Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 144 (2020) 1-12 EISSN 2392-2192

Smart ports: ranking of Spanish port system

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ABSTRACT

There is no doubt about the importance and impact of ports on our environment. The search for a mute smart, supported among other elements in the smart industry, makes ports look smart. The penetration of the concept in the Spanish port model makes it necessary to establish some indicators and some measurement indexes that allow categorizing the different ports according to their smart port component. It is concluded from the study that the ports of Valencia and Barcelona, predominantly container ports, are the ports that have a higher degree of smart ports.

Keywords**:** smart port, indicator, Spanish port system, ranking, index

1. INTRODUCTION

The search for efficiency, both social, environmental and economic, brings new value to the port sector beyond the large turnover it generates, but also in [1]. Due to the large number of port operations carried out daily, any improvement in the profitability of any aspect of the port sector will have a major impact on port planning and management. This is why the application of the Smart concept to this sector is particularly noteworthy, so that the term Smart

(Received 28 February 2020; Accepted 18 March 2020; Date of Publication 19 March 2020)

Port [2] has emerged and is of great interest to today's ports, as it is considered the basis for their future development and survival.

The use of new technologies to transform traditional port services into interactive and dynamic services, increasing their efficiency and transparency are the basis of the Smart Port concept [3]. The use of these technologies will allow the port system to walk hand in hand with data transport and big data systems, whose implementation will allow a complete transformation [4]. Digitization and automation of ports to reach 4.0 ports are currently two major drivers of change in port management systems [5].

Therefore, the main objective of Smart Ports is to be able to satisfy the needs and demands of users and clients, while including sustainability and the orientation of the port towards the city as fundamental pillars, generating quality spaces and services [6]. Therefore, the Smart Port is designed to be fully integrated with the Smart City concept [7].

In the commercial area, greater efficiency in maritime transport logistics, together with an improvement in the synchronization of traffic and the management of goods, will have a great impact on the final price of the product, which translates into greater commercial profitability [8].

Information and communication technologies (ICT) will allow for greater efficiency and safety in port management, while simplifying it, as well as improving relations between entities and the transmission of information, all from the institutional point of view [3]. A fundamental element of this process is that these technologies will allow greater control of incoming and outgoing goods, which will lead to an improvement in the customs security of the different countries.

In the social sphere, a Smart Port must be designed to place the citizens at the epicentre [9], which means that the port must be integrated in a sustainable way with the city and the environment [10]. At the same time, port management must be transparent and open, using IT platforms or applications that allow citizens to find out about day-to-day port activities and be able to take part in them [11].

The port must carry out its activities minimizing the negative impacts on citizens and the environment [1], having for this purpose technologies that regulate the activities carried out under the highest possible safety standards [12] and periodic analysis and controls that monitor pollution and spillage of hazardous substances in the port among other issues related to sustainability [13].

Paradoxically, the port system has not been renewed and adapted to the digital revolution as quickly as other economic sectors [14], there is a lack of definition, although as the presence of intelligent detection systems in ports increases, the concept is becoming established. It should be noted that in recent years great efforts are being made by the port authorities in this regard [15], of its foundations.

Therefore, the objective of the article is to show the indicator that has been developed to measure and prioritize the ports in its smart port category, as well as its application to the Spanish Port System, allowing to obtain a ranking of the Spanish smart ports.

2. MATERIAL AND METHODS

In order to obtain a ranking of the main Spanish ports according to their degree of adaptation to the Smart Port concept, it has been necessary to prepare an indicator that groups together all the characteristics related to this concept in order to apply it later to the ports under study. The methodology followed for this purpose is shown in Figure 1:

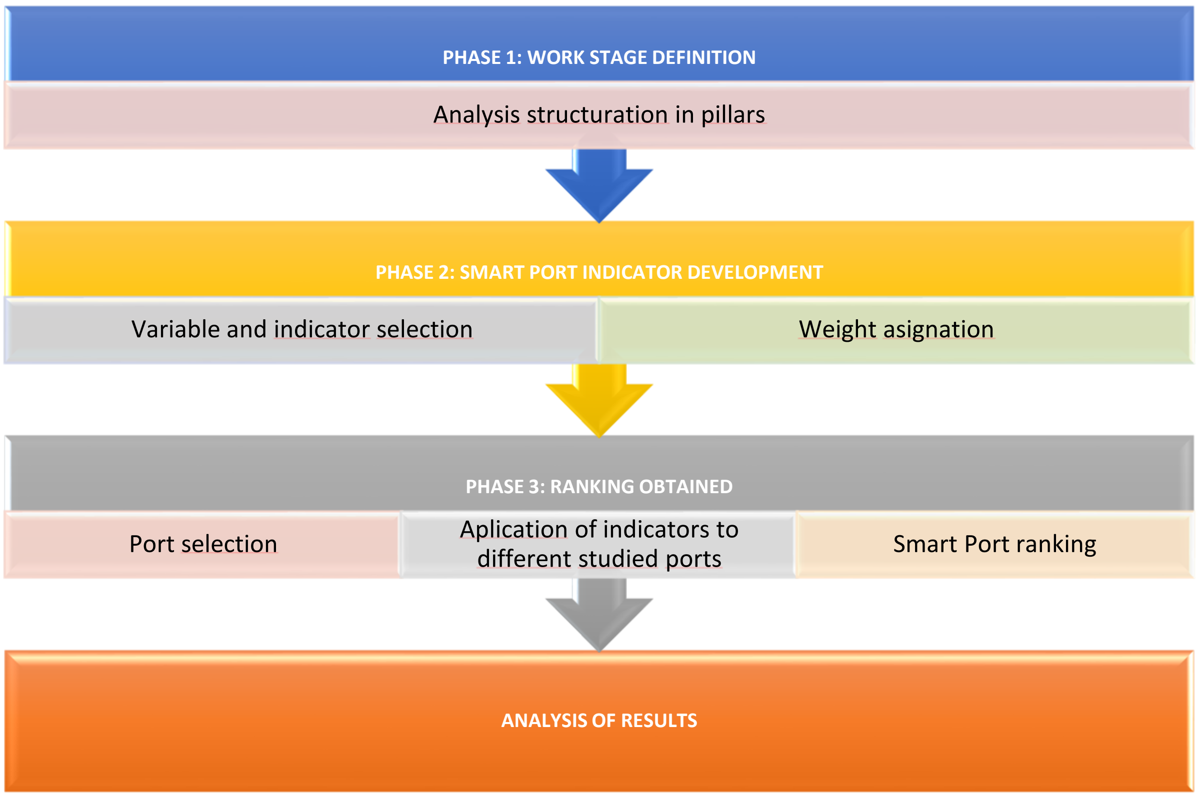

Figure 1. Applied methodology

2. 1. Phase 1: work stage definition

This phase consists of carrying out an exhaustive study of the entire Smart Port environment and its impacts in order to identify the main areas on which it has an outstanding impact. To this end, both the current state of development in the adaptation to the ideal smart port and the forecast of the approach of the concept in the future must be studied.

2. 2. Phase 2: smart port indicator development

This one consists of the definition and development of a global indicator capable of measuring and comparing the adaptation of a port to the smart port concept. This indicator must be easily applicable without losing the objectivity of the results. To do this, indicators, measurement variables and scoring rules must be defined clearly and concisely, referring to data and concepts that are easily measurable and identifiable when evaluating a port, avoiding indicators and variables that may refer to very specific characteristics of a particular port.

To obtain them, the following steps are followed:

a) Definition of the indicators, measurement variables and scoring rules most appropriate for the case study, using the Delphi panel methodology.

b) Weighting of the indicators, defining the importance of each one of them by assigning a particular weight to each one. This process is in turn divided into two phases:

- The overall weighting of each of the fundamental pillars defined trying to control and limit their importance within the smart port indicator is determined. The weighting is based mainly on the theoretical importance of the pillar itself rather than on its associated indicators.
- The importance of each indicator within the pillar in which it is contained is obtained, so that the total sum will be the overall total weight assigned to the pillar.

2. 3. Phase 3: ranking obtained

Development of the ranking of Spanish smart ports consists of applying the indicator to the ports considered. To do this, the ports under study must first be determined, so that they provide a complete and plural vision of 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, for which it is necessary to carry out research and data collection work, seeking the veracity of the data obtained. Thus, the assignment of a definitive score to each of the indicators for each port is carried out by developing the following two steps:

- Assigning scores to each indicator, using defined measurement rules to assign an objective and justified score to each of the indicators for each port.
- Application of weights to the scores of each indicator, multiplying the score of each indicator by its associated weight on the total of the Smart Port indicator, obtaining the quantitative contribution of a certain indicator in a certain port in the representation of its degree of adaptation to the Smart Port concept. The scores, once weighted, associated with each of the pillars, are added up to reflect the degree of adaptation of a given pillar to the ideal Smart Port.

Thus, once the overall score of each pillar is known, the weighted overall sum of all the pillars defined in the study is made to determine the total score of the Smart Port indicator in each port, obtaining a final classification of the selected ports in terms of Smart Port. The scoring system used is adapted to a total score over 100 points so that the results are more visual and easily analyzed, as well as the scores of each of the pillars.

3. RESULTS

Following the described methodology, after analyzing and analytically structuring the work scenario, the study focused on the analysis of smart ports considering 4 fundamental pillars:

- Economic operational
- Social
- Institutional policy

- Environmental

It was decided to consider digitalization as a transversal and intrinsic pillar to all of them, because if it were considered as an independent pillar, the other 4 pillars would only have the classic characteristics of a port sustainability study, when the final objective is the analysis of smart ports, which are focused on digitalization and new technologies.

Similarly, automation is also considered transversally in the study, affecting more directly and decisively the operational economic field, although it will also have effects on the social and environmental pillar. It has less weight on the political and institutional pillar, although the effect on the other pillars has certain repercussions in the political and institutional field.

Once the pillars had been defined, the choice of indicators and measurement variables was made using the DELPHI methodology. A total of 32 indicators were defined, distributed among the pillars as shown in Table 1.

Table 1. Indicators and variables of each pillar.

Pillar	Indicator	Measurement variables
Operational economic	Docking Line Efficiency	Tons of operated merchandise/linear meters of dock.
		Number of TEUs operated/linear meters of container dock
Operational economic	Use of storage capacity	Tons of merchandise operated/total commercial-port area
		Number of TEUs operated/container commercial-port area
Operational economic	Integrated digital merchandise management	Existence of open digital merchandise management systems, such as merchandise traceability, integrated scales, digital prior declaration of verified weight, merchandise and waste declaration. (RFID, OCR, GNSS, etc.)
Operational economic	Reception capacity of large ships	Docks of more than 14.5 meters of draft and dock of more than 250 meters of berthing
Operational economic	Terrestrial connectivity	Connection with high capacity road less than 1 km and railway in port terminal
Operational economic	Air connectivity	International airports with more than 5M travelers/year less than 25 km away
Operational economic	Degree of mechanical systems automation	Phase of the automation process in which the most automated terminal of the port is located, in relation to the percentage of dock cranes, patio porches and equipment for internal and external movement of automated goods

Pillar	Indicator	Measurement variables
Operational economic	Intermodality degree	% goods moved by Ro-Ro/total merchandise traffic
		% goods moved by railway/total merchandise traffic
		Existence of active Sea Highways in the port
Political and institutional	Management transparency	Digital platforms with open data system that offer transparent information about concession processes, online forms, announcements, economic data of the port and investments
Political and institutional	Management Systems Implemented	ISO 9001 Certification and EFQM Certification
Political and institutional	Navigation Aid Systems	Number of digital stations for weather and service conditions forecasting, wave measurement systems, tide control, beacons existence
Political and institutional	Adaptation to landlord models	Concession area/possible concession area
Political and institutional	Full ship assistance services	MARPOL Procurement, Bunkering, Repair and Waste Management
Political and institutional	Active transmission of acquired knowledge	Belonging to ECOPORTS, ESPO, RETE and IAPH
Political and institutional	Efficiency promotion in private operators	Number of private operators with quality of service bonus
Political and institutional	Customs process digitization	Single customs window (SCW)
Environmental	Water quality	Implementation of water quality measures: ROM 5.1, Improvements to the sanitation network, Follow-up of concessions for regulatory permits, Improvements in runoff management
Environmental	Environmental management systems	Environmental management certified by international standards (EMAS III and ISO 14001), PERS member
Environmental	Sustainable waste management	Transfer centers, Periodic monitoring of concessions, Clean points, Awareness campaigns

Pillar	Indicator	Measurement variables
Environmental	Automation of air quality assessment	Number of automated facilities for measuring contaminant particles in the air/Port surface
Environmental	Noise pollution	Surveillance and periodic inspections, Firm improvement in vials, Speed limitations in port vials, Installation of acoustic screens
Environmental	Renewable Energy Production	Implementation of renewable energy production systems: solar energy, wind energy, tidal energy
Environmental	Electricity consumption management	Annual electricity consumption BETWEEN Service surface unit. (kWh/m^2)
Environmental	Fuel use	Implementation of sustainable port vehicles: electric and natural gas
Environmental	Water consumption management	Annual water consumption/Service surface unit (m^3/m^2)
Social	Worker security	OHSAS 18001 certification
		Accident Frequency Index
		Accident severity index
		Port listed as cardioprotected space
Social	Digitization of access security	Digitization and access automation, such as automatic license plate reading systems, hardware connection such as cameras, wireless technology, sensors, RFID tags and data collection software
Social	Worker Training	Average hours of training per worker per year, both inside and outside the workforce
Social	Labor inclusion and equality in the workforce	% female workers of total workers
		% workers under 30 years of total workers
		% workers over 50 years of total workers
		% workers with a degree of disability greater than 33% of total workers
Social	Accessibility to the port for disabled users	Specific plans of the port authority to guarantee the accessibility of people with some degree of disability

Pillar	Indicator	Measurement variables
Social	Digital interaction with client	Digital port customer service and complaint collection systems
Social	Concern for citizenship acceptance	System of surveys or inquiries to citizen

Once the indicators and variables have been established, the scoring systems and rules to be followed are determined:

- Each indicator will receive a score between 0 and 4, with 0 being the worst value and 4 the optimal value in terms of adaptation to the smart port concept.
- Each indicator will be weighted according to its importance in reflecting the adaptation of a port to the smart port concept.
- The measurement variables chosen for each indicator must be easily applicable to the ports studied. Thus, in the event that a port does not present characteristics associated with that indicator or there is no information, the indicator will be assigned a score of 0.

To assign a particular weight to each indicator over the total set of indicators, the DELPHI methodology was again used, and the results obtained are shown in Figure 2.

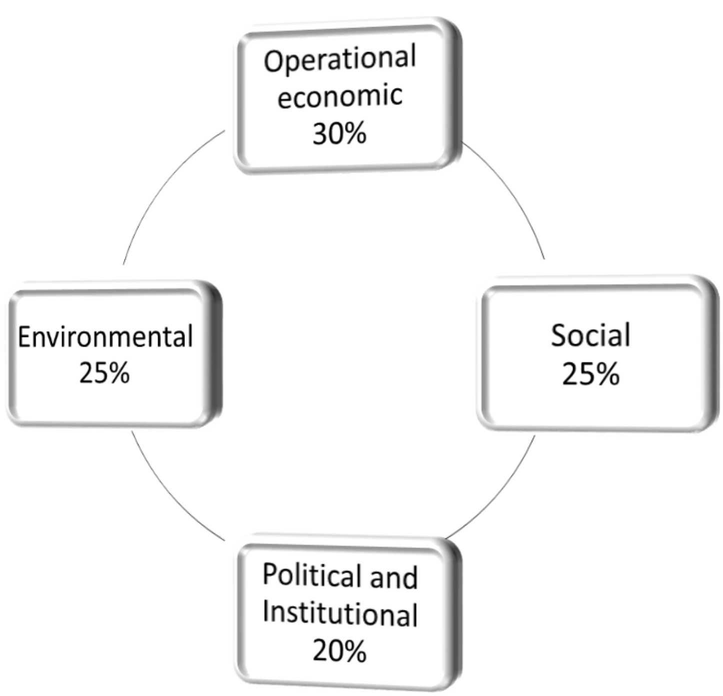

Figure 2. Weight assigned to each pillar

The assignment of weights to each indicator over the total was done by assigning a particular weight to each of them also through DELPHI methodology.

After that, the next step is selection of ports. Selected ports are included in Figure 3.

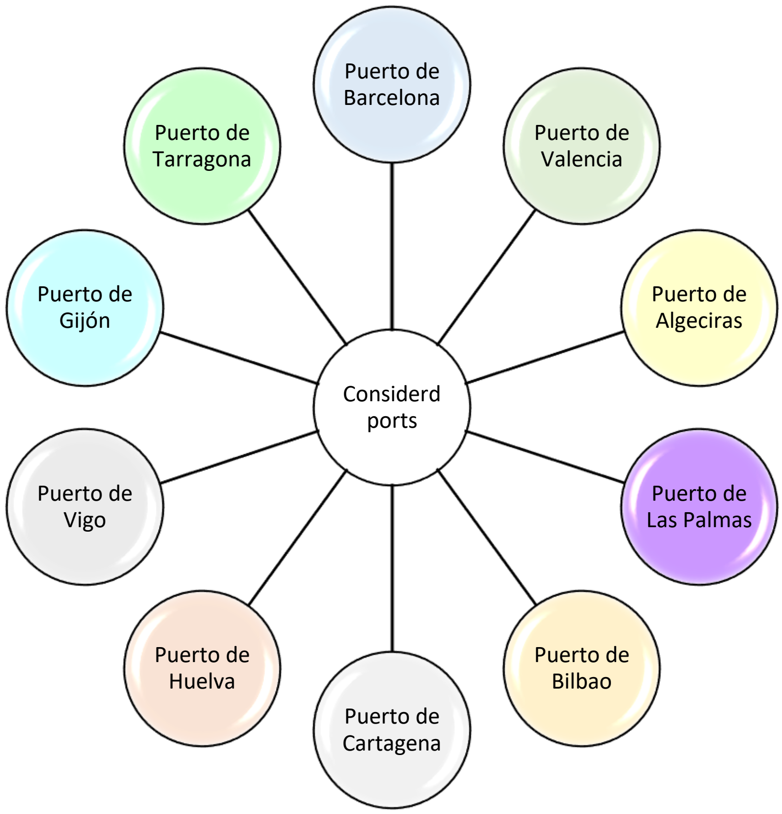

Figure 3. Selected port of Spanish Port System

After the collection of data from each of the ports considered, from the information available the ranking obtained for the overall classification, as well as for each of the pillars is as shown in Table 2.

Table 2. Smart port ranking obtained.

Ranking position	Ranking global	Ranking economic operational	Ranking social	Ranking institutional political	Ranking natural environment
1º	Valencia	Barcelona	Valencia	Barcelona	Valencia
2º	Barcelona	Valencia	Vigo	Valencia	Huelva
3º	Bilbao	Algeciras	Algeciras	Bilbao	Tarragona

Ranking position	Ranking global	Ranking economic operational	Ranking social	Ranking institutional political	Ranking natural environment
4º	Vigo	Bilbao	Barcelona	Vigo	Barcelona
5º	Algeciras	Vigo	Bilbao	Huelva	Bilbao
6º	Huelva	Las Palmas	Tarragona	Algeciras	Vigo
7º	Tarragona	Gijón	Gijón	Cartagena	Cartagena
8º	Gijón	Cartagena	Huelva	Tarragona	Gijón
9º	Cartagena	Huelva	Las Palmas	Las Palmas	Las Palmas
10º	Las Palmas	Tarragona	Cartagena	Gijón	Algeciras

4. DISCUSSION AND CONCLUSIONS

Once the Spanish Smart Ports Ranking is available, we proceed to the analysis of the different aspects of the results obtained, trying to reflect the situation of the ports with respect to each of the pillars and their role in the overall result, while identifying those aspects that the ports have developed in an optimal/poor way in terms of smart port.

Firstly, through the analysis of the Smart Port concept and its current and future trends, it has been determined that the development of a port towards this ideal must be based on digitalization, the use of ICT and the automation of its processes, gradually implementing them in the four dimensions or pillars considered to allow the port to progress towards a sustainable model oriented towards port efficiency and the creation of social value.

On the other hand, on analyzing the information and data collected from the ports under study, as well as the score associated with the digitalization and automation indicators, the conclusion is reached that the degree of development of the ports in these two aspects is very low, with the exception of the ports of Valencia and Barcelona, and those of Bilbao and Vigo, although on a smaller scale. It follows that, despite the fact that these four ports have invested in and implemented certain digitalization and automation measures, the degree of development is low compared to other international ports, such as Rotterdam or Antwerp, having only semi-automated terminals and digitized systems in the test phase and not fully functional and efficient.

Considering each of the four pillars, it can be seen that in the social aspect, the last positions are quite similar to the positions occupied in the overall ranking, which does not indicate a particular preference for the development of this pillar over the rest. However, the ports of Barcelona and Bilbao stand out in a negative way, occupying the 2nd and 3rd positions in the global ranking, and occupying the 4th and 5th positions in the social pillar, which shows that the development of this pillar can be interesting in both ports. On the other hand, the Port of Algeciras occupies the 5th position in the global ranking but the 3rd in the social one, which indicates that there may be other pillars of more urgent evaluation.

Likewise, in relation to the political-institutional sphere, it can be seen that, broadly speaking, the positions in most of the ports remain fairly similar to their relative positions in the overall ranking, so it can be considered that this pillar would not have special priority over another in most of the ports analyzed.

However, the Port of Gijón stands out as occupying the 8th position in the global ranking and the last one in the institutional political pillar, indicating that it would be interesting for the port to develop its institutional political aspects in smart port terms to place them on a par with its other pillars.

With regard to the results relating to the economic operating and environmental fields, it should be noted that, in general terms, the scores obtained are notably lower than those of the other two pillars, although there are specific cases in which these dimensions have obtained better scores than the rest which are generally more adapted. These ports coincide with the ports at the top of the ranking, which means that, in general, in order to advance in positions and achieve a greater degree of adaptation to the smart port concept, Spanish ports must invest more in the development of the operational and environmental dimensions, supported by digitalization and automation processes. The main limitation to the development in Smart Port terms in these two dimensions is due to the fact that the amount of investment in both is usually higher than the investment in the other two pillars.

Thus, in the economic operational aspect, the Ports of Barcelona and Valencia stand out, maintaining their positions of 1st and 2nd, interchanged in terms of the global position, while the Port of Algeciras is in 3rd position, its global position being 5th. This indicates that, in spite of doing a good job in the economic operational aspect, its performance in the other three pillars is not optimal and it has dropped several positions in the Global Ranking.

The rest of the ports evaluated maintain positions similar to their respective global positions, with the exception of the Port of Las Palmas, which occupies the 6th position in economic operational terms, the last one in the Global Ranking, despite being the pillar that has the greatest weight over the global score (30%), which implies that this port has left its development in the other three pillars in the background. On the other hand, the Ports of Huelva and Tarragona have a better overall score than the economic pillar, which shows that this would be a good aspect to take into account.

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