A Fuzzy-AHP classification of container terminals

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Abstract

This article proposes a methodology for the classification of container terminals aiming to identify groups of terminals with similar management characteristics. Based on physical and terminal operations data and the subjective judgement of experts in port management, we show that it is possible to identify the main factors affecting the management of container terminals, and produce a classification of these facilities that will allow them to know their strengths, weaknesses and their place within their port system and in relation to its competitors. The methodology is based on Fuzzy-Analytic Hierarchy Process (F-AHP). As a case study to validate the procedure, the Spanish port system is selected, and our results are compared with other classification methods not including subjectivity criteria, namely Cluster Analysis. By assigning more weight to expert judgements, results differ and become more trustable since expert knowledge can go beyond simple variables such as TEUs moved or number of available cranes.

Keywords: Container Terminals; Port Management; Fuzzy-AHP; Clustering; Port classification

1. INTRODUCTION

Maritime transport currently represents more than 90% of the volume of international trade, involving the world's maritime routes and multimodal exchange networks composed among others by ports and their host cities (Ducruet, et al., 2018).

Although throughout history developing countries have been the main suppliers of raw materials to developed countries, since 2014 an important change of trend has been detected: for the first time the goods unloaded in developing countries have overpassed the goods loaded, which implies the importance of world maritime trade, as well as the importance of all kind of countries in global value chains (UNCTAD, 2018).

Since its first documented appearance in 1956, the container has been a technological revolution of continuous innovation to minimise costs and delivery times. Forklifts have been used since the 1920's and utilised to a large extent in the 1950's to move pallets from the warehouse to the vessel side (Levinson, 2016). From that moment on, the use of the container has undergone processes of continuous improvement and technological innovations that have meant a revolution in the way goods are moved on a global scale.

It is almost impossible to quantify how much the container contributes to the global economy. It is estimated that 752.2 million TEUs were handled at container ports worldwide in 2017. For the management of such an immense number of boxes, the adoption of IT developments and the large-scale application of automation processes have become mandatory. Also, because of the growing demands of the sector, the capacity of container terminals has increased considerably in recent years and research efforts have focused on automating processes as much as possible.

Even though container terminals differ considerably in size, function and geometrical layout, they all share the need to offer their customers competitive conditions, involving a reduction in the length of stay of ships in port, and the completion of port operations in the shortest possible time at the lowest possible cost.

In this global context, a well-developed transport infrastructure network is a prerequisite for access to economic activities and services worldwide, while effective modes of transport allow corporations to meet their objectives (Torres & Rendón, 2013). These modes of transport usually end at container terminals, which are "*logistics points included in a global chain that can provide added value to their users as elements of wider systems of circulation*" (Rodrigue & Notteboom, 2009). Therefore, a container terminal is a port facility that constitutes the interface between the different modes of transport, making possible the transfer of cargo between ship and truck, or railroad, pipeline, etc. (Estrada Llaquet, 2007).

Considering this wide diversity of factors and the high competitiveness of the sector, it becomes interesting to establish a classification system that takes into account the most important variables defining container terminals, thus allowing to understand the different types of those facilities from the view point of management requirements. This could help to better understand the challenges facing the different types of terminals, as well as the most suitable way to manage each one.

1.1. Managing container terminals

An integrated container terminal is a very complex system including official agents, inspection agencies (Foreign and Veterinary Health, Phytosanitary Inspection and Foreign Trade Inspection Services) as well as private agents (moorers, shipowners, operators, tugboats, stevedores, customs agents, freight forwarders, transport companies, etc). Dealing with all these agents belongs to the daily management of any container terminal. A terminal's main mission is to provide the means and organisation necessary for the exchange of the container between the diferent modes of transport, to take place under the best conditions of speed, efficiency, safety, respect for the environment and economy (Monfort, et al., 2001).

Container terminals differ considerably in size, function and geometrical layout, but they are principally made up of four subsystems: ship to shore, transfer, storage, and delivery/reception (Sauri & Martin, 2011). It clearly looks like differences in sizes, infrastructure or arrangements of different container terminals may result in different management practices worth understanding further. It is highly probable for instance that a small, specialised, reefer container terminal will require a different management approach than a large transhipment terminal located on major trade routes.

This paper aims to determine the information necessary to enable the categorisation of container terminals and thus reveal the management characteristics they share or those that make each one unique. The intention is to offer a methodology that allows one to classify and group container terminals according to the factors or variables that affect their management, or make such management especially singular. We are going to systematise the subjective criteria of port managers and apply mathematical models that allow us to weight the physical and operational characteristics of terminals, thus being able to classify them according to how these variables affect their efficient management.

2. RELEVANT LITERATURE

In scientific literature, there is no agreed method for the classification of container terminals. Not even a consensual conventional terminology exists for such a classification. The existing literature on the functions of ports and their organisation is very extensive, but although there is a large number of proposals for the classification of ports, there is no single framework or even an accepted terminology (Bichou & Gray, 2005).

Multiple studies on port economics, performance, governance and management have appeared in the past few years in scientific literature (Pallis, et al., 2010).). Vieira et al. (2014) have identified a total of 63 main articles related to these subjects in the period 2004-2013, focusing on various aspects of port management and concluding that the relationship between governance models and port performance does not seem to have been sufficiently studied. Neither governance nor performance has the aspects that differentiate the management of port terminals, in a way that contributes to achieving excellence in the management of container terminals (Vieira, et al., 2014).

However, other aspects such as efficiency in the container industry have been widely studied from various approaches, such as "Data Envelopment Analysis" (DEA) or "Stochastic Frontier Analysis" (SFA) (Lampe & Hilgers, 2015; Lu & Wang, 2017). The sector's strong commercial competition has driven research efforts to improve the competitiveness of port terminals terminals (see for instance the early papers of Rios & Maçada, 2006; Wu et al., 2010).

There are numerous cases of the use of DEA for benchmarking container terminals using public data, but certain disadvantages have also been detected in the use of this method, such as the low reliability of the source data, or the actual lack of (predominantly port labor) data, given the fact that much of this information might be considered confidential and therefore impossible to access (Cullinane, et al., 2006). The above authors also conclude that the information obtained can be used to assist governments and authorities that manage container ports in making management decisions at the level of port authority or terminal operator. In addition, studies have tended to mix ports with container terminals and fail to take into account the differences between very large terminals and specialised terminals (De Koster, et al., 2009). The most likely explanation for this would be the lack of a systematic method to classify terminals beyond the differences in magnitude of the physical and operational variables of the terminals themselves.

Other frequently used methodology, according to reviews and systematic analysis of the state of the art, is Analytic Hierarchy Process (AHP) and its evolution, Fuzzy-AHP (F-AHP), both used in 25.84% of the 89 papers reviewed for the whole transportation system, with 5 of the papers reviewed focusing on the shipping industry (Mardani, et al., 2016).

AHP is also widely used in the port environment, although not directly used to categorise terminals as in our case, but to assist decision-making in transhipment port selection (Lirn, et al., 2004). Ugboma et al. (2006) highlight that "*AHP is able to assist port managers in obtaining a detailed understanding of the criteria that shippers deem important in port selection decisions and the strength of their preferences*".

Among the multicriteria (MCDM) techniques, F-AHP has been used in a vast number of applications, being actually the second most widely used methodology, behind AHP (Kubler, et al., 2016). Since human decision-making involves fuzziness and vagueness, F-AHP has proven to have great potential for the resolution of MCDM problems, as can be observed in the 190 scientific articles published in international journals between 2004 and 2016 (Kubler, et al., 2016).

Multiple examples of the use of AHP for decision-making in the port environment can be found, such as the analysis of the competitiveness of Chinese container ports (Song & Yeo, 2004), or the use of F-AHP to express the opinions from experts in the pairwise comparison stage (Ung, et al., 2006). Other papers have focused on *transhipment port selection* from a carrier's perspective (Lirn, et al., 2003). Seaport competitiveness models (Da Cruz, et al., 2013), or the location of international distribution centres in the global logistics of multinational corporations (Chou & Yu, 2013) are just some of the multiple applications of AHP and F-AHP to assist decision-making within the port environment.

The large number of examples in scientific literature on port efficiency contrasts with the low presence of port clustering and the lack of robust methodologies for the classification of seaports (Tovar & Rodríguez-Déniz, 2015).

The categorisation of terminals is important to understand the possible ways of collaboration between them, since the *size* of terminals does not seem to have a significant impact on the most important factors for collaboration and coopetition (Song, et al., 2015). Although F-AHP has been designed to aid decision-making, in this case it will be used to categorise terminals, by considering the variables that, according to industry experts, are the most appropriate for classifying them in regard to their management practices.

3. PROPOSED METHODOLOGY

The Analytic Hierarchy Process (AHP) is a general theory of measurement used to draw conclusions from discrete and continuous pair comparisons (Saaty, 1987). These comparisons can be based on actual measurements or on a fundamental scale that can reflect preferences. To perform the comparisons, a hierarchical structure must be defined, complex enough to capture the situation and small enough to be sensitive to the changes. This process has been extensively studied and standardised in seven basic steps (Vaidya & Kumar, 2006), including the statement of the problem, definition of the objective, identification of the influencing criteria, definition of the hierarchy, pairwise comparison of elements, calculation of the weights of each criteria and alternatives and the consistency of the judgements and, if the consistency is nor guarateed, repetion of the process (Guy & Urli, 2006).

To capture the fuzzy nature of human reasoning, AHP was extended by creating a fuzzy version to choose among a number of alternatives expressing the opinion of a decision-maker on the importance of a pair of factors, using triangular fuzzy numbers instead of crisp numbers (Van Laarhoven & Pedrycz, 1983). Fuzzy versions of consistency testing and weighting calcualtions have been defined for triangular fuzzy numbers, mimicking the logic of the crisp version (Chang, 1996). The F-AHP method has found multiple applications in decision-making, both in cases of a single decision-maker, as well as in cases where the decision must be made by consensus by a group of decision-makers. In our case, the aim consists of determining which weights correspond to each variable in the hierarchy to achieve a meaningful categorisation of port terminal management in a given context.

The relevance of using fuzzy numbers in this process comes from the fact that when the experts are making pairwise comparisons, it becomes very difficult to provide specific answers. Individuals' feelings and opinions are not devoid of subjectivity. If asked whether automation or equipment is more important for management categorisation, for example, it is very unlikely an expert would state that the one is exactly 20% more important than the other. It would be more accurate for them to define a range that would indicate the importance of one component over the other. To reflect this subjectivity, fuzzy numbers and the logic of the F-AHP methodology results are more convenient. In addition, to ensure that the responses are consistent, use is made of mechanisms to check consistency and reach consensus on the opinion of all the experts.

As a prerequisite for applying this methodology, some information and resources must be available. First, it is important to have access to consistent information from all terminals to be included in a study. Often, this is easier said than done due to *confidentiality* concerns it today's competitive environment of the port sector. Second, it is necessary to ensure access to experts of proven prestige, able to provide well-founded and consistent answers during the surveying process.

3.1 Logic of the procedure

Based on the principles of the F-AHP methodology, the most relevant factors in the management of container terminals must be initially identified, and a hierarchical structure developed considering these factors. It is very important to design a survey that is easy to understand by the experts, allowing the introduction of intervals (fuzzy numbers) representing the importance of each pair of factors. Once the experts' answers have been processed, the weight of each variable in the container terminal management hierarchy is determined.

Although the classic F-AHP method would end at this point, the information about the influential weight of each variable is used to establish a ranking of the container terminals by using the data available of each of the surveyed ports. Thus:

Step 1.- Identification of the relevant variables that best define the categorisation of a container terminal in terms of its management. It is necessary to identify variables that are proven to have an impact on the categorisation. These variables must be numerical, and available in all terminals. A review of the extant literature has identified such variables as total terminal surface; linear meters of berth; terminal draught; number of reefers connections; yard equipment; TEU's moved; etc.).

Step 2.- Expert verification of these variables and elimination of correlated ones. With the twofold aim of minimising the number of variables that can best categorise port terminals, *and* eliminate the variables that have a residual weight, a survey among a limited number of well-trained experts could endorse the correct selection of the variables.

Step 3.- Grouping the variables into a hierarchical structure. Following the F-AHP methodology, a hierarchical structure must be designed to group the variables, preparing the survey for the evaluation.

Step 4.- Survey delivery. To obtain consistent data, it is very important to correctly explain to the experts the motivation and the importance of adequately answering each question, to avoid receiving spurious information. The experts will have to perform the pairwise comparisons of the factors identified at each level of the hierarchy, using triangular numbers.

Step 5.- Processing the results. The survey results received are processed according to F-AHP methodology and the weights of each factor calculated.

Step 6.- Transfer of the weighting of the variables to the data of each terminal and calculation of the final results. Once the weight of each variable is obtained, it is necessary to calculate the weighted sum score for each terminal based on the available data of the facility. This requires the standardisation of the input data by setting a fixed maximum value for each variable according to the input data. These final scores are used in our categorisation of container terminals.

Regarding the last step (global score calculation for each terminal), further clarification might be needed. For each of the final variables, each port will receive a gross score from 0 to 10, depending on the facilities and characteristics of that terminal. For instance, 10 points could be assigned to a specific terminal if it has more than 4 railway tracks; 6 points for 1 to 4 railway tracks, and 0 points if it lacks this service. These scores are weighted with the weights obtained in the previous fuzzy procedure to obtain a final score for the terminal.

4. CASE OF STUDY: THE SPANISH PORT SYSTEM

To validate the methodology, we have chosen the Spanish Port System consisting of 28 Port Authorities managing 46 ports of general interest, moving -in 2017- nearly 16 million TEU's (Table1). Although the first Spanish port to appear in the Lloyds List (2018) "most important ports in 2017" is Valencia (29th place), the Spanish case could be interesting to consider, given the different sizes and management models found in this country. To focus our study on 'relevant' container terminals, terminals of a throughput of less than 60,000 TEUs per annum (11 ports) have been excluded.

===== TABLE 1 =====

4.1. Application of the Classification Method

Step 1. Our initial set of variables was selected from sets previously used in similar studies, such as Orive et al. (2016) who categorized Spanish ports using cluster analysis; Sharma & Yu (2009) who worked in benchmarking of container terminals, or Cabral & Sousa Ramos (2014) who studied the competitiveness of container ports in Brazil. Another source used to define the initial set of variables was the "Permanent Observatory of the Port Services Market" report, published by the Spanish authorities (Puertos del Estado, 2018). Other more infrequently used variables in this type of studies were discarded (for instance, "ice production", "liquid bulk traffic", "number of passengers" or "length of fishing docks").

Based on this literature review, an initial selection of 18 variables (Table 2) was made. Note that data corresponding to the Spanish ports in relation to these variables are not always available for public viewing, and specific figures had to be gathered from direct requests to port managers.

==== TABLE 2 ====

Step 2. A previous analysis was carried out, calling upon five local experts (directors of the Spanish port authorities) to validate the suitability of the initial variable selection. Considering the feedback from these pre-tests, we decided to eliminate 5 variables (Table 2), in some cases because they considered they were representing nearly the same concept (for instance, "Total terminal area" and "Storage area"). For another variable ("Number of reefer connections") they considered that although this may be an indicator of the type of traffic handled at the terminal, it is not significant for our study as the installation of connections is relatively quick in cases they are need for new traffic.

Five new variables were added by the experts, namely doors, cranes and yard equipment automatisation, number of railway tracks, and import/export percentage. Although these variables were not included in earlier literature, the experts agreed that these aspects are key to determining differences for the categorisation of the Spanish port system. This will help, as mentioned above, to identify the variables that we are going to use in our research. That is, the relevant factors affecting the classification of the container terminals, and therefore, affecting their management given their specific characteristics.

Step 3. With the feedback of the experts, the final variables were grouped according to the hierarchical structure shown in Figure 1, being the three main categories "Automation", "Operations and Installations" and "Equipment".

===== FIGURE 1 =====

Step 4. To design the survey, the previously mentioned hierarchy was described, and the process of the pairwise comparisons explained to the experts. The final variables were grouped into eight categories and subcategories and, therefore, the experts had to evaluate nine matrices to compare the importance of the variables that were part of these groupings.

The survey was distributed and answered by 14 experts consisting of operations directors, port directors, port infrastructure managers and researchers within the port sector. Looking for a heterogeneous profile in the answers, the experts came from the central governmental agency of the Spanish ports, five different Spanish Port Authorities, three private companies and two universities.

Note that the survey was designed to encourage experts to choose from a range of values (fuzzy numbers), which will be carried out following the F-AHP methodology in the next steps. As an example, Figure 2 shows the answers to the first comparison matrix of the survey. In this case, the expert indicated that the "Operations and Installations" category is slightly more important than the “Automatisation” category; “Automation” is more important (from strongly to weakly) than the “Equipment” category, and finally “Operations and installations” is of far more importance than the “Equipment” category.

===== FIGURE 2 =====

Step 5. Processing of the results:

With the data received by each of the 14 experts consulted, each matrix’s answers were converted into a matrix made up of fuzzy numbers (see Figure 2 and Palacio et al., 2015; Goepel, 2013). Answers were checked for consistency through standard consistency methods (Demirel, et al., 2008). For this purpose, fuzzy matrices were converted into crisp ones (Kwong & Bai, 2003) and the verification mechanisms of the consistency in the AHP methodology was applied (Saaty, 1987).

At this point there are 9 sets of 14 consistent matrices containing the answers of the 14 experts. Before proceeding with the calculation of weights, it is necessary to reach a consensus on all individual responses received to obtain a “group consensus matrix” on the importance of the variables and categories surveyed (Dong & Saaty, 2014). For each set, calculating the geometric mean of the 14 values that occupy the same position generates the first consensus matrix. Then, the process iterates measuring the global distance from the current “consensus matrix” to each matrix, until convergence is guaranteed in the final consensus matrix (Wu & Xu, 2012).

The weights of each of the variables of the final consensus matrix define the importance of each variable in the management of container terminals according to the experts consulted. These data were consolidated in the hierarchical structure of the F-AHP, to obtain the weights for each category (Figure 1).

In our specific case of the Spanish terminals, the importance of the automatisation variables (38.23%) should be noted. In other environments with a different degree of development (such as Central Africa or South America, where the terminals are not likely to be automated according to UNCTAD, 2018), perhaps this structure would not be the most appropriate and the experts would give different importance to this variable; therefore it is critical to highlight the importance of having the support of local experts to create a hierarchical structure suitable to the reality of the case study.

Step 6: As mentioned above, due to the necessity of normalisation of the final variables, a scale from 0 to 10 has been defined by our experts, taking into account the characteristics of the Spanish terminals and each variable (see Table 3). For example, 0 points are assigned to a terminal with no "Crane Automation", while 10 points are assigned otherwise. In the case of the “% Transhipment” variable, a terminal receives 0 points for values lower than 10%; 7 points for 10%-30%; and 10 points for transhipment figures higher than 30%.

===== Table 3 =====

To show how the final score of each terminal was calculated, a real example is shown in Table 4.

Variables have been categorised according to the criteria in Table 3, and these values are listed in the "Categorisation" column. The "Gross Points" column shows the numerical equivalent of this categorisation, while the "Weighting" column contains the weights of each of the variables, calculated in the previous steps of F-AHP. Finally, by weighting the gross points with their corresponding weight, it is possible to obtain the weighted points for each variable, listed in the last column of Table 4. The final classification of the 22 port terminals in this study is shown in Table 5.

===== Table 4 =====

===== Table 5 =====

Note that weighting can change the ranking of the assessed terminals. For instance, BEST-Barcelona terminal occupies the second position in the classification considering the gross points (105), but falls to the fourth position (5.34) after considering the variables' weights. On the other hand, it is important to note that the terminal that occupies the sixth position in a classification using only the gross points (TTI-Algeciras) rises to the first position due to the fact that it presents very high values for the variables with greater specific weight (mainly those related to automation).

4.2. COMPARATION OF THE RESULTS WITH CLUSTER ANALYSIS

To compare the results obtained using the F-AHP methodology with another methodology not based on the subjectivity of some experts, we have carried out a study using Cluster Analysis. By comparing both approaches, it is interesting to note how the results can vary when information received from experts is considered.

Cluster Analysis has been widely used in maritime research. For instance, Cabral *et al.* (2014) used it for the classification of 17 Brazilian container ports, which were grouped in three different clusters, based on competitiveness criteria. With the aim to identify homogeneous groups of ports in the Mediterranean region through clustering techniques, Gianfranco et al. (2014) focused on the possible strategic relations between 34 ports of the Mediterranean Basin, aiming to promote possible collective actions among ports of similar characteristics. In that study, 9 groups of ports were created, according to different factors including their yard organisation, type of traffic, geographic area, and what the authors call the set of three factors (dimensional factor, pre-crisis growth factor, and post-crisis growth factor). Those ports included several ones of our case, i.e., Alicante, Barcelona, Valencia and Algeciras, which were compared with other 30 ports in the Mediterranean Basin such as Genoa, Cagliari, Tanger, Beirut, Naples, Livorno or Venice among others. Within the geographical scope of our own research, Cluster Analysis has already been used previously for the categorisation of Port Authorities of the Spanish port system, instead of container terminals as in here (Orive, et al., 2016).

Given that cluster analysis does not introduce subjective factors like F-AHP, the variables considered here were those preselected prior to the consultation of the experts (i.e., variables 1 to 13 and variables in parentheses in Table 2). To simplify the variables used, all cranes were grouped into a single variable (adding variables 5-7, Feeder Cranes, and Automobile Cranes in Table 2), and the same was done for 'yard equipment' (variables 8-13 in table 2). Using Cluster Analysis techniques (Rousseeuw & Kaufman, 1990), the selection of the variables was checked, and the z-scores calculated, for the standardisation of the TEU Average variable (Milligan & Cooper, 1988).

Statistical software R was used for the computations, given the number of alternatives it provides for the grouping of the selected variables (Hothorn & Everitt, 2014). In our case, the "Average" method for clustering was selected (Wilks, 2011). The method defines cluster-to-cluster distance as the average distance between all possible pairs of points in the two groups being compared. As seen in the dendrogram in Figure3, terminals have been grouped into five clusters, with the last three groups made up of a single terminal (namely APM-Algeciras, BEST-Barcelona, and NOATUM-Valencia). These three are the largest facilities in the country and have very similar physical and operating characteristics, thus representing the “large terminals”.

===== FIGURE 3 =====

4.3. DISCUSSION OF THE RESULTS

In order to identify a company’s strengths, some of the competitive assets that could be considered are the superior technological skills, the economies of scale, and the learning and experience curve advantages over rivals (Thompson, et al., 2018). In our case, comparison with the other terminals may help to identify the competitive advantages of the terminals and, if necessary, adapt their management practices.

In view of the results obtained by the Cluster Analysis, the container terminals can be grouped into three main groups, namely "small terminals" (12 terminals named Cluster 1 in Table 6), "medium terminals" (seven terminals named Cluster 2), and "large terminals" (remaining three terminals). Note that this classification, based only on some physical variables as required by the cluster methodology, does not consider the complexity of the management of these terminals, but rather the mere observation and processing of the variables used for their classification.

On the other side, the final classification, taking into account the complexity of their management using F-AHP (Table 5), shows a first group, led by "TTI-Algeciras", made up of three other terminals (NOATUM-Valencia, APM-Algeciras and finally BEST-Barcelona). This group is characterized by a high degree of automation of the terminals. Strongly automated terminals are expected to be managed with a functional approach of the automating technologies with BPR as the action tool (Martín-Soberón et al., 2014). That should involve the reduction of human resources intervention in operations, thus focusing on the automation of the tasks, information flow, and decision making.

The F-AHP classification proves the predominance of the Mediterranean coast of Spain versus the Atlantic, not only in the physical and operating variables but also in the classification weighted according to the criteria of the experts. It can also be noted that a second group of terminals, separated by less than two weighted points, made up of seven terminals (positions 5 to 11 in Table 5) is characterized by a medium degree of automation (usually the access doors), a medium size, and non homogeneous characteristics in the rest of the variables studied. Finally, the third group, made up of 11 terminals from different geographical locations, in the opinion of the experts, represent a lower level of management complexity, whose main characteristics are their small size, a limited TEU movement, and a low degree of automation.

The low degree of automation of these latter groups means that most of the work has to involve manual work carried out in places with difficult access, and high involvement of heavy machinery, hazardous cargoes and dense traffic thereby making port work a dangerous job (Hinkka, et al., 2016). For these terminals human resource management is a relevant asset, taking into account the high labor costs, making manpower management a crucial activity (Di Francesco, et al., 2016). It is therefore to be expected that the management of these terminals will focus on the management of human resources as it is one of their main assets.

There are multiple visions to address management styles. According to the contingency theory, there is no one best way to structure the activities of an organization in all circumstances. Some contextual factors determine the nature of the structure of the organization, which is viewed by contingency theory as a center of mutual influence and interaction between four subsystems (goal, human, technical and managerial) that should be optimally coordinated (Jackson, 2007). Container terminals, like any other organization, are exposed to certain conditions such as legal mandates, obligations of a charter, trade union culture and traditions that can limit their autonomy and flexibility to carry out more efficient management models (Marios, 2006). However, one would expect terminals with a high degree of automation (namely TTI Algeciras) to have an IT approach to management, that is, a strong focus on employee training, continuous improvement processes and process automation. On the other side, other terminals could take a contingent approach and focus their management on the most important subsystems for each particular terminal.

Terminals located in the middle part of the table, such as NOATUM–Bilbao, have some feasible opportunities of improvement regarding the automation of their facilities, and should focus their management on the upgrading of their technical subsystem. Finally, terminals listed in the last positions (namely TCG–GIJÓN) would be more likely to focus their management on improving their human system, since automation must be implemented in a gradual pace.

Our results show the significance of grouping port terminals without considering the opinion of experts, for the calculation of the complexity of their management. Despite the fact that, for the gross points calculation in the F-AHP methodology, different variables were taken into account than those in the Cluster Analysis (which did not include, for example, variables related to the automation of port terminals), the results obtained in the classification for taking into account the gross-points of the F-AHP methodology (without weighthing), and the results of grouping the terminals by cluster analysis, are very similar, as shown in Table 6. This result shows that our non-subjective analysis could serve as a starting point for the subjective approach, introducing the fuzzy opinion of the experts, to better capture the pursued classification.

===== Table 6 =====

5. CONCLUSIONS

Characteristics of container terminals (such as the degree of automation, number of TEU's moved, or the terminal area), differ greatly and have a great influence on their management practices as mentioned previously . Therefore, knowing how to assess those variables and how they can affect the way decisions are taken, can help to develop new management tools. For instance, in the aforementioned case of the TTI Algeciras terminal, the set of automation variables and especially the most weighted variable (i.e., "Crane Automatization" with an importance of 15.36%), makes this terminal to climb to the top of the global ranking. That means that the automation characteristics are critical according to our classification approach, what makes necessary the use of a technological approach in the management policy.

This paper proposes a classification system of terminals based on the subjective opinions of a group of experts. The classification should be understood as a still photo, taken at a given moment, and may vary depending on the improvements made in the terminal, especially in the features that have more weight in the classification according to the criteria of the experts.

To the best of our knowledge, this paper proposes for the first time a systematic method of applying knowledge, based on expert views, to classify container terminals according to the criteria that determine their special management characteristics. Expert opinions are collected via surveys designed to capture fuzzy answers. By filling this gap in the scientific literature, it is hoped that our classification system will serve to identify opportunities to improve terminal management, with the understanding that those terminals have special characteristics, such as ABC, and they perhaps need ad-hoc management systems. Results of the F-AHP approach were compared to non-subjective classification techniques such as Cluster Analysis, yielding some variations in the classification after weighting some variables that the experts considered more relevant.

As further research, other case studies for different sets of port terminals could be considered as well. Checking the opinions of experts in different environments could provide information on different weights and changes in the final ranking of the terminals. With several case studies, a comparative study could be carried out of the variables that most affect the management of port terminals in different geographical areas including, in this comparison, the physical variables that define their traffic and thus check, for example, whether, in environments with a lower degree of automation, these variables have a lower weight. A longitudinal study carrying out a similar analysis in the future could allow the comparison of the evolution of container terminals.

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FIGURES AND TABLES

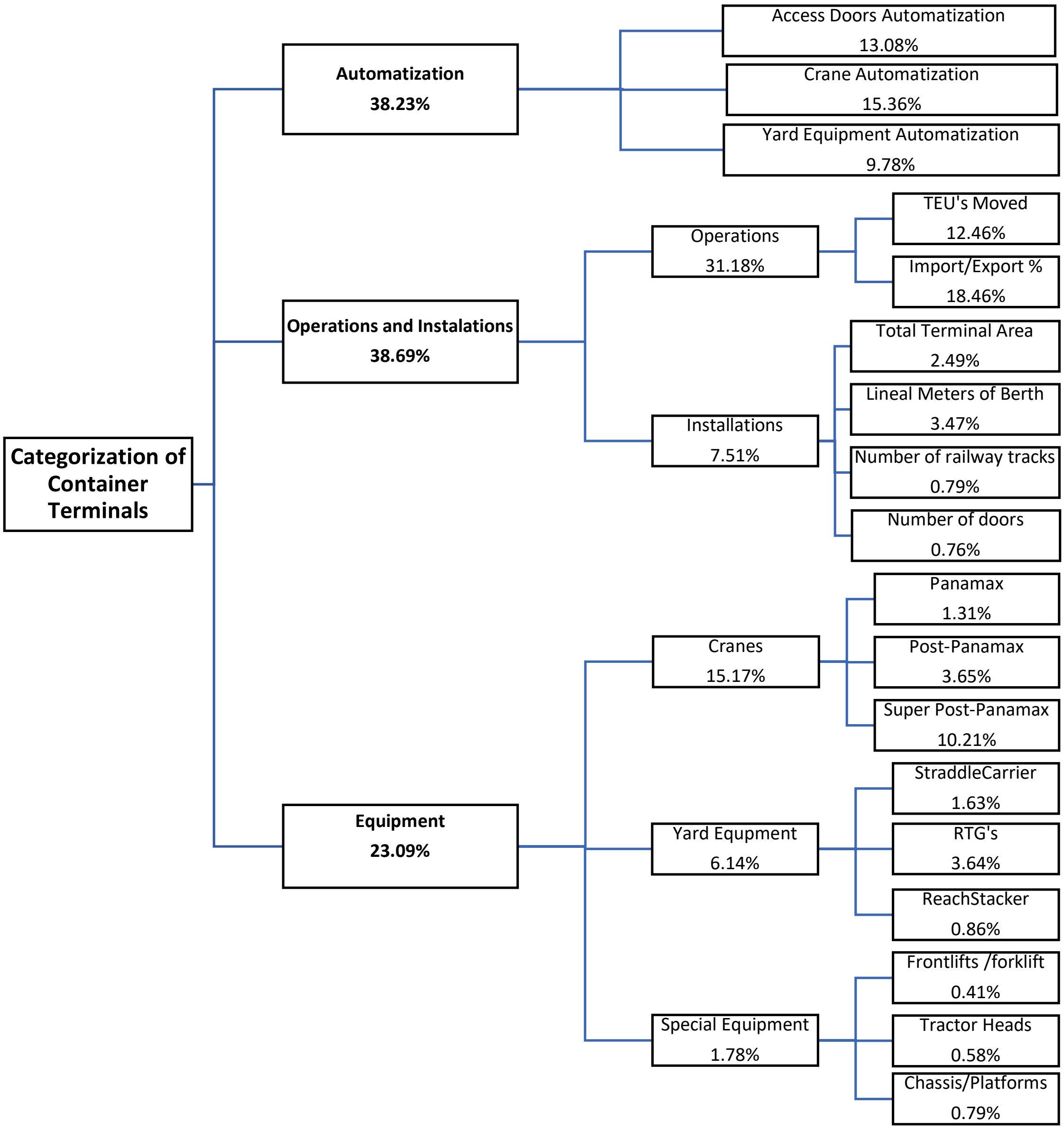
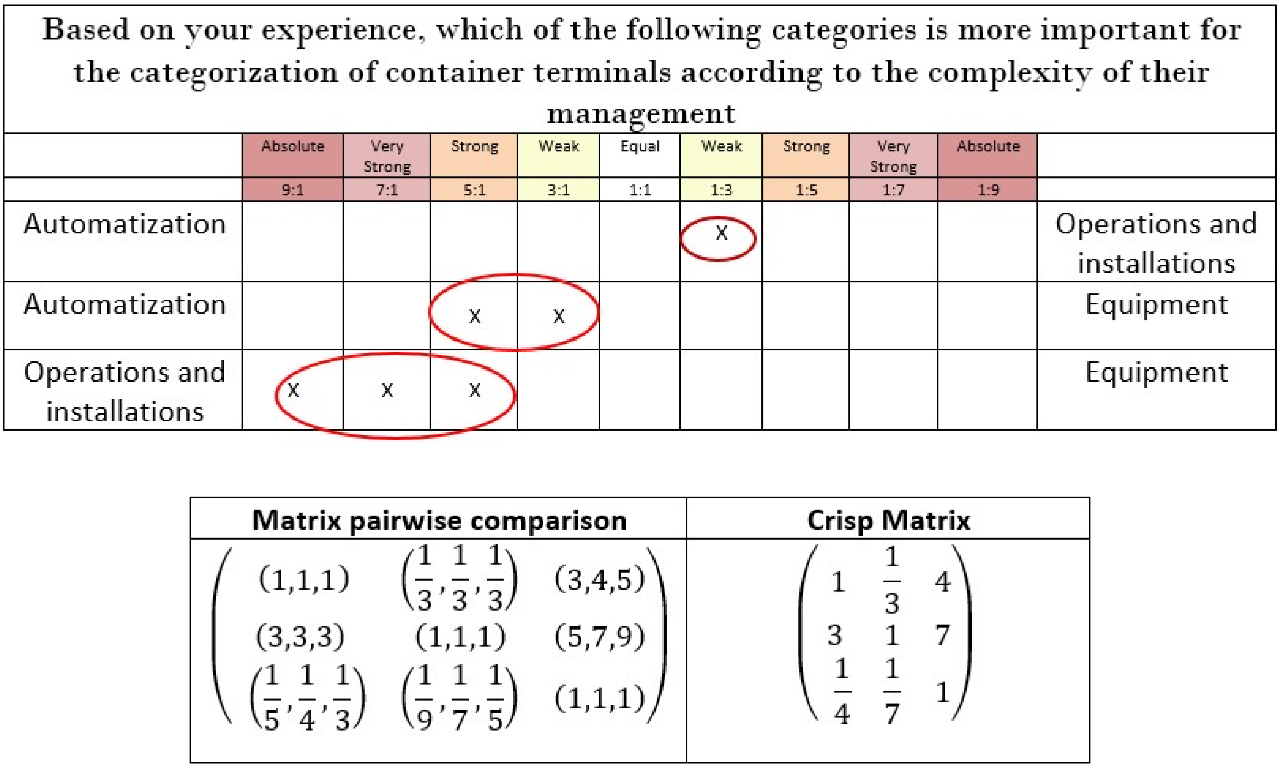


Figure 1: Structure for the Classification of terminals, including 8 categories and 18 final variables. Percentages represent the final weight of each variable obtained after using F-AHP.



Based on your experience, which of the following categories is more important for the categorization of container terminals according to the complexity of their management

	Absolute	Very Strong	Strong	Weak	Equal	Weak	Strong	Very Strong	Absolute	
	9:1	7:1	5:1	3:1	1:1	1:3	1:5	1:7	1:9	
Automatization						X				Operations and installations
Automatization			X	X						Equipment
Operations and installations	X	X	X							Equipment

Matrix pairwise comparison	Crisp Matrix
$\begin{pmatrix} (1,1,1) & \left(\frac{1}{3},\frac{1}{3},\frac{1}{3}\right) & (3,4,5) \\ (3,3,3) & (1,1,1) & (5,7,9) \\ \left(\frac{1}{5},\frac{1}{4},\frac{1}{3}\right) & \left(\frac{1}{9},\frac{1}{7},\frac{1}{5}\right) & (1,1,1) \end{pmatrix}$	$\begin{pmatrix} 1 & \frac{1}{3} & 4 \\ 3 & 1 & 7 \\ \frac{1}{4} & \frac{1}{7} & 1 \end{pmatrix}$

Figure 2: Example of survey response for the upper level in the hierarchy. Fuzzy matrix gathers the fuzzy information in the survey (f. i., element (2,3) comparing “Operations and installations" vs. “Equipment” goes from 5 to 9 representing the range 5:1 to 9:1 showed in the survey answer). The corresponding crisp matrix is used for consistency checking.

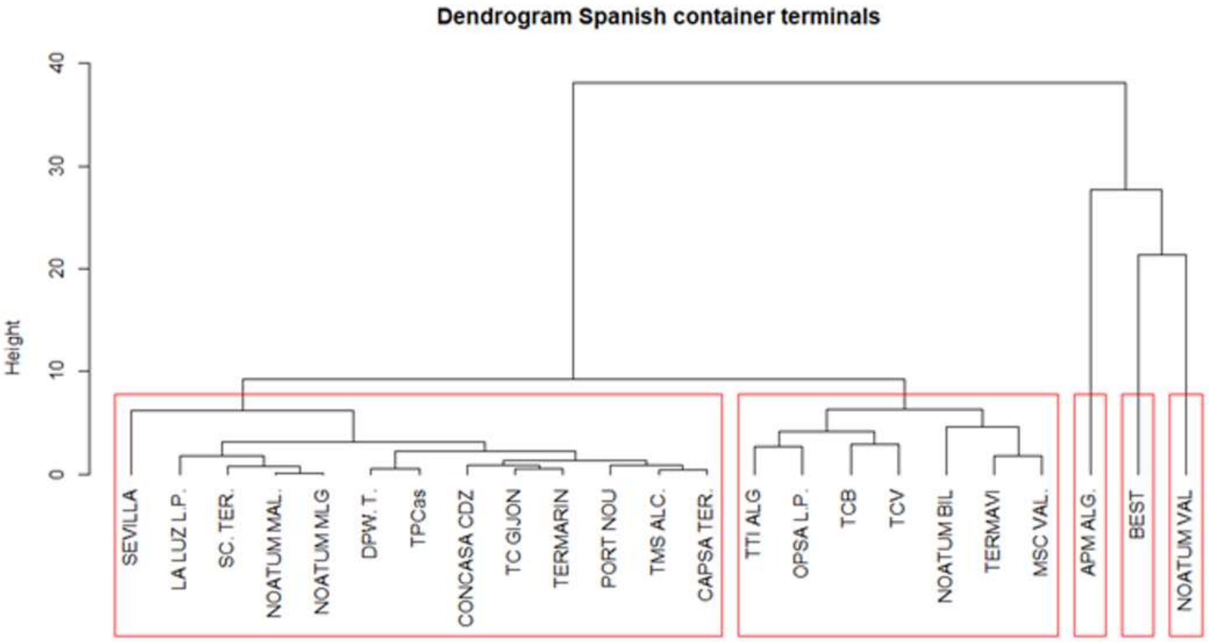


Figure 3: Dendrogram with the results of the Cluster Analysis

Table 1: Thousands of TEU'S moved in 2017 in the Spanish port authorities (Puertos del Estado, 2017)

PORT AUTHORITY	Container Terminals	TEU (×1000)
VALENCIA	TCV, MSC,NOATUM	4832
BAHÍA DE ALGECIRAS	TTI, APM	4380
BARCELONA	BEST, TCB, PORT NOU	3006
LAS PALMAS	LA LUZ, OPCSA	1174
BILBAO	NOATUM	604
SANTA CRUZ DE TENERIFE	CAPSA, TCT	466
CASTELLÓN	TPC	240
VIGO	TERMAVI	183
ALICANTE	TMS	164
SEVILLA	TCON	105
MARÍN Y RÍA DE PONTEVEDRA	TERMARIN	88
MÁLAGA	NOATUM	86
BAHÍA DE CÁDIZ	TTI	82
GIJÓN	TCG	76
TARRAGONA	DP WORLD	62
BALEARES	Diversified in 5 different small ports	120
CARTAGENA	Variable data	84
HUELVA		58
MELILLA		36
VILAGARCÍA		34
CEUTA		16
SANTANDER		6
ALMERÍA		6
MOTRIL		1
FERROL-SAN CIBRAO		0.45
PASAIA		0
A CORUÑA		0
AVILÉS		0

Table 2: Preselected and final variables considered. Variables into parenthesis were disregarded by the team of experts

Preselected variables from literature		Variables added by experts (F-AHP)
1. Total terminal area	2. Linear meters of berth	14. Access Doors Automatization
3. Number of doors	4. Average TEU's	15. Crane Automatization
5. Panamax	6. Post-Panamax	16. Yard Equipment Automatization
7. Super Post-Panamax	8. Reach Stacker	17. Railway Tracks
9. Front Lifts / Fork lifts	10. Tractor heads	18. Import / Export % (Transshipment)
11. Straddle Carrier	12. Chassis/Platforms	
13. RTG's	(Feeder Cranes)	
(Automobile Cranes)	(Number of reefer connections)	
(Storage area)	(Terminal draught)	

Table 3: Standardization criteria and scoring of each variable

Points: Variable	0	4	5	6	7	10
1. Total Terminal Area	SMALL <107496	MEDIUM <322489				LARGE >322489
2. Linear meters of berth	SMALL <660		MEDIUM <=1333			LARGE >1333
3. Number of doors	FEW (<=4)		MEDIUM (<8)			HIGH (>=8)
4. Average TEU's Moved	SMALL <500000		MEDIUM <=1500000			LARGE >1500000
5. Panamax	FEW (<=1)		MEDIUM (<=4)			HIGH (>4)
6. Post-Panamax	NO (0)		FEW (<6)			HIGH (>=6)
7. Super-PostPanamax	NO (0)		FEW (<6)			HIGH (>=6)
8. Reach Stacker	FEW (<=3)		MEDIUM (<6)			HIGH (>=6)
9. Front Lifts /Fork Lifts	FEW (<=8)		MEDIUM (<=16)			HIGH (>60)
10. Tractor Heads	FEW (<=30)		MEDIUM (<=60)			HIGH (>60)
11. Straddle Carrier	FEW (<=3)		MEDIUM (<6)			HIGH (>=6)
12. Chassis/Platforms	FEW (<25)		MEDIUM (<=50)			HIGH (>50)
13. RTG's	FEW (<=5)		MEDIUM (<=20)			HIGH (>20)
14. Access Doors Automat.	NO					YES
15. Crane Automatization	NO					YES
16. Yard Equipment Automat.	NO					YES
17. Number of railway tracks	NO (0)			FEW (1-4)		MANY (>4)
18. % Transshipment	FEW (<0.1)				MEDIUM (<=0.3)	HIGH (>0.3)

Table 4: Example of score evaluation for BEST-Barcelona Port Terminal

Variables	Categorization	Gross points	Weighting	Weighted Points
1. Total Terminal Area	BIG	10	2.49%	0.249
2. Linear meters of berth	BIG	10	3.47%	0.347
3. Number of doors	HIGH	10	0.76%	0.076
4. Average TEU's Moved	MEDIUM	5	12.46%	0.623
5. Panamax	FEW	0	1.31%	0
6. Post-Panamax	NO	0	3.65%	0
7. Super-Post-Panamax	HIGH	10	10.21%	1.021
8. Reach Stacker	HIGH	10	0.86%	0.086
9. Front Lifts /Fork Lifts	FEW	0	0.41%	0
10. Tractor Heads	FEW	0	0.58%	0
11. Straddle Carrier	HIGH	10	1.63%	0.163
12. Chassis/Platforms	FEW	0	0.79%	0
13. RTG's	FEW	0	3.64%	0
14. Access Doors Automat.	YES	10	13.08%	1.308
15. Crane Automatization	NO	0	15.36%	0
16. Yard Equipment Automat.	YES	10	9.78%	0.978
17. Number of railway tracks	MANY	10	0.79%	0.079
18. % Transshipment	HIGH	10	18.72%	1.872
TOTAL		105		6.80

Table 5: Final score of port terminals using F-AHP, sorted by weighted sum. Gross points are also shown**.**

CONTAINER TERMINAL	Weighted Sum	Weighted ranking	Gross points Sum	Gross points ranking
TTI - Algeciras	8.37	1	101	6
NOATUM - Valencia	6.98	2	130	1
APM TERMINALS – Algeciras	6.94	3	105	2
BEST- Barcelona	6.80	4	105	2
TCB - Barcelona	5.34	5	102	5
LA LUZ- Las Palmas	5.32	6	59	11
TCV– Valencia	5.06	7	103	4
TCT – Tenerife	4.65	8	44	13
MSC - Valencia	4.41	9	60	9
OPCSA - Las Palmas	4.09	10	80	8
NOATUM – Bilbao	3.36	11	81	7
TERMAVI – Vigo	2.66	12	60	9
NOATUM - Málaga	2.51	13	43	14
CAPSA - Tenerife	2.24	14	35	16
PORT NOU – Barcelona	1.85	15	45	12
TMS - Alicante	1.72	16	35	16
TCON - Sevilla	1.47	17	30	19
DP WORLD - Tarragona	1.15	18	40	15
TPC - Castellón	0.99	19	31	18
TCG – GIJÓN	0.15	20	16	20
TERMARIN - Marín	0.15	20	16	20
TTI - Cádiz	0.06	22	5	22

Table 6: Results after using Cluster Analysis, and comparison with the groups formed using F-AHP.

CONTAINER TERMINAL	CLUSTER	Gross points rank	Weighted rank
NOATUM - Valencia	5	1	2
BEST- Barcelona	4	2	4
APM – Algeciras	3	2	3
TCV– Valencia	2	4	7
TCB - Barcelona	2	5	5
TTI - Algeciras	2	6	1
NOATUM – Bilbao	2	7	11
OPCSA - Las Palmas	2	8	10
MSC - Valencia	2	9	9
TERMAVI – Vigo	2	9	12
LA LUZ- Las Palmas	1	11	6
PORT NOU – Barcelona	1	12	15
TCT – Tenerife	1	13	8
NOATUM - Málaga	1	14	13
DP WORLD - Tarragona	1	15	18
CAPSA - Tenerife	1	16	14
TMS - Alicante	1	16	16
TPC - Castellón	1	18	19
TCON - Sevilla	1	19	17
TCG – GIJÓN	1	20	20
TERMARIN - Marín	1	20	20
TTI - Cádiz	1	22	22