentage of greenhouse gas emissions in the port [60].

The study of Zhao, Wang [59] measures on smart regeneration, treatment of coal dust pollution, treatment of air pollution and wastewater treatment, improvement of customer and employee satisfaction, community participation as well as enhancing social reputation. The research investigates the effectiveness of measures for coal port sustainability by examining changes in key performance indicators, and also examines the integration and optimization roles of smart technologies. The study also conducted a case study in Huanghua Port; the results show that the measures taken by Huanghua Port can effectively increase handling efficiency, reduce energy consumption, and increase port productivity and revenue. Moreover, the approach can reduce the concentration of coal dust, lower the air pollution index, and increase the amount of sewage recovery. Moreover, efforts to achieve sustainability can increase the rate of customer satisfaction, improve the level of wages, increase investment in employee training, and increase the amount of social donations. The research also shows in detail that the intelligent operation control system, the environmental intelligent control system and the intelligent service platform play roles in integration and optimization in enhancing the sustainability of the coal port.

There is intense competition between ports to obtain a market share which provides a safe and efficient flow of goods in the whole world, and for this, ports are applying many smart technologies to manage operations better in order to meet new challenges in maintaining safe and energy-saving facilities to reduce environmental impacts, and from here, the idea of turning ports into smart ports begins, and the Smart Port Index has been used in order to improve the sustainability of these ports.

Based on the previous review of the most recurring themes in the literature, it has been illustrated that there is still a lack in the literature that tackles the integrated smart port index and show its impact on sustainability aspects; Attention should be paid to the truth that various ports may encounter difficulties in implementing a proper digitalization level that may be affected by several determinants, including operations, environment, energy, safety and security, and human resources. Besides, further confirms that investigating other possible activity domains to be included in their proposed index is important, hence, this research will develop an integrated smart port index capturing different elements of SP and show their impact on sustainable performance through a systematic review of the limited work on smart ports pillars with a focus on the role of sustainability.

3. Materials and Methods

A systematic literature review methodology is conducted to collect and explore literature discussing the theme of evaluating sustainable smart port performance. The research has been developed through a collection of different scientific published literature papers, available on different databases. Concerning the methodological strategy, this study adopts a review protocol proposed by [61]. This method allows the researchers to collect the needed information gathering, comparing, and assessing numerous sources through an unbiased approach. This method conducts transparent and reliable evidence-informed knowledge exploration. This method is direct, systematic, and replicable and is used to recognize, investigate, and report the current literature. The review protocol applies five main phases: (1) Question formulation; (2) Locating studies, (3) Study selection and evaluation, (4) Analysis and synthesis, and (5) Reporting and using the results as shown in Figure 3 and Table 1. Each stage contributes to decreasing errors and bias in appraising the review.

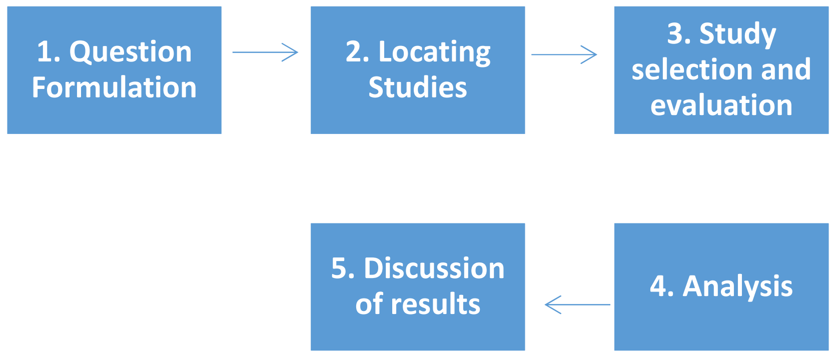

Figure 3. Research phases.

Table 1. Research of refining literature search.

Stage	Sub-Stage	Description	Number of Records
Step 1	Question formulation	The main characteristics of this research were identified by the CIMO as the performance of smart ports' domains (C), methods of the assessment of smart sustainable port (I), indicators and tools regarding smart ports (M), and the effectiveness, efficiency, positive and negative results on port sustainability (O).	
Step 2	Locating studies	The next step of this research is to filter the database: "Smart port" AND "sustainability" AND "Maritime transport" AND "Key performance indicators". Find the research string in title OR Abstract OR subject terms in data bases such as Emerald Insight, Scopus, Science Direct and Web of science Search timeline: 2000–2021 Language: English Source type: Academic journals.	148
Step 3	Study selection and evaluation	A broad screen of the abstract of the citation selected from the second step and then selection of the most relevant with the present research topic.	109
Step 4 & 5	Analysis and Discussion	A broad scanning for the selected articles are examined through introduction, methodology and conclusion Inclusion criteria: papers, which address smart port merge with maritime transport and sustainability Excluding criteria: Removal and extraction of un relevant and duplicates papers	48

The review in this paper uses the methodological structures and contributions previously defined by researchers in this field. At the end of the analysis, the review will summarize the main determining literature in a comprehensive way, revealing a structured gathering of definitions and knowledge otherwise contained in a dispersed range of studies, which will allow to fill the current gap in the assessment of sustainable smart ports.

Based on the gap, this research aims at answering the following research questions

- RQ1: What are the smart port pillars and indicators?
- RQ2: How will the smart port impact sustainability performance?
- RQ2: Which gaps and challenges in this research field can be recognized for further research agenda?

According to an iterative process for a keyword structure presented and the previous literature review studies, the structured keywords are determined and the following search string is used when searching the identical electronic databases. Based on the research questions and the core topics, the initial search strings include the following key terms: “Smart port” AND “sustainability” AND “Maritime transport” AND “Key performance indicators”. Additionally, the advanced search uses Boolean logic: “AND” to connect the two key terms; and “OR” to allow synonyms.

The primary online searches are conducted using the Scopus database (Elsevier), and various electronic international journal databases available are used including Emerald Insight, Google Scholar, Web of Science, Scopus and Science Direct, the selection and filtration of relevant articles are done through the following five steps:

- Stage (1) Question formulation: The appropriate research questions were established before starting the review. An approach called CIMO (Context, Interventions, Mechanisms, Outcomes) is applied to accommodate the research domain of business management and organization.
- Stage (2) Locating studies: Discovering the current studies relevant to answer the research questions by recognizing search databases and search strings involving three search techniques: search terms, databases for literature search, and inclusion and exclusion criteria.
- Stage (3) Study selection and evaluation: Using the keyword combinations detailed in Table 1, a broad skimming for the titles of the citations is derived from the literature search through defining the research scope upon which number of keywords are identified and used to online databases search.
- Stage (4) Analysis and synthesis: A descriptive overview of the information gained from the articles related to the research questions designated in the review process.
- Stage (5) Discussion of results: The results from the analysis of papers are summarized after strict screening of the remaining studies that pass the inclusion criteria in the previous stages to clarify how they support, develop, extend or are derived from each other and prepare the categorization and selection of the most appropriate and relevant one with the present research topic.

Additional Procedures During Search: the reference of all articles that achieved the selection criteria are scanned to identify other backward and forward articles within the review period that are related to the aim of the present study.

The Aggregate Outcome of the Search Strategy: The sum of the results recaptured from the literature search engine are shown in Table 1.

An initial search identifies a total of 450 papers. The results of the search through individual electronic databases are illustrated in Figure 4 and Table 1, after a broad scanning for the titles of derived citations, this has resulted in 148 articles (69 articles from web of science, 30 Scopus and 49 Science Direct). Then additional broad screening has been carried for the abstract of the selected titles, 109 articles are relevant to the study. Also, a large number of duplications resulting from the repetitive search using the electronic databases are excluded. On this basis, the number of articles is reduced to 97. Then, a broad scanning for the selected articles are examined through introduction, methodology and conclusion, this step has resulted in 48 articles. Finally, a full text reading stage has resulted in 48 articles.

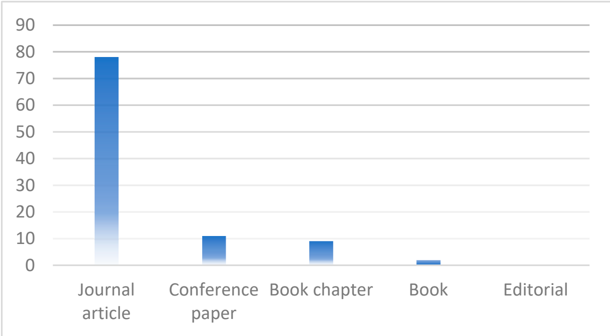

Figure 4. Type of Documents.

4. Results

The sustainable development of the port is described by a combined decision-making method and the engagement of several actors, involving economic, environmental, and social matters. In the light of a globalized economy, the current era has become the era of the smart economy, where efficiency, adaptability, innovation, and customer satisfaction are important matters along with the growth of revenues focusing on aspects related to sustainable development and ways to achieve them in all activities and areas of the maritime transport industry and creating an environmentally friendly work to bring out ports to the ranks of the world's advanced ports, which are classified as green ports, and work to create a new generation of ports, which is the generation of smart ports with the aim of finding innovative ways to reduce costs and eliminate waste, that increases the added value of operations [21].

The following table (Table 2) shows the developed data extraction used for selected studies and the most cited papers relating to researcher topics published from 2000 to 2021.

Table 2. Most Cited Paper, publication and JIF.

No	Paper	Cited by	Published by	Impact Factor
1	Toward a Smart Sustainable Development of Port Cities/Areas:	174	MDPI journal	2.101
2	The Role of the "Historic Urban Landscape" Approach	5	MDPI journal	2.101
3	Approach towards Sustainable and Smart Coal Port Development: The Case of Huanghua Port in China	11	MDPI journal	2.101
4	Preparation of a Smart Port Indicator and Calculation of a Ranking for the Spanish Port System	28	Elsevier	3.69
5	A new electrical energy management approach for ships using mixed energy sources to ensure sustainable port cities	11	IEEE Access	3.367
6	A sustainability assessment of ports and port-city plans: Comparing ambitions with achievements	5	MDPI journal	2.101
7	The Re-Conceptualization of the Port Supply Chain as a Smart Port Service System: The Case of the Port of Salerno	22	Elsevier	5.14
8	Energy-Aware Smart Connectivity for IoT Networks	89	Elsevier	4.513
9	Enabling Smart Ports	30	MDPI journal	1.92
10	A framework for building a smart port and smart port index	11	Düzce University Journal of Science & Technology	1.8

Table 2. *Cont.*

No	Paper	Cited by	Published by	Impact Factor
11	Integration of Cold Ironing and Renewable Sources in the Barcelona Smart Port	44	International Journal of Sustainable Transportation	3.5
12	Enabling Smart Ports Through the Integration of Micro grids: A Two-Stage Stochastic Programming Approach	6	IEEE Transactions on Industry Applications	3.488
13	A new electrical energy management approach for ships using mixed energy sources to ensure sustainable port cities	21	Elsevier	8.558
14	Corporate sustainability in Canadian and US maritime ports	26	Elsevier	4.513
15	How to recognize and measure the economic impacts of environmental regulation: the Sulphur Emission Control Area Case	24	Elsevier	7.2
16	A review of energy efficiency in ports: Operational strategies, technologies and energy management systems	25	Springers	5.651
17	A new electrical energy management approach for ships using mixed energy sources to ensure sustainable port cities	58	Elsevier	12.11

4.1. Type of Documents

Depending on the type of publication, the search results can be classified into eight categories: 78% of selected sources are journal articles, 11% are derived from conference papers and 11% of selected sources are books, other sources come from conference reviews, books and book chapters, reviews, editorials and erratum. It follows from the data that the search string is current from the point of view of scientific research work.

4.2. Documents by Country

Figure 5 shows that most of resources from which the research area is derived from Europe as much as 64 %. This percentage clearly extends to which variables change on different ports in different circumstances while the rest from the previous literature included ports in Asia as well as American ports.

Figure 5. World Map.

4.3. Documents by Subject Area

Figure 6 shows publications according to the research area. The largest shares are Smart port (32%), maritime industry (27%) and sustainability (16%). The logistics represents (28%) of all publications included. The study also included the 4th industrial revolution.

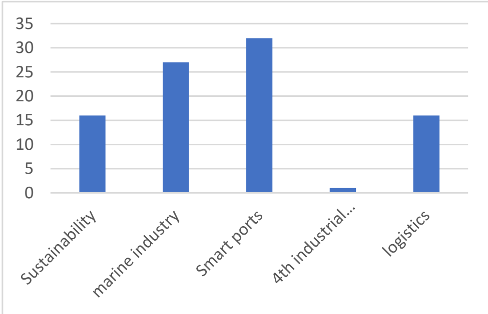

Figure 6. Documents by Subject Area.

Also publications are classified according to their purpose in Figure 7. According to the search term, the majority of publication included in the review represents the main topic of the paper, which is smart port index 30%, more than 20% of publication deals with sustainable smart ports, 15% are related to sustainability. Smart Sustainable Cities are also an interesting point; it is observed in 5% of all reviewed analyses. According to their purpose, research also falls into the following areas: 4th industrial revolution, logistics, operation, safety and security, environment and energy.

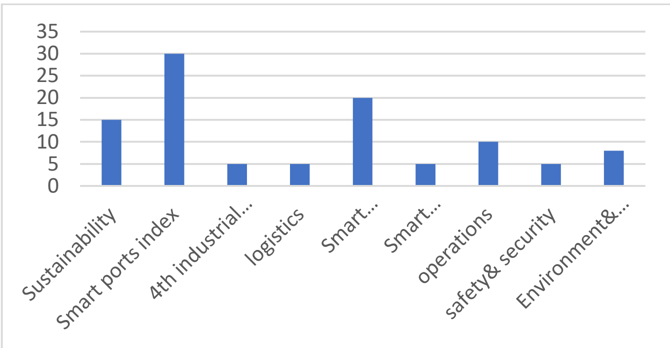

Figure 7. Documents by Purpose.

4.4. Documents by Year

To better understand the relevance of the topic presented, the publications are stored according to the time of publication. It is noteworthy that all of the significant papers are written after 2011. Figure 8 shows the evolution of the number of publications of 48 documents from 2015 to 2021. Citations have been increasing significantly, reaching a maximum number in 2020. Of all documents found, 89.5% have citation and 10.4% have less than 3 citations.

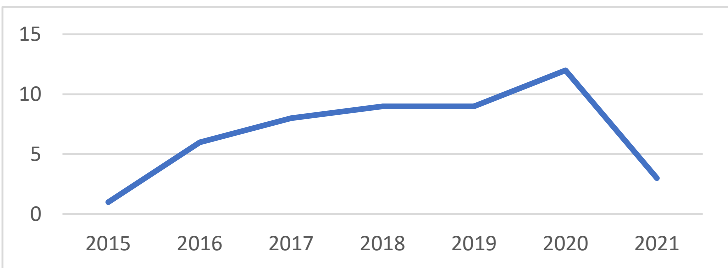

Figure 8. Document by Year.

Table 3 below contains all the critical findings and limitations that are observed during the review of the literature. This table contains 26 quotes prepared from different documents, the year published, country of release and research area.

Table 3. Critical findings and limitations.

Research Area	Year	Location	Major Findings Limitations
Smart Port Smart Port Index	2019	USA	The term "smart port" refers to a broad notion that incorporates many areas of port operations. A smart port's four primary activity domains (operations, energy, environment, and safety and security) as well as their connected subdomains are identified. The convex combination of the sub-indices is used to create the Smart port index. European ports have relatively comprehensive approaches toward smart focusing on port environmental and energy domains in comparison to the other port
Smart Port Renewable	2020	Spain	Distributed Energy Resources (DERs) can be used to create a micro grid inside port regions with sufficient renewable energy resources. When properly controlled, the port transforms into a smart port, with not only a flow of energy but also a flow of data that is appropriately managed to determine an efficient and intelligent distribution of energy throughout the entire power system. Port micro grid can engage to several aspects of port operation and management like avoiding serious facility downtime, energy savings, energy dependency and emission reduction.
Sustainability Maritime Sector Environmental Effect	2018	Turkey	The use of an energy management method in future ship and port designs will benefit the optimization of energy source utilization as well as the analysis of economic and environmental implications which will aid in the development of smart ship, green port, and sustainable city concepts.
Smart Port Logistics	2021	Poland	To increase the fluidity, dependability, and security of information exchanges and real-time decision-making, a smart port depends on interconnection between stakeholders in the port logistics chain in addition to automation of the port terminal's equipment and operations. These methods help in the enhancement of smart port's productivity and lowering its energy consumption at the same time. To track the port's progress, it is serious to generate new smart port indicators, integrate them into a dynamic performance assessment system, and link the different logistics components in the port area. To urge countries to engage in the smart port, there is a strong need to explain the concept by achieving an approximate quantification of the benefits and costs as well as the investments required.
Smart Port Index Sustainability	2020	Germany	The smart indicator works to reduce energy consumption and use renewable energies to reduce emissions. Ports are exposed to many safety and security problems and the smart port is used as regulations, standards, staff training, periodic monitoring of facilities, risk assessment and control systems to detect any security problem and increase and improve port readiness
Smart Port Smart Port Indicators	2020	Spain	The development of a port must be built on digitization, the use of ICT, and the automation of port procedures according to an examination of the Smart Port concept and its current and future trends. Not just in the economic operational dimension, but also in the social, institutional, and environmental policy dimensions, these procedures must be executed progressively. It enables ports to transition to a more sustainable approach. To advance in the rankings and achieve a greater degree of adaptation to the Smart Port concept, port investments in the operational and environmental dimensions must be increased, relying on digitalization and automation processes.
Smart Port Operation	2020	United States	The findings provide an initial assessment of how micro grids might be used to transform a traditional industrialized port into a contributing component of a sustainable ecosystem. We have implemented a set of KPIs from various major operation domains to aid in the formulation of a holistic approach to port micro grid planning. The port micro grid can help with a variety of elements of port operation and administration including minimizing important facility downtime, energy savings, reducing energy dependency and lowering emissions.
Smart Port Sustainability	2017	Germany	The building of sustainable ports, which is often located near urban development regions, is beneficial for maximizing the economic, environmental, and social benefits of ports. This methodology, which is based on evidence-based knowledge in the context of KPIs, is promising when new local data or updated expert judgement are available. It facilitates the evaluation and comparison of different port plans by providing a broader perspective on sustainability by comparing theoretical long-term port plan values with current port-city data, and assessing the sustainable and the economical measurements in port services.

Table 3. *Cont.*

Research Area	Year	Location	Major Findings Limitations
Smart Port Index Key Performance Indicators (KPIs)	2020	USA	The study highlights four key activity domains for smart ports: operations, energy, the environment, and safety and security to assess the port's performance in terms of smart port definition and activity domains. Smart port projects around the world have varying levels of comprehensiveness, and smart port penetration into port activities varies from one port to the next according to the report. The findings reveal that government policies and regional characteristics can influence the value of the smart port index.
Smart Port Sustainable Development	2018	Republic of Korea	A smart sustainable development can begin with the port areas' new circular metabolism, which should be expanded throughout the entire city/region, adjusting land and space utilization through new efficient planning and design capable of improving the urban landscape's overall quality. The smart port industry has an important economic effect on the manufacturing sectors and the service sectors.
Smart Port Port Sustainability	2020	China	In the economic dimension, there are indicators such as handling efficiency, energy consumption, port throughput, and port revenue; in the environmental dimension, there are indicators such as coal dust concentration, air pollution index, and sewage recovery amount; and in the social dimension, there are indicators such as customer satisfaction rate, wage level, employee training, and the amount of social donation. The intelligent operation control system, the ecological intelligent control system, and the intelligent service platform all play roles in strengthening the coal port's sustainability through integration and optimization. To accelerate the port's transformation and upgrade toward sustainable growth, port operators should encourage the construction of a sustainable and smart port on a broad scale. It is recommended that port operators invest in sustainable and smart activities. Port operators should play a supporting role in aiding supply chain coordination such as by building an integrated service platform. The government should give institutional guarantees as well as industry standards to ensure the coal port industry's long-term viability and smart development.
Smart Port Port Evaluation Smart Port Development	2019		Smart ports have emerged as the most common style of port construction indicating the pinnacle of modern port development. Future green ports investigate the use of LNG, dual fuel and hydrogen fuel cells to power the equipment as the percentage of energy from renewable resources is used as a KPI for smart and sustainable ports

Sufficient decision-making in such conditions needs sufficient support reflected in a relevant performance measurement system. Smart technologies have become a dominant paradigm of information technology and have been applied to the port industry with the advent of the Fourth Industrial Revolution. The smart port is characterized by high throughput and energy saving; Thus, building a smart port can be a feasible way to achieve sustainable port development [60]. Most current maritime decision-making tools concentrate on cost indicators or operational performance indicators [62]. Sub-domains of smart sustainability involve noise pollution, air quality, dredging operations, dredging disposal, and those considered in the environmental dimension concerning the economic dimension will involve returns on investment. Efficiency of the use of the port area, provision of facilities for companies, while social dimension will include a direct contribution to employment in port, contribution to knowledge development and education, and the livability of the area surrounding the port [15].

5. Discussion

After carrying out this study, several findings are reached on the degree of adaptation to the Smart Port concept.

Using a systematic literature review, this study has addressed the structure and patterns of adopting sustainable smart sea port index and assessment in the existing research; the review showed an increase in the number of publications on the subject in the past two years. It is well known that in recent years, the light of a globalized economy and the current era has become the era of the smart economy; the analysis witnessed that the largest shares of research area is the smart port.

Ports are the gateways of nations to each other. The efficient, secured, and environment-friendly operations and processes of these gates directly affect the expansion of this trade. Digitization in many areas has also expedited ports' operations. The point that characterizes the transformation in smart ports from an essential technology transformation is to concentrate on sustainability.

Regarding the growing data conversion of the finding, processing, monitoring, examination, and problem-solving leads to combining the domains of operations, environment, energy, safety and security, and human resources; it is observed that integrated smart port index will enhance the smartness of port processes and operations and affect sustainability performance and its levels (economic, social and environment) since it helps policymakers, directors, and administrators to maintain the flows of their processes in an efficient way by decreasing the consumption emissions, pollution, cost, and time, ensuring risk assessment, productivity, speed, safety, security, flexibility, and knowledge in decision-making processes. In this section, the findings from the analysis and synthesis of papers are summarized in relation to the five activity domains linked to sustainability performance.

5.1. Operation

Smart ports endeavor to implement advanced information technology along with adopting innovative and efficient management models in addition to automated and intelligent mechanical equipment to the daily production and operation management of ports which will lead to enhancing the entire process of port logistics supply chain services, improving the productivity of port operations and decreasing associated costs. Sub-domains of smart port operations involve productivity, automation, and intelligent infrastructure. Smart ports facilitate seamless connection and synergy among carriers, vessels, people, cargoes, and several systems of the port, growing its daily operational efficiency and increasing its advantages [13]. The smart port provides applications of emerging information technologies at ports and opens digital merchandise management systems to the port in terms of production and operation systems [63]. This empowers a safe, economical, convenient, green, and sustainable improvement which enhances the comprehensive competitiveness of ports [64].

5.2. Environment

A port should take the development of a green port as its key goal, and take the smart port improvement mode as its key technical means [65]. The green development of the port is the main reason for the low energy consumption, low emission, and low pollution [36]. Ports are the source of environmental pollution through land and sea transport due to air emissions, noise pollution, water pollution and consumption, and waste generation which poses a threat to living organisms while smart ports look for solutions to environmental problems through the verification of port environmental management systems (EMS) and activities to reduce pollution and manage water and waste [13]. For the scope of this research, the following environmental impacts of port activities are concentrated on: emissions to air, noise pollution, water pollution and consumption, and waste generation. Sub-domains of smart environment involve environmental management systems, emissions and pollutions control and wastes management [66].

5.3. Energy

The study of [13] showed that the port is one of the largest consumers of energy due to the increase in industrial activities, taking into account the limited sources of energy and the port budget. The smart indicator works to reduce energy consumption and use renewable energies to reduce emissions. Rolán, Manteca [41] agreed that as a result of port different operations, ports are one of the sectors with high energy usage [39]. The rising cost of energy and the availability of alternative energy sources are two major concerns for ports. Ports must undergo an energy-efficient makeover in order to provide logistics services [42]. Energy management is an important problem that port authorities should address as part of a smart and sustainable port development process [67].

5.4. Safety and Security

The enhancement of transport safety is urgently required. It is not only developing countries, but also many developed countries need to maintain a high level of transport safety and a low potential for incidents as part of intermodal transport by using smart transport systems [13]. Researchers observed that that ports are exposed to many safety and security problems and the smart port is used as regulations, standards, staff training, periodic monitoring of facilities, risk assessment and control systems to detect any security problem and increase and improve port readiness. Within the smart port framework, port authorities must priorities safety and security as well as productivity, environmental awareness, and energy efficiency. Employee training and contemporaneous monitoring are both required preparations. Port safety management systems, security management systems, integrated monitoring and optimization systems, and data security and privacy management are all part of the smart safety and security dimension [39].

5.5. Human Factor

Some of the most complicated problems associated with port performance is resistance to change while starting any new systems and instructions. Lack of human resources as preparing safety management manuals and reporting methods require human effort and time that are exceeding the skill of the current staff, as well as insufficient knowledge of procedures. Also, the lack of inter-departmental communication particularly the operation administration and the technical administration reduces operating costs by hiring low level of education which generates a lot of problems concerning technology and communications. Many staff turnovers increase the challenges of introducing any new systems and practices on board [68]. Thereby, the dimension “Human Capital” is further differentiated into three sub-dimensions which are knowledge and skills (Education), IT Capabilities and training and education that are included in the digital auditing tool because the smart transformation of ports is not safeguarded by only using innovative technologies, but also by measuring management staff’ knowledge and skills, in addition to practical IT methods and systems which guarantee a sustainable development towards a smart port [34].

Considering the comprehensive study of port management, in addition to the meaning of smart ports, the research investigated that different ports may face challenges in implementing a proper digitalization level that is influenced by many factors, including operations, environment, energy, safety and security, and human resources.

This paper focused on developing a theoretical framework that tackles different pillars of smart port in one index to enhance the economic, social, and environmental factors of port performance; however, the paper investigates some limitations that can propose different open issues and suggestions to future researchers and practitioners to foster new practical research initiatives using those pillars in their port transformation procedure and testing their impact on port sustainability or to test specifically the human resources and sustainability and their effect on the improvement of ports’ performance.

The previous steps are to investigate and structure the theoretical frame work, the research provides an authentic contribution to knowledge through developing comprehensive sustainable smart port index and testing their impact on the port performance. The paper focuses on research by theoretically connecting the concepts of Smart Port Index, Maritime transport, key performance indicators and Sustainability to address the several key issues related to ports and port operations, and to consider human resources factor as part of the smart port requirements.

In this analysis, the systematic study focuses on the analysis of Smart Ports related to the following five fundamental pillars from the industry practice and academic research results: operation, environment, energy, safety and security and human factor. On the one hand, digitalization is counted to be an essential pillar of all of the above-mentioned pillars because the five previous approaches are studied based on the digitalization and application of new technologies. Accordingly, those five domains are separately included in smart port different studies because they are considered as independent pillars, and on the other hand, the sustainable port performance is considered as a dependent pillar. According to the findings and the research questions as well as the research gap analysis, it is confirmed that there is a relationship between smart port practices and sustainability performance. The main goal of this work is to develop a comprehensive smart port index considering integrated pillars of smart port dimensions and measures and linking them with sustainable performance. Consequently, the scheme of theoretical framework is represented in Figure 9.

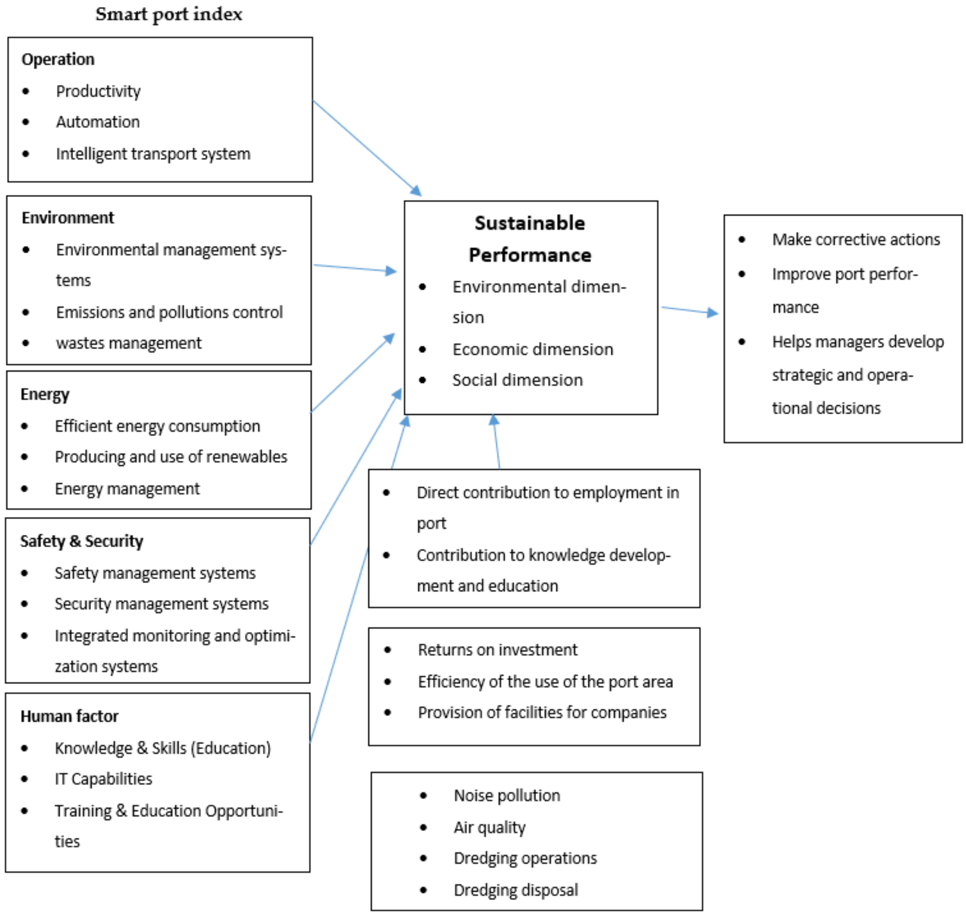

Figure 9. Research frame work for adapting sustainable smart port.

6. Conclusions

As a result of the conducted research, and the systematic literature review that are carried out, the research investigated that different ports may face challenges in implementing a proper digitalization level that is influenced by many factors, including operations, environment, energy, safety and security, and human resources. However, there is a critical need to address SP requirements in an integrated form to enhance the economic, social, and environmental factors of ports have been limited by the lack of previous studies. Thus, the research proposes a framework of an integrated smart port index and links it with sustainability performance. A smart port is an innovative city that uses information and communication technologies and other means to improve quality of life, operation efficiency, urban services, and competitiveness, ensuring that it meets the needs of current and future generations in terms of economic, social and environmental aspects. Smart ports are an integrated electronic system to transform the traditional administrative work into a technological work based on information systems that help in efficient decision-making at the lowest cost and shortest time, taking into account sustainable development by taking into consideration its three dimensions and among the components of the smart port.

The concept of smart ports can be in the presence of a port in which the environmental impacts are addressed, the efficiency of operations is supported, and energy consumption is reduced. This concept helps transform seaports into Smart Sustainable ports in global supply chains. There are five main groups that govern the smart port which are the environmental group, the operations group, safety and security, human factor and the energy group.

By adopting smart port index, a safe, economical, convenient, green, and sustainable improvement will be enabled; in addition, implementing technology along with adopting innovative and efficient management models to the daily production and operation management of ports will improve the overall performance increase the productivity of port operations and decrease associated costs which will enhance the comprehensive competitiveness of ports.

Various marine activities can lead to environmental pollution. Thus, various environmental, economic, and social performance indicators can play a pivotal role in smart ports to be particularly beneficial to both the port authority and a wide range of stakeholders in achieving environmental goals. In order to lower costs and the global fragmentation of value chains, ship owners are demanding their ships to perform new uses. The purpose is to reduce operating costs and increase competitiveness. Ports considered the smart port improvement mode as their key technical means as they are the main reason for the low energy consumption, low emission, and low pollution.

The standard of energy consumption is one of the important criteria for improving the performance of the smart port as it helps the growth of sustainability and competitiveness. The standard of energy efficiency and savings in various operations, buildings, equipment and warehouses is one of the important criteria as one of the requirements of smart ports. The marine industry aims to take advantage of renewable energies for ship designs. It aims to reduce material costs and operating expenses, especially when large ships with long life engines are built, and to save energy and new energies, such as green ships. In the fourth scenario, maritime transport moved towards integration into the global economy. This will improve the quality and performance levels of vessels.

Ports are exposed to many safety and security problems, by adapting smart port index framework; ports can improve safety and security as well as productivity, environmental awareness, and energy efficiency. Smart transformation of ports is not secured by only using innovative technologies but also by measuring management staff's knowledge and skills, in addition to practical IT methods and systems, which guarantees a sustainable development towards a smart port; resistance to change, lack of human resources, insufficient knowledge of procedures, and lack of interdepartmental communication increase the challenges of adaptation.

Considering the comprehensive analysis of previous studies, the research investigated that the five domains (operations, environment, energy, safety and security, and human resources) are separately included in smart port. Also different ports may face many challenges in implementing a proper digitalization level that is influenced by those domains. Therefore, the research proposes an integrated smart port index and linkage to sustainability performance.

The sustainable smart port index can be adapted to facilitate the improvement of sustainable smart port performance through utilizing the outcome measures, identifying the weaknesses and the challenges of adaptation and how to overcome, manage and improve those obstacles. Moreover, ports can use the sustainable smart port index to assess themselves and know where they stand in comparison to other ports.

The developed theoretical framework can aid port authorities, policymakers, and related stakeholders throughout the decision-making process and is capable of sustaining the identification and characterization of an efficient and adequate strategic approach for establishing the roadmap for the smart transformation of the seaport.

This paper presents a systematic literature review about adopting integrated smart port index and its effect on sustainability performance. Although the review shows an increase in the number of publications on the subject in the past years especially in developed countries, it has been observed that this is not enough to study in the developing countries. It is well known that in recent years, rapid smart urbanization and development have been witnessed. The result is an above-average burden on the smart port. Therefore, it could be stated that it is essential to apply an integrated smart port index as well as linking it with the port sustainability performance, which could stimulate the port activities and improve port service possibilities. This also may contribute to the improvement of their competitive position in the maritime transport services market as well as enhancing their overall performance.

7. Further Research

Since there is limited work in the publications that endeavors to enhance the smart port, and according to the developed framework, there is much left to be investigated. Some limitations followed by some suggestions for further review papers are as follows: The smart port is a recent and developing concept, and the focus of this paper is on the seaport. Accordingly, it may vary according to the opinions of the specialists, their experiences and their points of view about smart port applicability; the lack of detailed information about the inland port has created a constraint for decision-makers. Nevertheless, the port operators may practice these outcomes to use in their port transformation procedures. Moreover, the review is very comprehensive and dedicated to the majority of the previous literature, and it adds to the knowledge of the human resources factor, links the index to sustainability, and focuses on the relationship between the smart sea port index and port sustainability performance; however, this comprehensive review classified the theoretical framework into five domains and sub-domains of the smart seaport. Researchers can investigate other possible activity domains to be included in the smart port index.

These open a future agenda for future researchers to conduct empirical studies to test the applicability of the framework and test specifically the human resources and sustainability and its effect on the improvement of ports' performance. In this concern, this review paper provided some possibilities to encounter gaps in the study that can be addressed for future research directions, and still need dedicated efforts and significant attention from industry and/ or academia, and findings suggest investigating the following areas:

- Smart inland (dry) port: Regarding the lack of detailed information about the inland ports and dry ports, future researches can be developed to follow, monitor, and control traffic, logistics, containers, and inland depots in an adjustable way to improve the local and global port performance
- Short sea shipping: future research can develop decision making tools to improve the competitiveness of the coastal shipping sector, such as technical optimization of speed and route.
- Human resources: Future research can test specifically the human resources and sustainability and its effect on the improvement of the performance of ports
- Applying practical evaluation: Putting the five aspects of smart port into action and establishment of a more practical evaluation system that better complies with the actual situations. It is worth enlarging the analysis to the development of green and smart ports, which is in the planning phase to discover in-depth the content and theories concerning ports, expand the research scope, increase the rationality of the indicator system, and resolve insufficiencies. The empirical research can be extended to test the applicability of the model presented in this paper
- Integrating new indicators: future research should discover a more precise sympathetic of the properties of the smart port for various types of ports. Consequently, it is essential to develop new indicators for smart ports as operational or financial domains, integrate them into a dynamic performance measurement system, and link the various logistics aspects in the port area to obtain the development of the port. It is recommended that further research can study and categorize papers in different domains and sub-domains.

- Employment of technological solutions and information technology: more research will be necessary to fill this gap as most of the solutions are not yet mature to maintain the full vision of the smart port
- Promoting the applications of smart port: extra research could be proceeded to design and extend vital applications and the underlying digital back-end that promote an efficient collaboration platform for reaching a win-win collaboration.
- Usage of Cybersecurity in smart ports: further research is required to develop resilient and intelligent security systems which could predict forthcoming attacks.
- Enhancing technology exploration: a secure, geo-distributed network environment for IOS is still an open challenge concern, therefore, a framework combining big data, artificial intelligence, and IOS-based technologies is required for future IOS research. Nevertheless, some research studies have focused on ways to enhance intelligence in maritime operations, and maximizing intelligence in an IOS environment remains an essential part to be considered.
- Utilization of Big data: further investigations should be proceeded to design an information system updated with big data analytics to achieve reliable use of the extensive amount of data.
- Adaptation of Block chain technology: further effort is required for a cultural mind changing from an extremely competitive to a collaborative logistics environment.

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