Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 132 (2019) 16-34 EISSN 2392-2192

Determination of key operational and environmental performance indicators in dirty solid bulk terminals. Implementation in the Spanish Port System

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ABSTRACT

Sustainable management of the port sector should be understood as one that brings together a reduction in the consumption of energy and natural resources, the volume of waste generated and the negative impacts on social systems and ecosystems in the areas of influence of the port; and allows for an increase in the volume of merchandise traffic and the number of passengers. In order to carry out a sustainable management it is necessary a previous study and to deduce a series of behaviors and tendencies to propose solutions or alternatives. For this reason, an integration of environmental indicators and operational performance indicators (KPIs) has been made in the research, customized for dirty solid bulk. Six representative terminals have been chosen to represent the entire Spanish port system, so that once our list of indicators has been defined, a study of behavior and interrelation of some parameters with others has been carried out in order to describe trends or conduct, and a Cluster analysis has also been performed. Through the study that relates the environmental factors and the indicators of management and operation, it is observed, a priori, that the solid bulk terminals of the Spanish port system that have a similar behavior, based on the management Vs environmental relationship, are those of Santander, Carboneras (Almería), Tarragona and A Coruña. Gijón and Algeciras are the terminals that exhibit different behaviors.

***Keywords*:** Sustainable management, dirty solid bulk, environmental KPIs, operational KPIs, Cluster analysis, Spanish Port System

(Received 16 June 2019; Accepted 05 July 2019; Date of Publication 06 July 2019)

1. INTRODUCTION

Port activity helps the economic independence of nations and is a strategic factor in their international trade. Ports, due to their essential role in foreign traffic and their action as promoters of the growth of the areas in which they are located, promoting traffic determination, generating income for the State coffers (port taxes), creating employment, etc., contributes to the development of countries [1].

The trend, however, is that the ports' role should exceed by far that of providing services to the ship and the cargo. Although acting as an interface between the maritime and land environments remains their primary role, ports increasingly tend to integrate into the logistics chains of production, transport and distribution and to become real added value centers [2], in such a way that they act not only as a mere link in the transport chain but also as a productive and logistical environment of great importance, in which industrial, tourist, business activities are carried out, etc. that go far beyond the simple modal exchange. This means that, in addition to the largest existing modal interchange centers, ports are strategic points in the current system of production, transport and world trade [3].

In recent times, especially since 2005, there has been much talk in the port environment of the need for sustainability in port management and operation. Production, distribution and service systems, in general, have been forced to consider the introduction of sustainability criteria given the increase in social, and therefore governmental, interest in these issues [4].

Also in recent decades there has been an intensification of competition among ports and a specialization of operations, so that the basic operating unit is no longer the port as a whole but the cargo terminals, located within the port services area and specializing in a particular type of traffic. This specialization has led international terminal operators to extend their activity throughout the world [5].

Currently, world trade is structured globally and is based on services that are provided individually but coordinated with each other [6]. Ports are identified as platforms of operations, not limited to vessels alone. This means that companies will move their activities where the human and physical capital necessary for their business is concentrated. In many cases, the availability of qualified personnel and the quality of telecommunications will be absolutely essential when choosing a port. Infrastructure, transport and energy will undoubtedly also be essential [7]. As in the case of cities, these elements listed above do not act separately, but are interconnected and must be understood throughout the entire port system. In fact, there is a much closer level of interrelationship in ports than in cities. Problems in transport, communications or supplies can seriously affect the daily activities of many sectors, and for this reason it is desirable that there should be the greatest guarantees of minimum risk. More clearly than has just been seen in cities, the improvements adopted in ports represent a significant increase in competitiveness as it is an almost exclusive business environment [8].

The ports develop an activity of public interest serving the international trade and benefiting the economy of the states. Their development boosts the economic growth of large coastal areas and thus play a social function by creating employment and wealth in their areas of influence. Ports therefore exercise a public function in which the State administration to which they belong must intervene [9]. To these are added the requirements of public administrations and society in general which focus their demands on other aspects such as safety and respect for the environment and the development of sustainable activities and infrastructures.

The port industry is under stress: it presents major uncertainties, tectonic changes in its functioning, upside risks and downside benefits, and may soon require different forms of public-private partnerships and port governance. The reasons for widespread stress (i.e. in both the government and private sectors) correspond to the interaction of endogenous and exogenous factors.

In most cases ports occupy urban-coastal land, which increases the incidence of the environment and the need for the port to respond to environmental issues. The Ports Authorities have assumed a role in promoting and overseeing these issues. It seems necessary, consequently, to introduce the principles of sustainable development in the planning, construction and operation of Spanish ports.

The great concern of the ports to " to be the best " in order to capture the greatest possible traffic, has been generating in recent years different initiatives, not only to promote greater development at the level of port operations, where undoubtedly current and emerging technology are directing their efforts, but also at the level of environmental and energy performance.

The commitments established in the European Strategy for 2020 point towards a consolidation of intelligent, sustainable and integrated transport in Europe [10]. The term "Sustainable Development" is understood as that which meets the needs of the present generation without compromising the ability of future generations to meet their own needs [11].

The smart concept is undoubtedly one of the most widely used in recent years when referring to a place, entity or product that, based on technology [12], manages to offer a highly sustainable service, that increases the quality of life of citizens, that is achieved with greater efficiency of available resources and that is supported by active user participation. Much progress has been made since the first references to the subject, but much remains to be done. The Spanish Ports Act establishes that Port Authorities must report on environmental sustainability objectives and indicators for each port and have a Sustainability Report prepared in accordance with an ad-hoc methodology. In December 2010, "Puertos del Estado" presented an initial proposal for such methodology, which contemplated the objectives, scope and contents of such instruments [i]. The Sustainability Reports of the Spanish ports, although coordinated by "Puertos del Estado", are not homogenized, making it very difficult to compare different Port Authorities. In addition, the versions are lengthening in time and current data are not available. Most of the information is neither structured nor homogeneous. Some data refer to the Spanish Port System as a whole and others to the Port Authorities (PA), data by terminals are non-existent.

In spite of the efforts, it can still be seen that the environmental, social, economic and institutional variable, to a lesser extent, are still emerging components of development strategies in some local port authorities, in private operators and in some port companies. In any case, the institutional component is the least recognized and dealt with in development strategies [13]. The drafting of Sustainability Reports, based on the recommendations of the Global Reporting Initiative [ii], involves an effort to integrate information on PA behavior and its environmental, economic and social performance.

At the beginning of the 2000's much was theorized about port sustainability and about the need that in order to identify the weaknesses and opportunities offered by the new scenario, it is necessary to contemplate the port from its different social functions and environmental aspects beyond its physical fact, by means of a triple port reality [14].

The reality is that the attempts to date towards a sustainable system have been more theoretical than real and there are no clear methodologies to develop and apply the concept to the Spanish port system.

One of the first works with a sustainable approach supported by the Sustainability Reports of "Puertos del Estado" is that of Camarero & Camarero [15]. This work is based on the studies of the cities and is transferred to the port world to make a classification according to environmental sustainability indicators. To this end, appropriate indicators are selected to evaluate the environmental sustainable activity of the ports. Once the indicators have been defined, they are assigned through the collection of available data, and the values of these indicators are used to classify the ports using cluster-type tools. In addition, the study is complemented with the study of physical and exploitation indicators, by means of regression analysis with other indicators. In this case, we only work with environmental indicators, we do not take into account the rest of sustainability components, in addition, the study is carried out by Port and not by terminals and it is not segregated by goods, as is the case of this study.

Another recent study [16] presents a methodology inspired by artificial intelligence models, consisting of inference with a Bayesian model for the analysis of the sustainability management of the Spanish port system, with which a decision-making aid tool has been obtained. This study integrates the four dimensions of sustainability in a similar way to "Puertos del Estado". Thus, starting from the port sustainability variables from the annual Sustainability Reports of "Puertos del Estado", a probabilistic model has been constructed that represents these variables and their conditional dependencies through a Bayesian network. An advance of this work can be seen in the work of Camarero et al. [17], for which a working methodology was followed that covers all phases of the research: context, characterization, data source, cluster analysis, results and analysis of results. The results obtained showed that Spanish ports can be correctly characterized by means of physical and exploitation indicators, and that cluster analysis is a valid and useful tool for the port environment, in this line a similar study has been attempted but applied to port terminals and not to ports. Some previous study has determined the efficiency scenarios of the container terminals of the ports that make up the current Port System in a way that allows port managers to take the appropriate measures to improve port management. For the analysis of the container terminal efficiency scenarios and through the use of probabilistic graphic models, Bayesian Networks specifically, the main variables were defined, some of them related to sustainability and inference has been made in virtual scenarios [18].

Other studies have used similar techniques to classify the ports of the Spanish Port System [19], but in no case taking into account sustainability indicators or focusing on port terminals of any type [15].

There is no study in the technical literature that deals with the sustainability of the Spanish port system, of its different Port Authorities and less of its terminals, which is why this study aims to lay the first foundations of a sustainability study, specifically for solid bulk terminals.

2. METHODOLOGY. INTEGRATION OF INDICATORS

For the integration of environmental indicators and KPIs, a methodological process has been followed that involves generating the database in order to be able to process the information. This process is summarized in Figure 1.

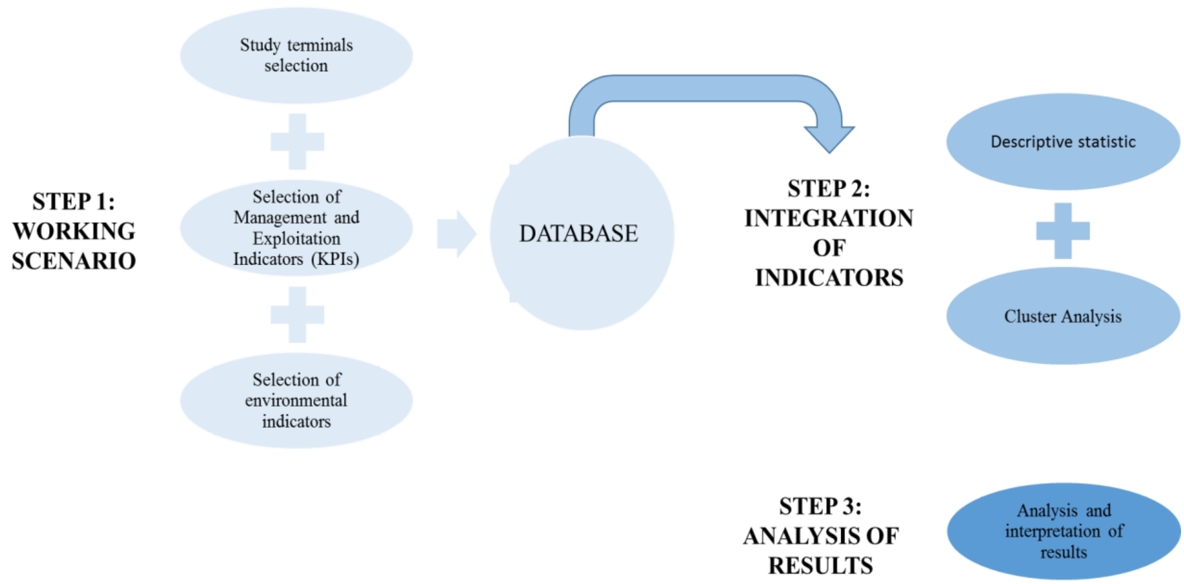

Figure 1. Methodology applied in research

2. 1. Work Scenario Determination

First of all, it is necessary to define the working scenario, the study focuses on dirty bulk terminals, a priori the most problematic from the environmental point of view.

Solid bulks can be classified into dirty and clean bulks. The dirty ones correspond to coal, minerals, fertilizers, scrap metal, etc. and the clean ones are those that are associated with human consumption, either directly or indirectly as cereals, among others.

In port operations, the movement and storage of cargo is the central activity of the physical process of transporting cargo. This consists of all the operations necessary to ensure the flow of goods entering or leaving the port by ship, with which it leaves or enters the port by truck, train, or conveyor belt [16] [iii].

This activity is fundamental, from an environmental point of view, since the physical handling of merchandise is the main cause of environmental incidents, such as spills, dust emissions or spills into docks.

The cleaning and maintenance of mechanical means of operation, work surfaces and complementary infrastructures, such as drains, workshops or machinery cleaning areas, is very relevant, from an environmental point of view, for two reasons: firstly, it is an activity that helps to control pollution, since guaranteeing cleanliness and the correct state of maintenance of machinery and infrastructure substantially reduces the environmental risk linked to the operation; secondly, the incorrect development of said activity can turn it, in itself, into a source of problems, as is the case of cleaning with adequate means [iii].

The movement and storage of dirty solid bulks, as well as the maintenance tasks of the machinery used, entail the generation of environmental aspects such as the emission of particles or the generation of waste, which, in turn, can give rise to negative impacts on the natural, social and economic environment, which is why we have chosen to work with this type of goods for the proposed study. For the selection of the study terminals, an intersection will be made between the dirty solid bulk terminals of the Spanish port system and the work indicators, given that when working with terminals, the generation of the database will depend on the public data to be collected.

As this is a study of terminals in the case of dirty solid bulk traffic, it is very important to try to characterize all the data in relation to dirty solid bulk and it is not enough to obtain general data from the terminals, as this would lead to a more generic study and distance us from the particular objective.

Finally, the panel of experts, on the basis of the data obtained for the preparation of the database and as a preliminary study on terminals and sustainability, considers it a step forward to be able to work with those terminals for which complete data were available. It is therefore very important to try to characterize all the data in relation to dirty solid bulks and it is not enough to obtain general data from the terminals.

2. 1. 1. A Coruña Port Authority

Solid bulk traffic through the A Coruña port represents around 30% of total port traffic; the most important traffics being agro food products, followed by coal and cokes. Other bulk materials that move through the port are cement, alumina and quartz.

The docks of the inner harbor in which these loads are operated are the Battery dock, where the special facility for the operation of alumina is located; the Centenary dock, which accommodates coal movements in the closed facility known as "La Medusa", as well as movements of agro-food products and the San Diego dock.

On the other hand, in the dock and operations area of the Exterior Port, movements of clinker loading and unloading of cement, coal and cereals are being developed, and the process of moving the main port operators that have been implanted in the new facilities of Punta Langosteira has begun, with warehouses for the storage and distribution of solid bulks, in which their volume of activity will gradually increase.

The environmental sustainability strategy of the port of A Coruña, consistent with its Integrated Management Policy, has the following objectives:

- To achieve a high level of technical commitment in port services and operations by controlling them, systematizing environmental management and preventing risks,
- Recognize and internalize the concerns of our stakeholders,
- Communicate, report on our response, and
- Seek the collaboration of the competent Administrations

2. 1. 2. Gijón Port Authority

The port of Gijón has some spaces, 415 hectares of land surface and 7,000 linear meters of quay, structured in areas with the appropriate characteristics to attend to each traffic. Specialized terminals for solid bulk, liquid and container, and multipurpose facilities for various types of traffic.

APG's environmental strategy is one of the priority strategic lines in the port's global strategy. In environmental matters, the main aspect on which work is done is air quality, both in improving analytical value and citizen perception, without abandoning the improvement of the rest of the environmental aspects of the organization. The Port Authority, during 2016, has continued to develop an intense environmental investment installing a screen with new characteristics in the Aboño area, for the reduction of particle emissions; it has developed the building work to the ordering of traffic in the area of the Bulk Terminal, thus enabling the installation of a wheel washer and the paving of the area; and it has begun sending on-line data on air quality to the Principality, thus completing the measurement network of the agglomeration of Gijón.

2. 1. 3. Santander Port Authority

Solid Mineral Bulk Terminal is automated in all its processes with state-of-the-art equipment. It allows to reach high yields with minimum emissions to the atmosphere.

Santander's solid bulk terminal was ranked as one of the two best in the world in the 2017 edition of BIMCO's annual report on dry cargo terminals [iv]. Santander was the best classified in the four main categories: loading and unloading operations; berths and moorings; exchange of information between the ship and the terminal and its equipment. The latest research report by the International Maritime and Baltic Council on solid bulk terminals has concluded, after evaluating the performance of a total of 278, that the best facilities for this type of traffic are those of Santander and Bilbao, together with that of Quebec in Canada.

Noatum Terminal Santander is the most modern terminal in Spain for handling powdery bulk solids and complies with the highest environmental, quality and occupational safety standards.

2. 1. 4. Tarragona Port Authority

The movement of energy and mineral products represents a very important volume of traffic in the Tarragona Port: 4 million tons a year are distributed through our facilities. In this group of goods, coal and petroleum coke represent almost 85% of the total.

Of the remaining minerals, common mineral salt and phosphate are the most prominent.

On the other hand, the rest of minerals, most of them imported, are raw materials that will be used in industrial processes of companies in the hinterland near the Port.

The Port of Tarragona has protocols that establish that the movement of these goods is done with the greatest consideration towards the environment.

Any environmental improvement implies a reduction of the impacts that some activities have on others, which results in a better quality of service and, in turn, improves reliability and operating costs.

2. 1. 5. Almeria Port Authority (Carboneras terminal)

The Port Terminal is located in Carboneras and its activity is focused on the unloading and loading of coal.

Since 2006, the Terminal has a Management System under the standards UNE-EN-ISO 9001:2008 (quality), and since 2008 under UNE-EN-ISO 14001:2004 (environment). The management system includes all the necessary resources to establish and implement the Quality and Environment Policy.

2. 1. 6. Bahía de Algeciras Port Authority

Endesa Generación's Los Barrios Port Terminal is home to the largest solid bulk port in the Bay of Algeciras and one of the largest in Spain. The excellent port facilities of the Terminal, its location in the industrial area of the Bay and its proximity to the petrochemical complex of the Guadarranque industrial estate, give this enclave a privileged situation within Algeciras Port. This is enhanced by the fortresses of this: sheltered bay, extensives anchoring spot and unbeatable global strategic location. The terminals considered are those included in Figure 2. The aim is to cover all the port facades.

Figure 2. Terminals considered in the study

2. 2. Selection of Management and Exploitation Indicators (KPIs)

2. 2. 1. Management indicators: KPI

The management indicators are very common in the business environment but not so much in the port sector, which is why for the selection of KPIs an expert panel has been raised through a Delphi, with experts from both the private and public sector, starting from the indicators that are collected in the annual reports published by "Puertos del Estado". The reports are a platform for communicating positive and negative sustainability impacts, and for capturing information that can influence the organisation's policy, strategy and operations on an ongoing basis. The Sustainability Reports published by "Puertos de Estado" are relatively new, have been published since 2010 and the last one published is 2016. The sustainability reports are in continuous change and evolution, so their format from one publication to another varies, as well as the data and the way they are presented and aggregated. The data are aggregated by Port Authorities, not by exploitation terminals and in default by the entire port system, which makes it more difficult to undertake a job of this type.

The general trend in the analysis of the operation of a terminal is to compare the ratios and international parameters, and to establish what a terminal moves away or approaches in its operation to the values of these international parameters.

In this work the KPIs established by the IAPH (International Association of Ports and Harbors) have been taken as the most suitable indicators to be able to compare some terminals with others, although this study is for container terminals it is taken as a base due to its international application and its simplicity.

The European Union's 2010 project, coordinated by the European Sea Ports Organisation (ESPO), is one of the largest and most ambitious. With the PPRISM project[1], ESPO has taken a first step towards establishing a performance measurement culture in European ports. Another Portopia project [20] aims to create an integrated knowledge base and a port performance management system to serve industry stakeholders in improving the sustainability and competitiveness of the port system.

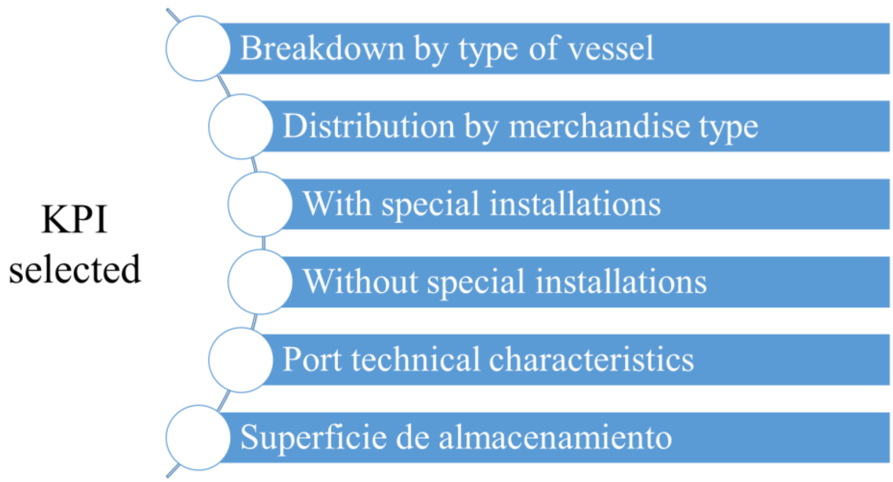

Figure 3. Management KPIs considered in the study

Observing all the data collected from the reports and following the development of the Delphi panel, seven indicators have been proposed, on which work has been done to facilitate their understanding by percentages. It is necessary to separate, whenever possible, the general data of each Port Authority in order to obtain the particulars of solid bulks, in order to construct a more specific and real analysis.

Firstly, the distribution by type of ship, in our particular case of dirty solid bulks.

The distribution by vessel of solid bulk is separated into number of vessels and GT. At the same time the origin of the ships is distinguished, which gives us an idea of the traffic of these terminals.

Secondly, the distribution by type of merchandise has been a more laborious indicator, since it has been necessary to distinguish dirty solid bulks from other solid bulks such as agrifood.

Within the group of dirty solid bulks, we have distinguished between coal, cement, oil and others, where the rest of the dirty solid bulks are included.

In order to make it easier to understand the total amount of goods moved by each terminal, it was decided to use the percentage of goods loaded and unloaded.

In the terminals, two areas can be distinguished that are prepared for the reception or dispatch of dirty bulk solids. For this reason, we have considered it appropriate to distinguish

[1] pprism.espo.be

between areas fitted out with special installations and those without special installations, as is commonly dealt with on the exploitation.

With regard to the technical characteristics of the port, we have obtained the total length of the quays destined for dirty solid bulks and we have compared the traffic moved in order to obtain a relationship.

Finally, an exhaustive study of the type of storage carried out in these terminals has been considered very opportune, for which the last indicator is the storage surface which has been obtained in three subgroups, covered, overdrafts closed and total.

At the level of management and operation, following the methodology described, the KPIs selected are those included in Figure 3.

2. 2. 2. Environmental indicators

The obtaining of environmental indicators has been structured as follows:

- Analysis of the 2016 sustainability reports of each Port Authority under study.
- Obtaining common environmental indicators.
- Complementation of the necessary information by other means.
- Transformation from qualitative to quantitative indicators

Firstly, based on the six sustainability reports, we can structure the environmental indicators into three groups:

- Water quality management.
- Air quality management.
- Noise quality management.

Once these three groups of indicators had been defined, relevant data was sought. It is worth mentioning that each Port Authority is obliged to elaborate the Environmental Sustainability Reports annually, but the way in which they should be carried out is not regulated. Nor are there any minimum indicators that each authority should evaluate in order to make an effective comparison.

For this reason they have been complemented with information provided by the autonomous community where our terminals are located.

i. Water quality management. According to ROM 5.1-13 [v], there is a programme for the delimitation and typification of port aquatic management units.

ii. Air quality management. Air quality assessment is defined as the result of applying any method that makes it possible to measure, calculate, predict or estimate the concentrations of a pollutant in ambient air or its deposit on surfaces at a given time. The evaluation is carried out by means of measurements at a series of sampling points that are considered representative of each terminal.

iii. Noise quality management. There are a multitude of variables that make it possible to differentiate some noises from others: their frequency composition, intensity, temporal variation, cadence and rhythm, etc. The current national legislative framework on noise is as follows:

- Law 37/2003, of 17 November, on noise [21]
- Royal Decree 1367/2007, of 23 October, developing the Noise Act in relation to acoustic zoning, quality objectives and acoustic emissions [vi]

According to this regulation, acoustic quality objectives are established, i.e. the overall noise of an area or territory. In order to do this, it is first necessary to carry out acoustic zoning (for example, industrial areas, residential areas, special protection areas such as hospitals, schools, etc.).
On the other hand, acoustic emission limit values are also set for certain activities to ensure that the quality objectives of the area where they are located are met.
Thus, the current regulation requires industrial acoustic areas emission limit values of 70 dBA in daytime and 60 dBA at night, as a general reference, being reduced by 10 dBA in residential areas and 15 dBA in sensitive areas, such as health and education.

On the other hand, the environmental indicators considered, according to the methodology described above, are those included in Table 1:

Table 1. Environmental indicators considered

Management	Indicator
Water quality Aquatic Port Management Units (UGAP). Quality	Physical-chemical sediment
	Biological (chlorophyll)
	Physical-chemical water
	Water and sediment chemistry
Air quality	Sulphur dioxide SO_2
	Carbon monoxide CO
	Nitrogen dioxide NO_2
	Small solid particles PM 10
	Ozone O_3
Noise quality management (dB)	dB

Finally, the following table (Table 2) contains in maximum detail the indicators used in the research.

Table 2. Indicators used in the study.

Indicator type	**Group**	**Subgroup**	**Units**
Management	Distribution by type of vessel	Number vessels Spanish Number of foreign vessels Total number of vessels Spanish GT (Gross Tons) Foreign GT Total number GT	Number Number Number Gross Tons GT GT
Management	Dirty solid bulk distribution (aggregate set) WITH special facilities	Cabotage Embarked Cabotage Disembarked Total Cabotage Exterior Embarked Exterior Disembarked Exterior Total Total	Tons Tons Tons Tons Tons Tons Tons
Management	Distribution by type of bulk solids dirty WITH special facilities	Goods shipped Goods landed	%of total soiled bulk solids %of total soiled bulk solids
Management	Dirty solid bulk distribution (aggregate set) WITHOUT special facilities	Cabotage Embarked Cabotage Disembarked Total Cabotage Exterior Embarked Exterior Disembarked Exterior Total Total	Tons Tons Tons Tons Tons Tons Tons
Management	Distribution by type of bulk solids dirty WITHOUT special facilities	Goods shipped Goods landed	%of total soiled bulk solids %of total soiled bulk solids
	Port technical characteristics	Length of berthing line Draft with special installations Draft without special installations Total draught Uncovered storage area Covered storage area Closed storage area Total storage area	meters meters meters meters square meters square meters square meters square meters
Environmental	Water quality	Port aquatic management units	Indicator from 1 to 5
Environmental	Air quality	Water quality units	Indicator from 1 to 5
Environmental	Noise quality	Noise	dB

2. 3. Database Generation

In order to obtain the KPIs, the reports and data available from each Port Authority have been used. Figure 4 is included as an example.

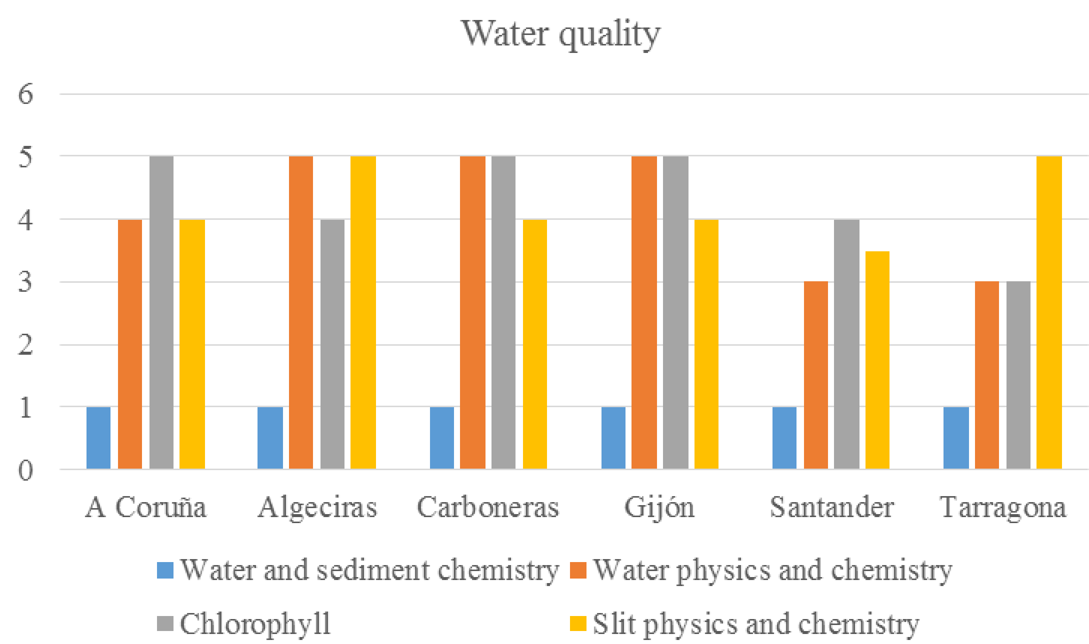

Figure 4. KPI example available

2. 4. Integration: KPIs relationship with environmental indicators

In this point we intend to relate the selected KPIs with the environmental indicators to see the relationship between the management of the infrastructure and its environmental component, in such a way that the interaction between management and the environment is known. Two methods are proposed:

- Descriptive statistics
- Cluster analysis

2. 4. 1. Descriptive statistics.

Descriptive statistics is the branch of Mathematics that collects, presents, and characterizes a set of data in order to appropriately describe the various characteristics of that set. Descriptive Statistics or Exploratory Data Analysis methods help to present data in such a way that its structure can be emphasized. There are several simple and interesting ways to organize data into graphs that allow you to detect both outstanding and unexpected characteristics. Alternatively, the data can be summarized into one or two numbers intended to characterize the whole with as little distortion or loss of information as possible.

In order to relate all the indicators, a database has been created, in which the six terminals with their 10 indicators are located and, by means of descriptive statistics, each KPI has been analyzed with each environmental indicator, thus being able to observe each one in detail.

2. 4. 2. Cluster analysis.

Cluster analysis is a set of multivariate techniques used to classify a set of individuals into homogeneous groups.

Like other typologies and discriminant analysis, it belongs to the set of techniques aimed at classifying individuals. The fundamental difference between cluster analysis and discriminant analysis lies in the fact that in cluster analysis groups are unknown a priori and are precisely what we want to determine; whereas in discriminant analysis, groups are known and what we want is to know to what extent the available variables discriminate against these groups and can help us to classify or assign individuals in the given groups.

Therefore, the objective is to obtain classifications (clusters), thus the analysis has a marked exploratory character.

The aim of cluster analysis is to find a set of groups to which the different individuals can be assigned according to some homogeneity criterion. For this reason, it is essential to define a measure of similarity or divergence in order to classify individuals into one or other groups.

2. 4. 3. Main results

The main results obtained after the study carried out with descriptive statistic are those shown in Figures 5, 6, 7 and 8. The figure indicates that the more vessels operated the noise does not increase. The same can be observed with respect to water quality, which does not worsen if more vessels are operated in the port (Figure 6), and similarly for air quality (Figure 7). This indicates that, although many dirty solid bulk ships are operated in a port, a priori the quality of water, air and noise should not be affected if the measures to be taken are adequate.

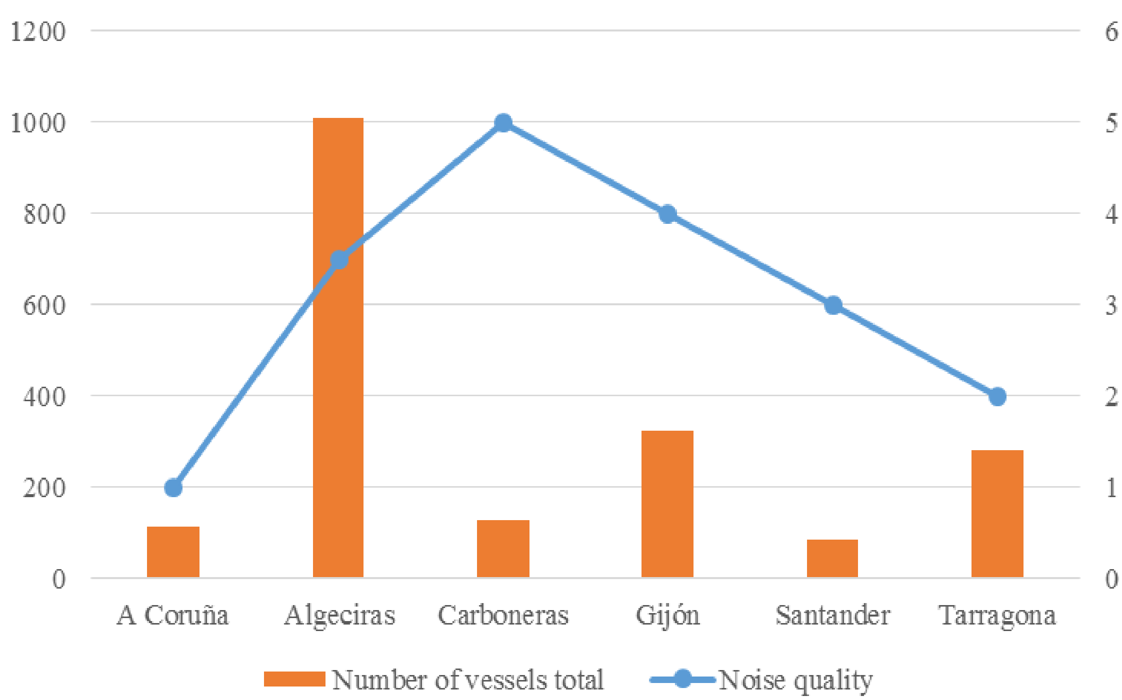

Figure 5. Noise quality ratio and number of vessels

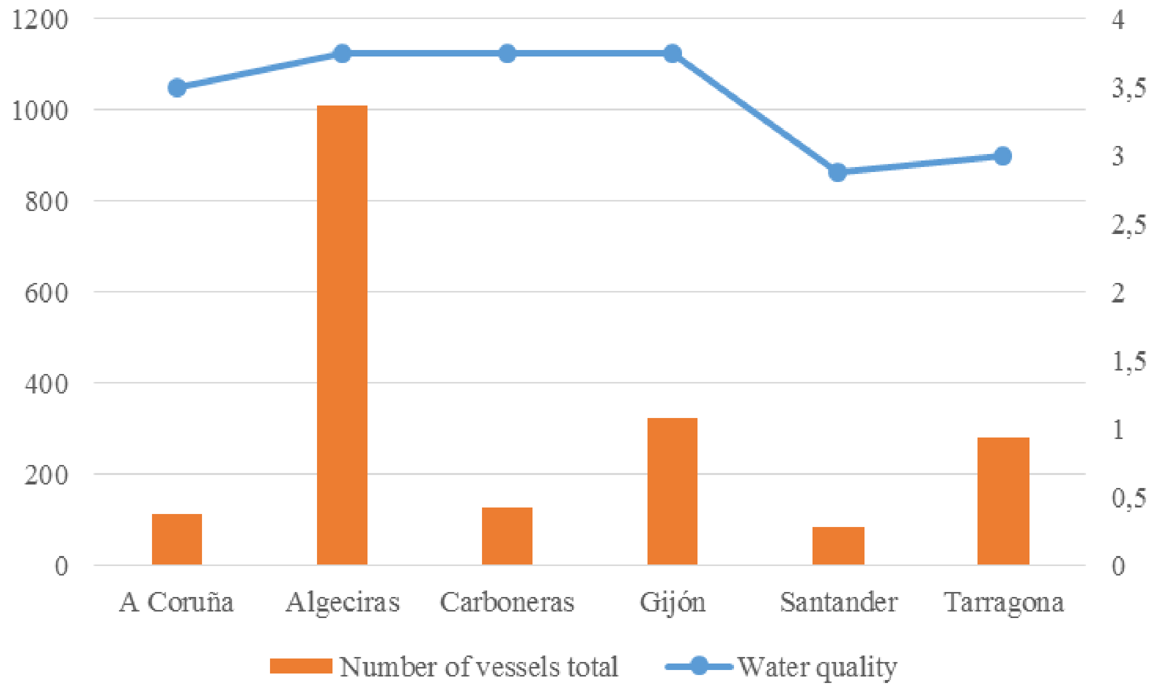

Figure 6. Water quality ratio and number of vessels

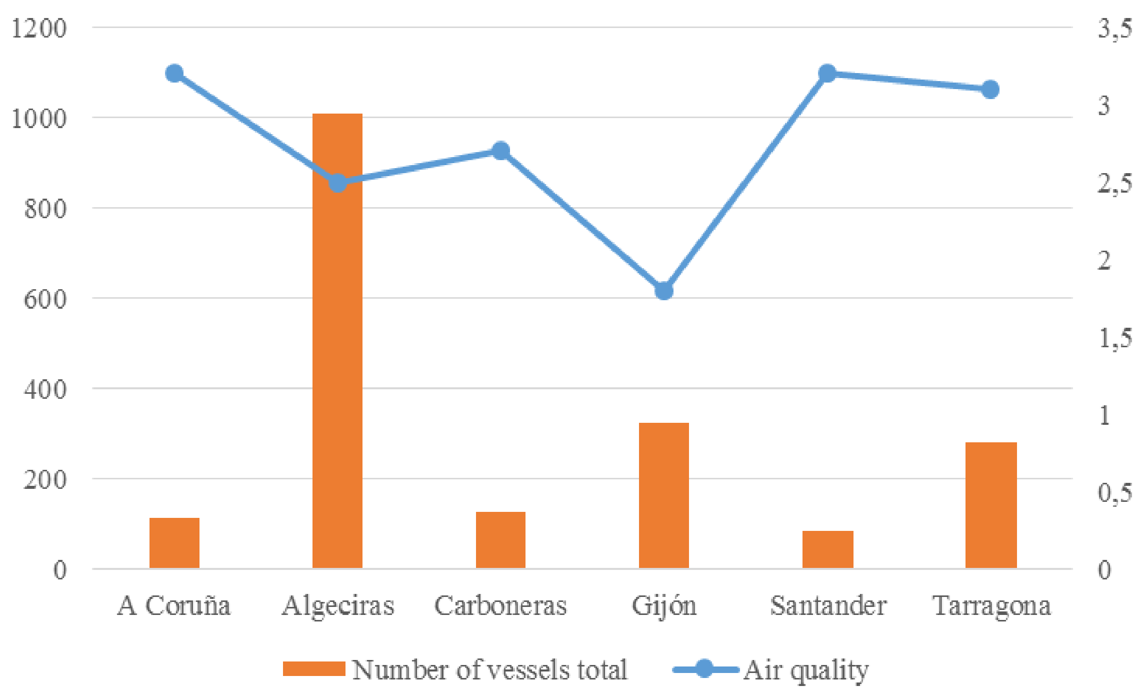

Figure 7. Air quality ratio and number of vessels

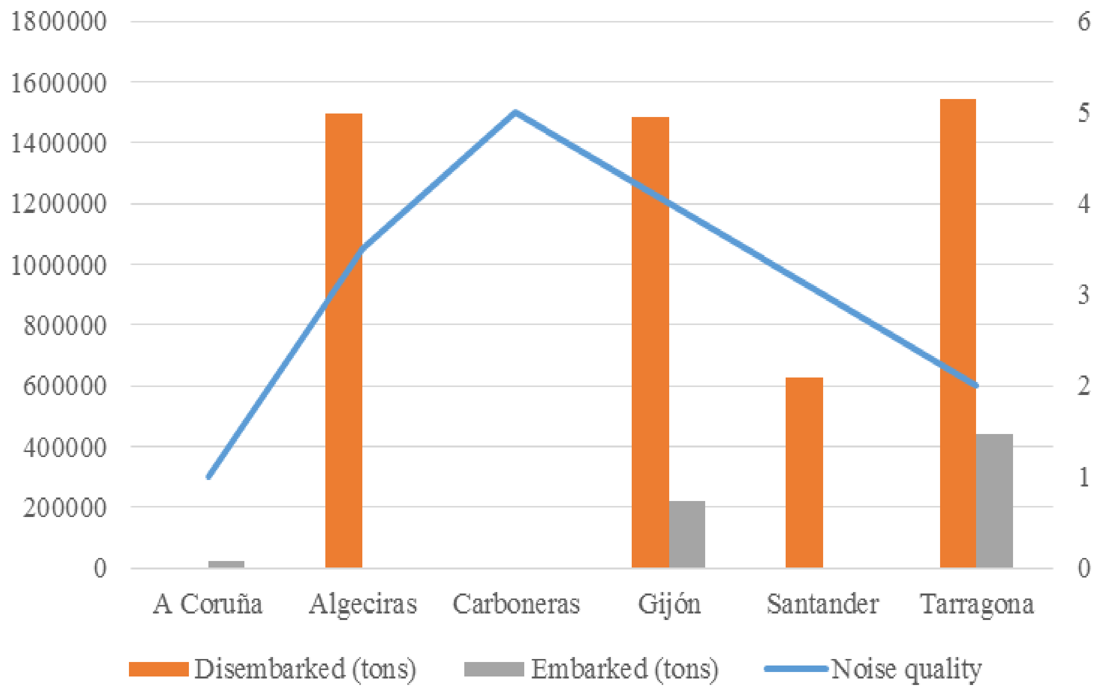

Figure 8. Noise quality ratio with special installation

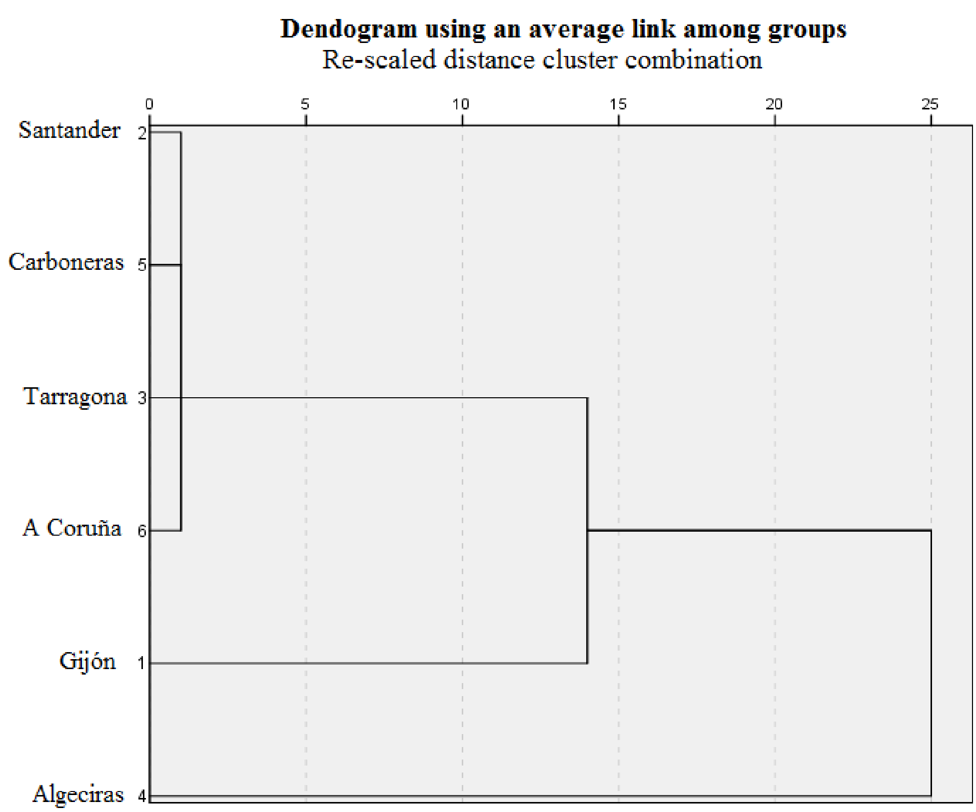

Figure 9. Dendogram intermediate link

What's more, after using cluster analysis, the results obtained are those shown in the dendogram in Figure 9.

The resulting dendogram shows that the dirty solid bulk terminals in Santander, Carboneras, Tarragona and La Coruña are similar in terms of their management and environmental measures. By far the most distant would be Gijón and finally Algeciras.

3. CONCLUSIONS

Finally, after carrying out this research by analyzing the results and comparing them, a series of conclusions have been obtained, which are shown below.

There is a great difficulty in generating the database, due to the lack of information from solid bulks. In Spain there are no open data on this subject, which makes it difficult to draw up specific studies on this subject. The Sustainability Reports of the Spanish ports, although coordinated by "Puertos del Estado", are not homogenized, which makes it very difficult to compare different Port Authorities in environmental terms.

Through the study relating the environmental components and the management and operation indicators, it can be observed that the solid bulk terminals of the Spanish port system that behave similarly with respect to the management vs. environment relationship are the terminals of Santander, Carboneras, Tarragona and A Coruña. Gijón and Algeciras are the terminals with different behaviors.

In spite of the fact that, during the study, the terminals of Gijón and Tarragona were very similar in terms of management and operation, when integrating the environmental variable their similarities disappear. It should be noted that, if they behave similar in terms of management, number of solid bulk vessels, size, but this is not an indicator that they are behaving environmentally equal according to the results.

From the study carried out, it can be concluded that a greater number of ships or greater movement in a terminal does not imply having excellent environmental quality, this would be the case of Gijón, which with a significant traffic does not take high environmental values. On the other hand, the example of Tarragona stands out as a terminal that behaves quite well environmentally.

The limitation of this study is that it is a first estimate that allows us to reflect on the relationship that may exist between KPIs and environmental indicators, but that will need a more detailed analysis, in which environmental indicators are obtained from parameters measured in the terminal.

The contribution of this study is not the results obtained in themselves in the comparison made between productivity parameters and the environmental indicators of the terminals, as these results suffer from the limitations referred to environmental indicators. However, it proposes a methodology for comparing the two indicators and defines some relevant indicators to be considered with regard to both productivity and environmental performance.

With regard to the prospective of the indicators to be considered in dirty solid bulk terminals, an integral approach should be sought that includes a related vision between the different parameters, both productivity and environmental behavior or others. Bearing in mind the lack of availability of environmental parameters that has surfaced in this study, it is suggested that terminals be encouraged to have these parameters in the future, and it seems that the most immediate practical way is to encourage terminals to have a unified environmental management system.

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