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Improving the Performance of Dry and Maritime Ports by Increasing Knowledge about the Most Relevant Functionalities of the Terminal Operating System (TOS)

Miguel Hervás-Peralta [1,*], Sara Poveda-Reyes [1], Gemma Dolores Molero [1], Francisco Enrique Santarremigia [1] and Juan-Pascual Pastor-Ferrando [2]

[1] AITEC Research & Innovation Projects, Parque Tecnológico C/Charles Robert Darwin 20, 46980 Valencia, Spain; spoveda@aitec-intl.com (S.P.-R.); gmolero@aitec-intl.com (G.D.M.); fsantarremigia@aitec-intl.com (F.E.S.)
[2] Universitat Politècnica de València, Camino de Vera s/n., 46022 Valencia, Spain; jppastor@dpi.upv.es
* Correspondence: mhervas@aitec-intl.com; Tel.: +34-961-366-969

Received: 5 February 2019; Accepted: 15 March 2019; Published: 19 March 2019

Abstract: Maritime transport in the European Union has increased in the last years, triggering congestion in many of the most important sea and river ports. A lot of works have highlighted how the connection between these ports and dry ports can contribute to reducing port congestion and emission of greenhouse gases (GHGs). This work aims to improve the knowledge about the functionalities of Terminal Operating Systems (TOSs) managing container terminals of sea, river, and dry ports, with the aim of improving their performance and contributing to reducing congestion and GHG emissions to achieve a higher sustainability. The contribution and novelty of this paper in the field of container-terminals logistics research is the use of the Analytic Hierarchy Process (AHP) to identify and hierarchize TOS functionalities. The robustness of the model was checked by applying a sensitivity analysis. One hundred and seven functionalities were grouped into six main clusters: Warehouse, Maritime Operations, Gate, Master Data, Communications, and ERP (Enterprise Resource Planning) Dashboard. The results show that time tracking of vessels, space optimization, development of loading and unloading lists, and optimization of container locations are the most important functionalities of a TOS. This work is addressed to developers, sellers, managers, and users of TOSs and researchers working on container-terminal performance.

Keywords: dry ports; container terminal performance; terminal operating system; TOS functionalities; multicriteria decision making process; analytic hierarchy process

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1. Introduction

Maritime transport in the European Union has increased in the last years from 898 million tonnes in 2013 to 985 million tonnes in the second quarter of 2017 [1]. In the US, the annual rate of growth of maritime imports to European ports amounts to almost 10% while exports increased by 4.6% in 2015 compared with the previous year [2]. Several European countries have shown an increase in the traffic of goods in their terminals. This increase has been translated into an increase in ocean transportation. In 2014, major shipping lines showed a four-fold increase in ocean transportation compared to 1992 [3]. This growth is driven largely by the rapid increase in mass traffic from China to other countries, and it is expected that in 2030 the volume of trade will be twice that in 2009 [4].

Additionally, it is expected that the Transatlantic Trade and Investment Partnership (TTIP) will further stimulate maritime traffic and, above all, bidirectional shipments between the US and

Europe [2], as well as promoting the building of larger containerships that need faster loading and unloading facilities, which can only be achieved with a huge level of automation. Nowadays, vessels such as the OOCL (Orient Overseas Container Line) Hong Kong [5], with a capacity of up to 22,000 TEUs, have already been built, and such values will become increasingly common with time. This creates the need for container terminals capable of operating with these big vessels with respect to not only the dimensions of the berth and the terminal or equipment used but also the management capacity of the number of TEUs.

The evidence that the future will not look like the past is increasing and emphasizes the burgeoning need for sustainability [6]. Sustainability generally refers to environmental, social, and economic issues [7,8]. The development of inland terminals or dry ports is one of the approaches that has attracted more attention in the last years to reduce seaport congestion, greenhouse gas (GHG) emissions, and the environmental impact on the seaport surroundings [9–11]. Over the past 25 years, a considerable amount of literature addressing inland port development has emerged [12]. Witte et al. (2019) reviewed a total of 80 papers from 1992 until 2017 [12]. They showed that the amount of research on inland terminals started rising in the early 2000s and that many of the studies are focused on the role of inland terminals as part of the supply chain.

Woxenius et al. (2004) stated that the concept of the dry port is based on the idea of "a seaport directly connected with inland intermodal terminals where goods in intermodal loading units can be turned in as if directly to the seaport" [9]. An inland terminal can be understood as an inland facility that is directly connected with the seaport terminal by rail, inland waterway, and/or road transport, offers services that are usually available at seaports (e.g., maintenance services and customs clearance), and is a place where customers can leave and/or pick up their standardized units in the same way as in a seaport [13]. The development and use of this type of facility has shown potential in the reduction of port congestion and therefore in the reduction of carbon footprints [10,14,15]. Also, locating dry ports near strategic urban locations could reduce the number of freight trips and costs [16]. Wiegmans et al. (2015) analyzed factors affecting inland port performance and concluded that a good connection by road to the inland terminal is key in order to improve its performance in terms of transshipment volume and growth [17].

On the other hand, mathematical, optimization, and modeling methods have been used to analyze the effect of inland terminals on carbon emissions. Crainic et al. (2015) used mixed integer programming mathematical formulation to solve planning problems of dry intermodal inland terminals regarding schedules of fleet vehicles and optimal routes [18]. Tsao and Linh (2018) used a non-linear optimization method (the continuous approximation model) to help in the design of seaport–dry-port networks and concluded that the development of dry ports and the use of multimodal transport, for example using rail transport, which is a greener type of transport than road, could reduce carbon costs [15]. Roso (2007) analyzed the dry port concept using modeling and simulation. The study performed showed that the implementation of a dry port could reduce carbon emissions by 25% as well as reducing truck waiting times and port congestion [10].

In addition to the efforts made until now, both port and inland container terminals can still be improved by improving their management systems, the equipment used, and/or their infrastructure. The optimization of the internal elements is very important to improve the container terminal performance and to reduce the carbon footprint. From the different elements of the terminal (e.g., information and communication technology (ICT) systems, container handling equipment, infrastructure and terminal operators performance), it is important to highlight the "brain" of the terminal, known as the Terminal Operating System (TOS), which is the computational management system in charge of all the processes produced within the terminal and is the focus of this paper.

Port terminals use different types of information systems. Heilig and Voβ (2017) divide them into ten different types: national single window, port community systems, vessel traffic services, TOSs, gate appointment systems, automated gate systems, automated yard systems, port road and traffic control information systems, intelligent transportation systems, and port hinterland intermodal information systems, and analyzed their potential for improving the efficiency of the whole supply chain [19].

Carlan et al. (2017) indicated that the main reasons behind the decision to invest in new innovation in the port sector are cost reduction, improvement of service level, greater transport and monitoring control, and the improvement of safety and security issues [20]. They also stated that the most important goal of seaport platforms is to optimize the infrastructure capacity usage in order to reduce port congestion, which is one of the objectives of a TOS.

After this brief introduction to the current situation of transport flows and port and inland terminals, the following subsections present: (i) the general structure of a container terminal, (ii) a description of a TOS, and (iii) the state of the art of different studies done to date on TOSs and previous works on port and inland terminals using the Analytic Hierarchy Process (AHP).

1.1. Container Terminal Structure

A container terminal is an intermodal facility that usually connects container vessels at sea (in the case of seaport terminals) with trucks on land [21] and in many cases also with rail or inland waterways [22–24].

A sea container terminal consists of at least three operational areas [25]; see Figure 1:

1. The operational area between the quay wall and container yard (area just behind the berth front).
2. The container yard (terminal storage, which is the stacking area): the area where the containers are stocked and where the loading and unloading activities of these units are carried out.
3. The terminal area of landside operations, which includes the gate, parking, office buildings, customs facilities, container freight station with an area for stuffing and stripping, empty container storage, a container maintenance and repair area, and so on.

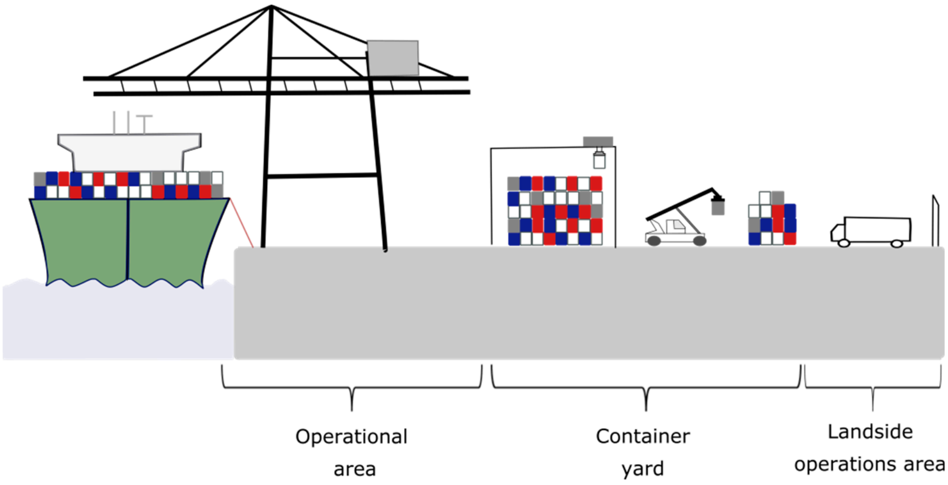

Figure 1. Scheme of a port terminal of containers showing the three main zones: operational area, container yard, and landside operations area (truck, rail, and inland waterway transport).

The most common processes in the terminal are loading/unloading from the vessel by crane, internal transport by yard tractors, also known as tug masters, or AGVs (Auto Guided Vehicles) to the storage yard, the container loading/unloading operations in the yard, and temporary storage in the yard before loading containers onto vessels, trucks, or trains. All of these processes, as well as the equipment involved, need to be monitored and managed in the most automatic way possible [26].

Similarly to the port terminal, the inland container terminal also has different zones (see Figure 2): the container yard and the operational areas for each of the modes of transport that enter and leave the terminal.

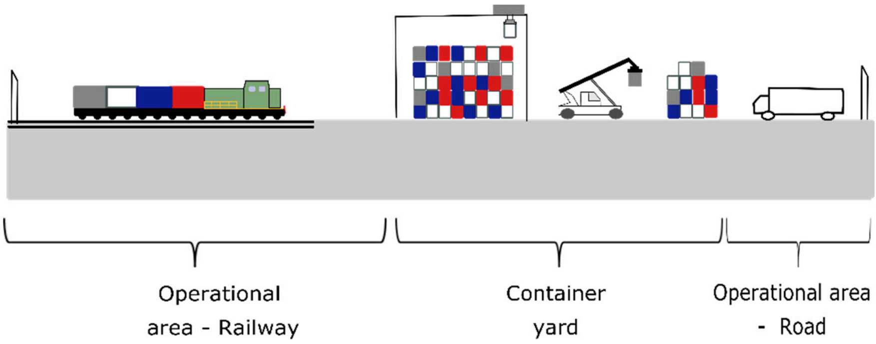

Figure 2. Scheme of an inland terminal of containers showing the three main zones: two operational areas (entry area and exit area for the different transport means that enter and leave the terminal) and the container yard.

1.2. Terminal Operating System—Definition

The TOS is the central nervous system of the container terminal, capable of automatizing an infinite number of processes that would otherwise have to be performed manually. Different definitions of TOS can be found in the literature. Some authors have defined a TOS as:

- Software that provides management, storage, and movement control of different types of loads in terminals, with the basic function of supporting the logistic processes [27].
- "A computer system that is designed to plan, track, and manage the movement and storage of all cargo, the use of assets, and the deployment of people in and around the seaport terminal or the port (including the hinterland) on a real-time basis" [28].
- "Terminal Operating System (TOS) is the core application used by container terminal for both for planning, monitor and execute the containers movement from truck to yard, yard to truck, truck to vessel and vessel to truck using heavy lifting equipment (called Container Handling Equipment—CHE)" [29].
- "A TOS provides a set of applications to collect, store, manage, analyze, and disseminate information from different terminal activities in order to provide an integrated view on core terminal processes and ensure an efficient use of resources for handling cargo" [19].

Therefore, merging definitions, a TOS can be defined as the core software of a terminal whose functions include the planning, management, and monitoring of all the processes carried out in the terminal (e.g., loading/unloading/transport/storage processes developed by the equipment of the terminal) and its surroundings (e.g., vessel and/or truck arrival planning, truck queue at the gate) as well as the assignment of people to the different processes, on a real-time basis with the aim of ensuring efficient use of resources.

A TOS can be integrated with other systems and technologies to monitor cargo within the terminal (e.g., RFID-Radio Frequency Identification, GPS-Global Positioning System) and to exchange data with external parties (e.g., port community system) and usually includes decision support applications based on simulations or optimization algorithms for more efficient planning and scheduling [19,30]. Also, current trends are towards the use of cloud-based collaborative platforms and the analysis of big data (e.g., for maintenance) [19].

To understand the importance of a TOS in a container terminal, its implementation for the first time or its modification by a new one can be considered as a heart transplant of the terminal [31]. The implementation of a TOS system in a terminal is among the most demanding projects any terminal operator will ever undertake, requiring a lot of effort on the operator's side.

Terminal operators of all sizes can reap tremendous benefits from the implementation of a commercial TOS. Even very modest-sized terminals can substantially reduce the amount of manual processes, increase the accuracy of data, improve reporting capabilities, enhance communication with business partners, and in general, streamline their operations [28,29,32].

1.3. State-of-the-Art of Previous Research on Inland Terminals, the Use of AHP in Inland and Port Terminals, and TOS

1.3.1. Application of AHP to Port and Inland Terminals

Improvements to a TOS must be applied simultaneously in both port and inland terminals working together as an interdependent pair. There should be a direct connection between port and inland terminals and sharing of information in real time in order to increase their efficiency, facilitate scheduling and management tasks, and reduce waiting times during loading and unloading procedures.

Currently there are different TOSs on the market. Each of them offers different functionalities and the selection of one or another is not easy for terminal managers since information is not always fully clear or there may be a lack of knowledge about the full potential of the terminal management solution. Multicriteria decision making (MCDM) methods have been widely used when there is a need to make a choice between different alternatives and different principles or considerations have to be taken into account. The use of a MCDM is appropriate for the purpose of this study. The definition of the functionalities to be included in an ICT tool needs of a decision making method to aid in this decision making process in order to have a tool as much functional as possible, and then a MCDM technique was selected for the development of this study.

Velasquez and Hester (2013) compared the different MCDM methods, analyzed their advantages and disadvantages, and identified the types of studies for which they are more suitable [33]. AHP is a suitable method when the researcher wants to rate a criterion against the other criteria at the same level of the hierarchical tree [34] and has been widely used in the study of supply chain problems [35–40].

Ghorbanzadeh et al. (2019) described several MCDM methods used in the transportation sector and used the interval calculus of AHP (IAHP), which is a more practical method when experts are not confident about Eigen values of AHP in complex decisions [41]. Other studies have suggested the use of the AHP with statistical approaches such as the Monte Carlo simulation [42]. Nazari et al. (2018) used fuzzy-AHP method, which is based on different membership functions being an effective and flexible technique in some cases [43].

The main disadvantage of AHP is the fact that dependencies between variables can lead to inconsistencies in the ranking of criteria and produce rank reversal [33]. Blanquero et al. (2006) examined Pareto optimality of AHP weight vectors derived from the pairwise comparison matrices and found that these vectors may not be Pareto optimal [44]. A recent real case study developed by Duleba and Moslem (2019) modified the calculation of the AHP eigenvectors by applying a Pareto-efficiency test. This study showed that the traditional AHP calculation process can be improved by applying Pareto-efficiency tests on the gained AHP scores in order to obtain improved weights that are Pareto optimal [45].

Ka (2011) stated that one of the problems of dry ports in China is the lack of a systematic procedure for the selection of the most appropriate location. To solve this, he proposed a methodology that combines AHP and ELECTRE (ELimination Et Choix Traduisant la REalité) methods based on six factors: transportation, economic level, infrastructure facilities, trade level, political environment, and costs [46].

Li and Jiang (2014) used the balanced score card method, which uses AHP, in order to establish an indicator system for evaluating cooperation performance between seaports and dry ports based on four parameters: customer satisfaction, finance, cooperative relations, and non-market tools. They analyzed cooperation between Qingdao Port and Xi’an Port and identified customer dissatisfaction, non-optimal financial cooperation, and deficiencies in non-market tools [47].

Ha et al. (2017) used AHP combined with FTOPSIS (fuzzy technique for order preference by similarity to an ideal solution) for the prioritization of port performance improvement strategies [48]. The different strategies (i.e., crane productivity, yard utilization, training and education, commitment and loyalty, culture, leadership, accuracy of documentation and information, incidence of service delay, sea-side connectivity, value-added service to customers, and port information and technology systems) were evaluated by eight experts an weighted using the AHP-FTOPSIS hybrid method. The obtained results indicated that crane productivity and incidence of service delay were the most important port performance indicators. The analysis using FTOPSIS in three different terminal operating companies showed that those with a poor performance index were more interested in increasing performance and then in the implementation of the identified strategies.

Molero et al. (2017) weighted criteria affecting the design of the layout of a terminal of containers with dangerous goods using the AHP method [36]. Criteria related to five main areas (i.e., safety and security, environmental care, operational, business intelligence, and ICT) were used for the analysis of experts' priorities. Criteria related with operational, safety and security, and environmental care areas were used by Santarremigia et al. (2018) for the prioritization of five different yard layout alternatives for a container terminal, with each layout being directly dependent on the container-handling equipment used in the yard [24].

After analysing the different methods, the AHP in the classical form was selected for this study since it allows hierarchizing qualitative data easily, and has an intuitive design, structuring the analysis what permits a better understanding of the problem. In addition, a sensitivity analysis was developed in order to evaluate rank reversal, which is a known drawback of this method, and to check the robustness of the method.

1.3.2. Terminal Operating System—Previous Studies

The need for optimization of container terminal operation has become more and more important in recent years. Stahlbock and Voβ (2008) provided an exhaustive review of operations at container terminals and optimization methods, including the analysis of operations for ship planning processes, storage and stacking logistics, transport optimization, and the analysis of integrative approaches [49]. Authors identified as keys factors for efficiency the automation of in-yard transportation, storing and stacking, the use of optimization methods, and, due to the complexity of the operations in the terminal, an integrated optimization of operations. Different operations research methods have been used in the literature with optimization purposes [50] (e.g., computational experiments in ship planning [51], mathematical models in storage and stacking logistics [52,53], or heuristic algorithms in transport optimization [54]). In addition, interest in the study and improvement of TOSs has also increased. Since 2005, there has been an explosion in the number of scientific papers that deal with these management elements of terminals. A search for the keywords "terminal operating system" in Google Scholar gives almost no references prior to 2005. From 2005 to 2009, there are around 50 references; from 2010 to 2014, there are almost 100, with this period having the highest number of references on the topic. From 2015 to 2017, the number of publications related to TOSs exceeded 50 [55].

Therefore, it can be concluded that a TOS is the most important planning and management element to be considered in the optimization of inland and port terminals.

Shen et al. (2008) developed a first approximation to the model structure of a TOS, identifying seven main modules: fundamental data, gate in, gate out, discharge operation, loading operation, movement management, and yard operations. Moreover, they listed what they understood as the five key processes in the management of a TOS: equipment control, vessel stowage, yard planning, discharge scheduling, and load scheduling [26].

On the other hand, Min et al. (2017) proponed a TOS to increase the efficiency of port terminal operators that was divided into six main modules: berth planning, yard planning, vessel planning, resource planning, communications, and interface module [28]. Recently, the communication module is an expansion of the TOS on which more effort is being spent in order to allow stakeholders to exchange data and information [55]. Other modules that are being studied or are under development include supplementary technologies, such as automated data capture tools [30] or real-time tracking systems [29], which may be added and integrated within the TOS as the terminal grows.

Finally, given the importance demonstrated by the recent increase in papers about TOSs, the main objective of our study is to offer valuable information to software developers and users of TOSs about the most important functionalities that a TOS should include from a holistic point of view, considering operational and administrative efficiency, reduction of the carbon footprint, as well as added value services to customers. The analysis and ranking of functionalities from this holistic point of view was obtained gathering the opinions of the stakeholders involved in the development, use, and management of TOSs.

Through an analysis of the scientific literature and with the collaboration of experts in TOSs and terminal operation procedures, this work develops a basic structure of functionalities or requirements that a TOS must include to develop its function. These functionalities will be prioritized by a multidisciplinary and international expert panel and the AHP [56] will be used to calculate the weights of each functionality. This prioritization allows the identification of the most important ones and then those that will have a greater effect on the performance of the terminal and thus the achievement of the objectives of terminal operators. This paper contributes a method that allows the prioritization of TOS functionalities to assist the scientific community and TOS developers by allowing them to focus on those functionalities which are more important for the final users. This is the first time, to the authors' knowledge, that the AHP methodology has been used for the prioritization of TOS functionalities, which is the main contribution of this paper.

The prioritization and definition of functionalities to be included in a TOS is a problem that entails taking decisions by ICT developers, and then the use of a MCDM method to help in this task is appropriate and has been used for the development of this study. The prioritization of requirements or functionalities has been demonstrated as the main method when carrying out a decision-making process during the process of software development. AHP is a MCDM method that deals with typical problems of complex scenarios, being appropriate for decision-making problems that have to consider multiple criteria and multiple stakeholder groups [57]. Among the MCDM methods, the AHP has been recognized as the most cited and used in the scientific literature [35,58,59]. This high usage is produced due to its simplicity, traceability, and the systematic method used to calculate the weights of each criterion or, in this case, each functionality [24]. Due to all these advantages, together with its successful application in several knowledge areas [35] and its suitability for the case being analyzed, we have selected AHP as the method followed to prioritize the TOS functionalities. The application of AHP contributes to the design of TOSs with a structured analysis that makes it possible to establish a hierarchy, based on a contrasted mathematical method, of the different functionalities or requirements that can be included in a TOS. The results obtained show that the different functionalities of a TOS can be grouped into six main areas: Warehouse, Maritime Operations, Gate, Master Data, Communications, and ERP (Enterprise Resource Planning) Dashboard. A total of 107 functionalities were analyzed, from which the ones with the highest importance were time tracking of vessels, optimization of space, the development of loading and unloading lists, and optimization of container locations.

After the brief introduction developed in Section 1, in which the current state of the art of ports, inland terminals, TOSs and the use of AHP in port and inland terminal studies was introduced, this paper is organized into four additional sections. Section 2 of the paper describes the members of the expert panel and the steps followed for the development of the AHP methodology. The results section (Section 3) is divided into four subsections: definitions of TOS functionalities, the hierarchical model of TOS functionalities, prioritization of functionalities using AHP, and sensitivity analysis. In Section 4, the results are discussed, and finally Section 5 gives the main conclusions.

2. Materials and Methods

Figure 3 shows the general scheme followed for the development of this study based on the AHP methodology. Its main goal is the prioritization of the different functionalities of a TOS from a holistic point of view in order to find those with greater influence on the operational performance of the terminal and then on the energy consumption and GHG emissions; addressing economic and environmental aspects for a better sustainability.

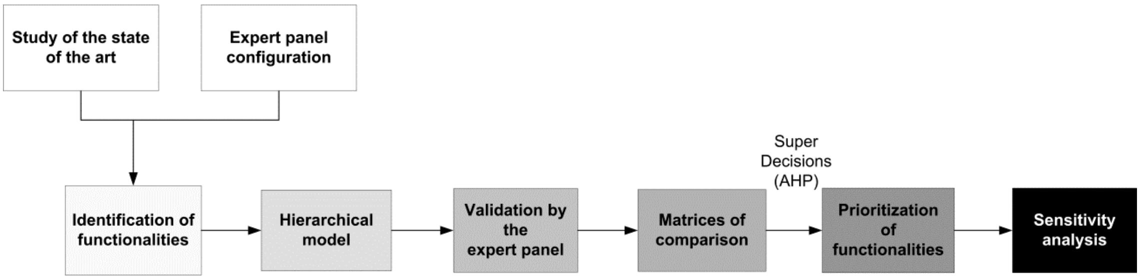

Figure 3. Scheme of the methodology followed based on the Analytic Hierarchy Process.

2.1. Description of Expert Panel

The expert panel was established following stakeholder theory [60] and was formed of twelve experts: a container terminal manager, two container terminal operators, one quality, safety, health, and environment manager expert in transport and logistics, two terminal customers, one head of the Commissariat of the port, two software developers, one expert in microsimulations of container terminals operations, and two experts in freight transport and yard planning.

2.2. Method

The methodology can be divided into six main steps:

1. Identification of TOS functionalities. The first step is the identification of functionalities of the TOS (including current functionalities and potential functionalities that will improve the TOS performance and increase the efficiency of port and inland terminals). The selection of the methods to gather the requirements was done following the methodology developed by Carrizo et al. (2014) [61]. The selection of these functionalities was firstly assessed through a study of the state of the art, obtaining a first draft of the functionalities, which were then further extended by the expert panel through individual interviews.
2. Construction of the hierarchical model. After finding all the functionalities of a TOS, they were clustered into groups, forming the hierarchical model. The number of functionalities within each cluster or level was kept at seven or below, since there is a limit on the amount of information that the human mind can process and more variables will reduce the consistency and validity of the results [62,63].
3. Validation by the expert panel. The role of the expert panel was to: (a) add, remove, and/or validate the functionalities defined in (1), (b) change or validate the defined hierarchical model, and (c) perform a pairwise comparison of the functionalities included in each of the clusters of criteria or levels with respect to the overall focus, using the scale of Saaty [56] (see Table 1).
4. Obtainment of comparison matrices. In order to obtain a single matrix of comparison for each of the clusters or levels of functionalities, consensus between the responses of the expert panel was obtained through calculation of the consistency ratio [34].
5. Prioritization of TOS functionalities. Prioritization of TOS functionalities was performed using the software Super Decisions, which uses the AHP to prioritize criteria.
6. Sensitivity analysis. Finally, a sensitivity analysis was developed, changing the weights of first-level criteria by ±20%, in order to assess the robustness of the results.

Table 1. Saaty's scale used by the experts to perform pairwise comparisons.

Level of Importance of Functionality i Compared with j (a_{ij})	Description
1	Functionalities i and j have the *same importance.*
3	i is *moderate*ly more important than j.
5	i is *strongly favored* over j.
7	i is *very strongly favored* over j.
9	*Extreme importance.* i is fully preferred when compared with j.
2, 4, 6, 8	Judgments can be refined using intermediate values.
Reciprocals (1/3, 1/7, etc.)	If j is the preferred option over i, then the same scale from 1 to 9 is used but in the form of a fraction (from 1/3 to 1/9). For example, if functionality i is strongly favored over j it will be given a 5, and when j is preferred to i, it will have the reciprocal value (1/5).

3. Results

3.1. Identification of TOS Functionalities

After the literature review and the validation by the expert panel, a total of 107 functionalities were identified and organized into six main areas (i.e., Warehouse, Maritime Operations, Gate, Master Data, ERP Dashboard, and Communications), also called first-level functionalities in this paper, as well as 17 second-level functionalities, 23 third-level functionalities, and 107 fourth-level functionalities. The identified requirements and their descriptions can be seen in Table A1 (Appendix A). The interoperability and integration among different equipment working in the terminal are relevant issues what have been included as functionalities (see for example clusters A1.2. Technical optimizations or F1.1: Communications and messaging).

3.2. Hierarchical Model

As shown in Table A1, the identified functionalities were grouped into different clusters according with their main themes (Warehouse, Maritime Operations, Gate, Master Data, Communications, and ERP Dashboard), forming the hierarchical model shown in Figure 4.

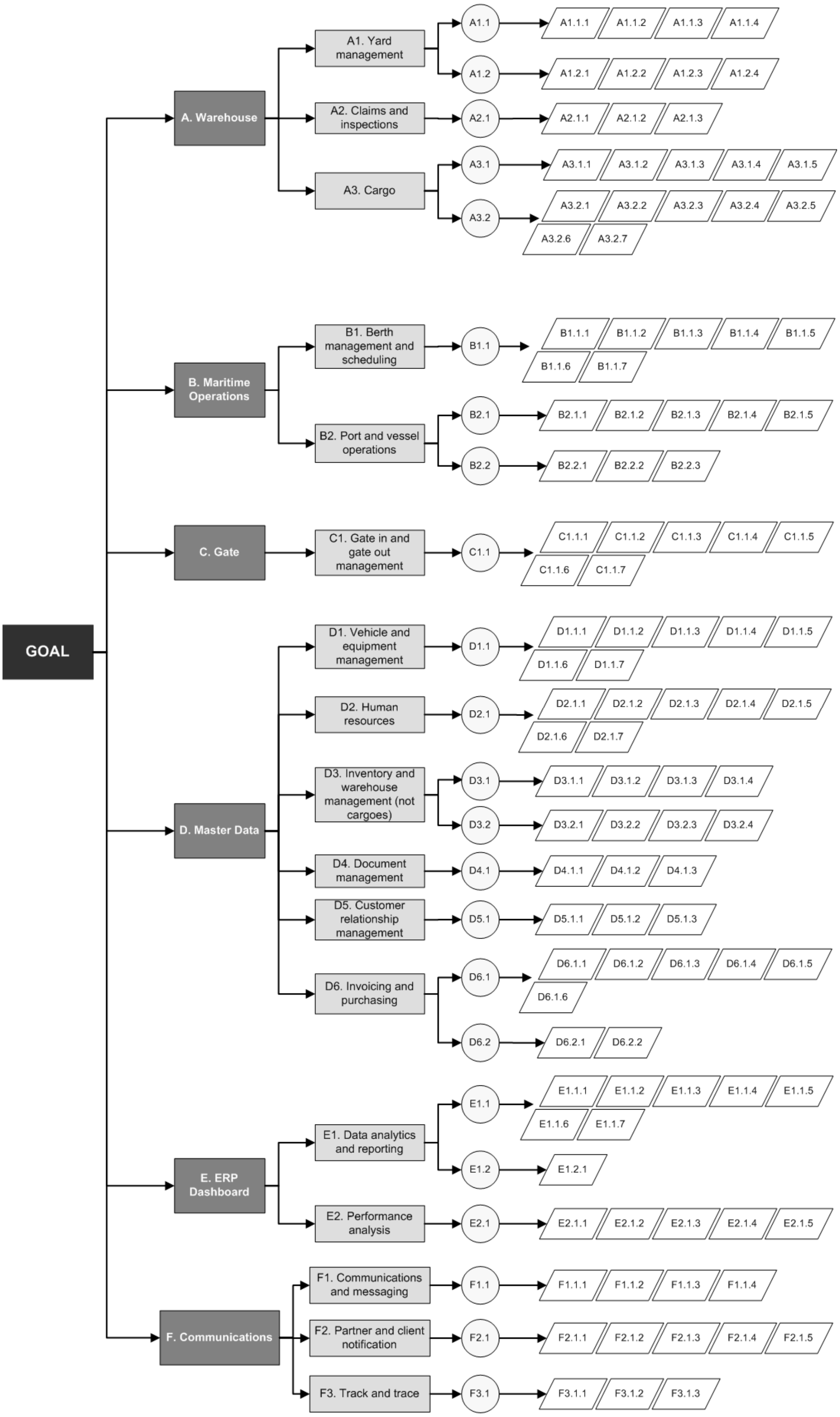

Figure 4. Analytic Hierarchy Process (AHP) hierarchical model of Terminal Operating System (TOS) functionalities.

3.3. Prioritization of Functionalities Using AHP

The AHP methodology was used to prioritize the different functionalities [56]. In this methodology, the different functionalities (first-, second-, third-, and fourth-level functionalities) within each cluster were compared pairwise by the experts, who gave their opinions using the scale of Saaty [56]. The geometric mean was calculated and used as the consensus value. The consistency ratios (CRs) of all the obtained matrices were below 0.1, and then it was not necessary to apply the Delphi technique. Table 2 shows the consensus matrix obtained after applying the geometric mean to the responses of the experts for the "A1.1. Yard Configurations" cluster of criteria and the local normalized weights of the criteria.

Table 2. Comparison matrix obtained for the fourth-level subcriteria belonging to the third-level cluster A1.1. Yard Configurations, the second-level cluster A1. Yard Management, and the general cluster A. Warehouse. Values for the consistency ratio (CR) of the matrix and the local normalized weight for the fourth-level criteria (w_{c_m}) are shown.

CR = 0.059	A.1.1.1 Customizable Layout	A.1.1.2 Historic Location	A.1.1.3 Space Optimized	A.1.1.4 Location Optimized	w_{c_m}
A.1.1.1 Customizable Layout	1	1.24	0.76	0.87	0.230
A.1.1.2 Historic Location		1	0.50	0.46	0.159
A.1.1.3 Space Optimized			1	1.1	0.314
A.1.1.4 Location Optimized				1	0.297

The consistency of each of the matrices of comparison was evaluated by calculating the Consistency Ratio (CR) (Equation (1)).

$$CR = \frac{(\lambda_{max} - n)/(n-1)}{RI}, \tag{1}$$

where λ_{max} is the principal eigenvalue of the matrix, n is the order of the matrix, and RI is the Random Index, which is an average random consistency index derived from a sample of size 500 filled with random values from the Saaty scale [62]. The values of RI based on the order of the matrix n can be seen in Table 3. When the calculated CR value is above 0.1, the matrix is rejected and answers to the matrix need to be revised [56].

Table 3. Values of the random consistency index (RI) for each matrix size ***n***.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

For the calculation of *normalized local weights* for first-level functionalities (w_{c_i}), the following procedure was used:

i. The consensus values obtained from the comparisons of the n functionalities at the same level and in the same cluster form, for each level, a comparison Matrix A:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix}, \tag{2}$$

where $a_{ji} = 1/a_{ij};\ i, j = 1, \ldots, n$ (Equation (2))

ii. The local normalized weight of each functionality for each cluster, $w_{c_i} = (w_{c_1}, w_{c_2}, \cdots, w_{c_i}, \cdots, w_{c_n})$, is calculated by raising this Matrix A to a sufficiently large power:

$$Q = \left[q_{il}^{k}\right] = \lim_{k \to \infty} (A)^{k}. \tag{3}$$

iii. Then, summing over the rows and normalizing, the local normalized weight is obtained at the kth power:

$$w_{c_i}^{k} = \frac{\sum_{l=1}^{n} q_{il}^{k}}{\sum_{i=1}^{n} \sum_{l=1}^{n} q_{il}^{k}}. \tag{4}$$

The process was stopped when the difference between $w_{c_i}^{k}$ obtained at the kth power and $w_{c_i}^{k+1}$ obtained at the (k+1)th power was less than 10^{-4}. The same process was applied to calculate the local normalized weight for each second-level w_{c_j}, third-level w_{c_k}, and fourth-level w_{c_m} functionality.

iv. The global normalized weights for each functionality at the fourth level (W_{CG_m}), third level (W_{CG_k}), and second level (W_{CG_j}) are calculated as shown in Equations (5)–(7), respectively:

$$W_{CG_m} = w_{c_i} \cdot w_{c_j} \cdot w_{c_k} \cdot w_{c_m}, \tag{5}$$

$$W_{CG_k} = w_{c_i} \cdot w_{c_j} \cdot w_{c_k}, \tag{6}$$

$$W_{CG_j} = w_{c_i} \cdot w_{c_j}. \tag{7}$$

For the calculation of W_{CG_m}, W_{CG_k}, and W_{CG_j}, the corresponding w_{c_i}, w_{c_j}, and w_{c_k} were selected based on the established hierarchy of groups and subgroups in the hierarchical model (see Figure 4).

Table 4 shows the global normalized weights of each of the functionalities ordered by level of importance.

Table 4. Weighted functionalities, in descending order, with their global normalized weights and the cumulative weights.

Functionality	W_{CG}	Cumulative Weight	Functionality	W_{CG}	Cumulative Weight
B.1.1.1	0.04562	0.04562	**A.3.1.5.**	0.00543	0.84982
A.1.1.3	0.03567	0.08129	**D.2.1.1.**	0.00513	0.85495
B.2.1.2.	0.03401	0.11530	**F.2.1.2.**	0.00511	0.86006
A.1.1.4.	0.03372	0.14902	**A.3.2.1.**	0.00500	0.86506
B.2.2.3.	0.02871	0.17773	**A.3.2.3.**	0.00470	0.86976
C.1.1.5.	0.02728	0.20501	**D.4.1.3.**	0.00463	0.87439
A.1.1.1.	0.02614	0.23115	**D.1.1.5.**	0.00456	0.87895
C.1.1.1.	0.02480	0.25595	**A.3.1.2.**	0.00451	0.88346
B.1.1.2.	0.02479	0.28074	**D.3.1.2.**	0.00451	0.88797
C.1.1.2.	0.02476	0.30550	**D.2.1.2.**	0.00434	0.89231
B.2.1.1.	0.02468	0.33018	**A.3.2.4.**	0.00419	0.8965
C.1.1.7.	0.02179	0.35197	**F.1.1.4.**	0.00415	0.90065
B.2.1.3.	0.02162	0.37359	**D.2.1.6.**	0.00412	0.90477
B.2.1.4.	0.02158	0.39517	**D.3.1.4.**	0.00411	0.90888
B.2.1.5.	0.02149	0.41666	**F.2.1.1.**	0.00398	0.91286
B.1.1.5.	0.02087	0.43753	**D.1.1.7.**	0.00394	0.91680
B.2.2.1.	0.01939	0.45692	**D.1.1.1.**	0.00352	0.92032
B.1.1.7.	0.01886	0.47578	**A.3.2.2.**	0.00345	0.92377
A.1.1.2.	0.01804	0.49382	**F.2.1.4.**	0.00342	0.92719
C.1.1.6.	0.01748	0.51130	**F.1.1.2.**	0.00338	0.93057

Table 4. *Cont.*

Functionality	W_{CG}	Cumulative Weight	Functionality	W_{CG}	Cumulative Weight
B.1.1.4.	0.01690	0.52820	**D.6.1.1.**	0.00325	0.93382
B.1.1.3.	0.01585	0.54405	**D.4.1.2.**	0.00307	0.93689
A.2.1.1.	0.01569	0.55974	**D.1.1.4.**	0.00302	0.93991
A.2.1.2.	0.01496	0.57470	**D.2.1.4.**	0.00299	0.94290
F.3.1.2.	0.01341	0.58811	**D.2.1.5.**	0.00285	0.94575
C.1.1.3.	0.01315	0.60126	**D.3.2.4.**	0.00274	0.94849
A.1.2.2.	0.01280	0.61406	**D.3.1.3.**	0.00273	0.95122
A.3.2.6.	0.01246	0.62652	**D.3.2.1.**	0.00270	0.95392
D.5.1.1.	0.01193	0.63845	**D.1.1.2.**	0.00266	0.95658
C.1.1.4.	0.01092	0.64937	**D.1.1.3.**	0.00260	0.95918
F.1.1.3.	0.01051	0.65988	**A.1.2.1.**	0.00251	0.96169
D.3.1.1.	0.01026	0.67014	**D.6.1.2.**	0.00244	0.96413
A.2.1.3.	0.01008	0.68022	**D.6.1.3.**	0.00236	0.96649
B.2.2.2.	0.00982	0.69004	**D.3.2.2.**	0.00235	0.96884
E.2.1.2.	0.00942	0.69946	**E.1.1.2.**	0.0023	0.97114
B.1.1.6.	0.00939	0.70885	**D.2.1.3.**	0.00228	0.97342
A.3.2.7.	0.00894	0.71779	**D.6.1.4.**	0.00222	0.97564
E.2.1.1.	0.00893	0.72672	**D.3.2.3.**	0.00212	0.97776
A.3.1.4.	0.00845	0.73517	**F.2.1.3.**	0.00206	0.97982
A.1.2.4.	0.00836	0.74353	**A.3.2.5.**	0.00203	0.98185
A.3.1.1.	0.00826	0.75179	**D.2.1.7.**	0.00184	0.98369
D.6.2.1.	0.00818	0.75997	**D.6.2.2.**	0.00184	0.98553
D.5.1.3.	0.00814	0.76811	**E.1.1.4.**	0.00179	0.98732
F.1.1.1.	0.00804	0.78424	**E.1.1.1.**	0.00174	0.98906
D.5.1.2.	0.00794	0.79218	**E.1.1.5.**	0.00165	0.99071
F.3.1.1.	0.00791	0.80009	**E.1.1.3.**	0.00156	0.99227
A.3.1.3.	0.00761	0.80770	**D.6.1.6.**	0.00155	0.99382
A.1.2.3.	0.00711	0.81481	**E.1.1.7.**	0.00140	0.99522
E.2.1.3.	0.00669	0.82150	**E.1.1.6.**	0.00121	0.99643
E.2.1.4.	0.00587	0.82737	**D.6.1.5.**	0.00120	0.99763
F.3.1.3.	0.00569	0.83306	**D.1.1.6.**	0.00118	0.99881
D.4.1.1.	0.00568	0.83874	**F.2.1.5.**	0.00118	0.99999
E.2.1.5.	0.00565	0.84439			

The results show that the 47 functionalities with higher weights have a cumulative weight of 80%. These top functionalities are the ones on which TOS developers should focus for the improvement of the performance of the TOS, which will be finally translated into a higher efficiency of maritime and dry ports.

3.4. Sensitivity Analysis

The sensitivity analysis allows us to analyze the robustness of the results. The robustness was analyzed by changing the local normalized weights of the first-level functionalities by ±20%. Table 5 shows how this change in first-level weights changes the prioritization of the 15 functionalities of highest weight.

In addition, the sensitivity analysis also shows small changes in the number of functionalities making up the 80% (see Table 6). The maximum difference is produced when the local normalized weight of "B. Maritime Operations" is reduced by 20% or when the local normalized weight of "D. Master Data" is increased by 20%, increasing the number of functionalities by three, which is not very significant compared with the total number of functionalities that make up the 80%.

Table 5. Rank of priorities of the most relevant functionalities of the fourth-level analysis when increasing the values of w_{c_i} of the main areas A—Warehouse, B—Maritime operations, C—Gate, D—Master Data, E—ERP Dashboard, and F—Communications. Gray background indicates those functionalities that are not included in the initial top 15 ranking.

N°	**Initial**	**A + 20%**	**A − 20%**	**B + 20%**	**B − 20%**	**C + 20%**	**C − 20%**	**D + 20%**	**D − 20%**	**E + 20%**	**E − 20%**	**F + 20%**	**F − 20%**
1	B.1.1.1	A.1.1.3	B.1.1.1	B.1.1.1	A.1.1.3	B.1.1.1	B.1.1.1	B.1.1.1	B.1.1.1	B.1.1.1	B.1.1.1	B.1.1.1	B.1.1.1
2	A.1.1.3	B.1.1.1	B.2.1.2	B.2.1.2	A.1.1.4	A.1.1.3	A.1.1.3	A.1.1.3	A.1.1.3	A.1.1.3	A.1.1.3	A.1.1.3	A.1.1.3
3	B.2.1.2	A.1.1.4	B.2.2.3	B.2.2.3	B.1.1.1	B.2.1.2	B.2.1.2	B.2.1.2	B.2.1.2	B.2.1.2	B.2.1.2	B.2.1.2	B.2.1.2
4	A.1.1.4	B.2.1.2	A.1.1.3	A.1.1.3	C.1.1.5	C.1.1.5	A.1.1.4	A.1.1.4	A.1.1.4	A.1.1.4	A.1.1.4	A.1.1.4	A.1.1.4
5	B.2.2.3	A.1.1.1	C.1.1.5	A.1.1.4	A.1.1.1	A.1.1.4	B.2.2.3	B.2.2.3	B.2.2.3	B.2.2.3	B.2.2.3	B.2.2.3	B.2.2.3
6	C.1.1.5	B.2.2.3	A.1.1.4	B.1.1.2	B.2.1.2	C.1.1.1	A.1.1.1	C.1.1.5	C.1.1.5	C.1.1.5	C.1.1.5	C.1.1.5	C.1.1.5
7	A.1.1.1	C.1.1.5	C.1.1.1	B.2.1.1	C.1.1.1	C.1.1.2	B.1.1.2	A.1.1.1	A.1.1.1	A.1.1.1	A.1.1.1	A.1.1.1	A.1.1.1
8	C.1.1.1	C.1.1.1	B.1.1.2	B.2.1.3	C.1.1.2	B.2.2.3	B.2.1.1	C.1.1.1	C.1.1.1	C.1.1.1	C.1.1.1	C.1.1.1	C.1.1.1
9	B.1.1.2	C.1.1.2	C.1.1.2	B.2.1.4	C.1.1.7	C.1.1.7	B.2.1.3	B.1.1.2	B.1.1.2	B.1.1.2	B.1.1.2	B.1.1.2	B.1.1.2
10	C.1.1.2	B.1.1.2	B.2.1.1	B.2.1.5	B.2.2.3	A.1.1.1	B.2.1.4	C.1.1.2	C.1.1.2	C.1.1.2	C.1.1.2	C.1.1.2	C.1.1.2
11	B.2.1.1	B.2.1.1	C.1.1.7	B.1.1.5	B.1.1.2	B.1.1.2	B.2.1.5	B.2.1.1	B.2.1.1	B.2.1.1	B.2.1.1	B.2.1.1	B.2.1.1
12	C.1.1.7	A.1.1.2	B.2.1.3	C.1.1.5	B.2.1.1	B.2.1.1	C.1.1.5	C.1.1.7	C.1.1.7	C.1.1.7	C.1.1.7	C.1.1.7	C.1.1.7
13	B.2.1.3	C.1.1.7	B.2.1.4	A.1.1.1	A.1.1.2	C.1.1.6	B.1.1.5	B.2.1.3	B.2.1.3	B.2.1.3	B.2.1.3	B.2.1.3	B.2.1.3
14	B.2.1.4	B.2.1.3	B.2.1.5	B.2.2.1	C.1.1.6	B.2.1.3	B.2.2.1	B.2.1.4	B.2.1.4	B.2.1.4	B.2.1.4	B.2.1.4	B.2.1.4
15	B.2.1.5	B.2.1.4	A.1.1.1	B.1.1.7	B.2.1.3	B.2.1.4	C.1.1.1	B.2.1.5	B.2.1.5	B.2.1.5	B.2.1.5	B.2.1.5	B.2.1.5
Number of functionalities in the initial top 15		**14**	**15**	**12**	**13**	**14**	**13**	**15**	**15**	**15**	**15**	**15**	**15**

Table 6. Number of functionalities making up 80% of the total weight after varying the values of w_{c_i} of the main areas A—Warehouse, B—Maritime Operations, C—Gate, D—Master Data, E—ERP Dashboard, and F—Communications by ±20%.

	Functionalities Making Up 80%
Initial	47
A + 20%	47
A − 20%	48
B + 20%	45
B − 20%	50
C + 20%	47
C − 20%	48
D + 20%	50
D − 20%	45
E + 20%	48
E − 20%	47
F + 20%	48
F − 20%	47

Therefore, through the analysis of the sensitivity in the different scenarios, we found that: (i) for the 15 functionalities with initially greater weights, few changes in rank happened when changing the value of w_{c_i} and (ii) there were also few changes in the number of functionalities making up the 80%, which indicates that the model is robust and reliable.

4. Discussion

The results show that as the most important functionality in a TOS is the "time tracking of vessels", it is mandatory that a TOS can track all related data with vessel arrivals and departures and the time during which a vessel is in the berth. All the operations developed in a container terminal depend on the arrival and departure of vessels, or in the case of inland terminals, on the arrival and departure of vehicles (trucks and trains), so it is logical that this type of data is a must in a TOS. In fact, Kia et al. (2000) compared two different operational systems by simulation, one with a tracking system and the other without, and highlighted that those involved in terminal management give higher priority to container-tracking systems among operational computer applications in ports. In addition, Jamal et al. (2017) analyzed the benefits of using GDPS in the TOS and obtained a 38.17% reduction of Truck Round Time, a 16.67% increase in Box Container per Hour (BCH), with BCH being the number of operations in the container made by a CHE unit in an hour, and a 3.3% decrease of operating costs [29].

The second most important functionality is the "optimization of the space" of the yard. Several studies can be found in the literature showing the effect of optimization of the space in the yard [64–68]. The utilization of the yard in an optimal way can increase, for example, the efficiency of the equipment used in the yard by travelling shorter distances or reducing the number of moves needed to store a container in the storage yard. In line with this functionality, the functionality "location optimized" appears in fourth position on the list. In many TOSs, the identification of the optimal location for each unit depending on different characteristics (destination by carrier, loading/unloading sequence, weight, dangerous or not dangerous goods, reefer container, etc.) needs the intervention and good performance of the terminal manager to determine the most appropriate location for each container. The implementation of this type of functionality reduces administrative and operational times, reduces human errors, and increases the safety of the terminal.

The third most important functionality in a TOS is the development of loading lists for terminal operators with information about the cargo to be loaded/unloaded, including information about its location. In line with this, Olesen et al. (2013) highlighted in their study that a lack of information is the main reason for not making a good plan and that waiting time reduction, storage improvements, and reworking activities cannot be done efficiently without having all the necessary information on time [69].

Other important functionalities of the TOS include emergency reports, retrieve and dispatch requests for gate operations, allowing the customization of the layout, and providing extended data information about vessel voyages (e.g., security requirements or maintenance information).

On the other hand, results obtained in the sensitivity analysis indicate that the largest change in the top 15 is produced when the local normalized weight of the main functionality area "B. Maritime Operations" is increased by 20%. However, this is not significant since it only produces a change in three of the functionalities, which are still among the 20 most important functionalities. Therefore, it can be concluded that the obtained model is robust.

5. Conclusions

The maritime transport is increasing the number of operations and the level of occupancy of their storage yard, triggering congestion in sea/river ports and consequently in dry ports. Some measures to boost port capacity are: (i) increasing the space of container terminals of both sea and dry ports and (ii) improving the performance of the TOS by acting on some functionalities that result in a higher efficiency of the terminal (e.g., improving the total container throughput, reducing operational time per TEU, etc.).

Recently, there are many TOSs on the market with different functionalities. The influence of each functionality on the TOS performance is not clear, making it more difficult, on the one hand, for TOS software developers to develop more efficient TOSs, and, on the other hand, for sea and dry port managers to select the most appropriate TOSs for their container terminals.

The contribution and novelty of this paper in the field of container terminals logistics research is the use of the AHP method to identify and hierarchize TOS functionalities. This method will be helpful for the scientific community and TOS developers involved in the improvement of TOSs and terminal logistics operations, allowing them to focus on those which are more important for the final users. This is the first time, to the authors' knowledge, that the AHP methodology has been used for the prioritization of TOS functionalities, which is the main contribution of this paper.

Functionalities have been identified, weighted, and hierarchized based on the opinions of twelve experts from different sectors (i.e., container terminal operators and managers, TOS developers, shipping lines, port authorities, a quality, safety, health, and environment manager, terminal customers, and experts in simulation of container terminal operations, freight transport, and yard planning). Functionalities were grouped into six main themes or clusters: Warehouse, Maritime Operations, Gate, Master Data, Communications, and ERP Dashboard.

The study has shown that of a total of 107 TOS functionalities, 47of them account for 80% of the total weight. Some of the most relevant functionalities include time tracking of vessels, optimization of the space, the development of loading and unloading lists, and the optimization of container locations. The sensitivity analysis indicates that the model is robust.

Container terminals' performance in dry and maritime ports can be improved by acting on these more relevant TOS functionalities, contributing to a less stressed port ecosystem, with less congestion and lower GHG emissions.

Further developments should focus on the evaluation of the method and of the results using a wider expert panel from different countries and afterwards on the validation of this model by acting on these functionalities in a case study and analyzing some key performance indicators related to cost efficiency, environmental care, and safety and security in the container terminal.

Author Contributions: Conceptualization, G.D.M., F.E.S., and J.-P.P.-F.; Data curation, M.H.-P.; Formal analysis, M.H.-P.; Investigation, M.H.-P., S.P.-R., and F.E.S.; Methodology, M.H.-P., G.D.M., F.E.S., and J.-P.P.-F.; Supervision, G.D.M. and J.-P.P.-F.; Visualization, S.P.-R.; Writing—original draft, M.H.-P. and S.P.-R.; Writing—review & editing, G.D.M., F.E.S., and J.-P.P.-F.

Funding: This study was co-funded by Instituto Valenciano de Competitividad (IVACE) and European Regional Development Funds (ERDF) under project reference IMIDCA/2017/32.

Acknowledgments: The authors would like to acknowledge the help of the members of the expert board (sorted alphabetically): AITEC, INFOPORTS, Intersagunto Terminales, Nisa Maritima, Port Authority of Valencia, SIM Agencia, and University of Zagreb.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Description of each of the identified TOS functionalities or requirements.

A. Warehouse		
A1. Yard Management	*A1.1. Yard Configurations*	A.1.1.1 CUSTOMIZABLE LAYOUT: Ability to create a customizable yard layout for multiple terminals/yards and traffic patterns/routes.
		A.1.1.2 HISTORIC LOCATION: Provide real-time visibility of each unit at all applicable locations (e.g., terminal/yard/workshop/loading/bays/vessel).
		A.1.1.3 SPACE OPTIMIZED: Optimize space utilization of the yard(s).
		A.1.1.4 LOCATION OPTIMIZED: Identify the optimal location for each unit based on its destination by carrier, loading/unloading sequence, or intervention requirements.
	A1.2. Technical Optimizations	A.1.2.1 GIS INTEGRATION: Provides integration with GIS, allowing the display of geospatial related data from the TOS.
		A.1.2.2 OPERATING PROCEDURES: Integration with operating procedures.
		A.1.2.3 CUSTOMER INTEGRATION: Integration with equipment and carrier operating systems.
		A.1.2.4 MULTIMODAL OPTIMIZATION capability.
A2. Claims and Inspections	*A2.1. Claims and Inspections*	A.2.1.1 INSPECTION TRACEABILITY: Record when an inspection request has been submitted.
		A.2.1.2 INSPECTION ALERTS: Notify when inspection has not occurred within time frame from when it was requested.
		A.2.1.3 INSPECTION REPORTS: Capture cargo inspection information, for example: whether cargo was inspected, when it was inspected, inspector's name, and how much time it took to complete the inspection.
A3. Cargo	*A3.1. Track and Notifications*	A3.1.1 DELIVERY NOTIFICATIONS: Verification of delivery order data against manifest data and notification of customer services about discrepancies for reconciliation.
		A.3.1.2 DELIVERY ALERTS: Notification when a delivery order has not been received within the time frame from the original receipt date.
		A.3.1.3 ARRIVAL NOTIFICATIONS: Provide notifications of truck or rail arrival to other parties in the process such as security, longshore, and railcar coordinators.
		A.3.1.4 ACCEPTANCE NOTIFICATIONS: Record/confirm received cargo against the broker or freight forwarder dock receipt.
		A.3.1.5 WORKS TRACEABILITY: Record and track cargo mitigation, for example: seasonal fumigation for cargo, country-specific requirements for steam cleaning, or manufacturer requirements for specific protective coatings for cargo.
	A3.2. Cargo Control	A.3.2.1 BILL OF LADING (BoL) UPDATES: Add cargo items to a bill of lading; for example: a component of a unit has to be removed and added as a separate item before the document is created for the truck driver.
		A.3.2.2 FLEXIBLE TARIFFS: Change the tariff item/billing rate for a specific delivery, for example: engine on a drivable cargo unit will not start and the unit must be lifted onto the truck and, as a result, billed using a different tariff item/rate.
		A.3.2.3 CARGO VERIFICATIONS: Verify broker and freight forwarder dock receipts against the shipping line's export lineup and notify operations of discrepancies for reconciliation.
		A.3.2.4. RECORDING OF DAMAGES: Record cargo damages.
		A.3.2.5 Generate and print CARGO TAGS.
		A.3.2.6 Verify GROSS MASS on yard.
		A.3.2.7 PACKING LISTS: Provide a means to reconcile project cargo (cargo disassembled for shipping) prior to releasing cargo for loading.

Table A1. *Cont.*

B. Maritime Operations		
B1. Berth Management and Scheduling	*B1.1. Berth Management*	B.1.1.1. TIME TRACKING: Track vessel time related data, for example: estimated time of arrival, estimated time of departure, actual arrival, actual departure, time anchored, time in berth, etc. B.1.1.2 EXTENDED VESSEL DATA: Establish additional data related to vessel voyages, for example: berth, terminal name, number of projected shifts, stevedore, maintenance and security requirements, etc. B.1.1.3 SPECIAL CALLS: Flag certain voyages, for example: military not to be included in reports or viewable in the system except by designated personnel. B.1.1.4 CUSTOMIZABLE ALERTS: Configurable alert notifications, for example: two-hour delay in vessel arrival or departure, customs release has occurred, etc. B.1.1.5 WATERWAY CONTROL: Visibility and data for waterway activities at all berths. B.1.1.6 BARGE BERTHS: Designate some berths as 'lay berths' (typically for barges). B.1.1.7 MOBILE DATA: Remote or mobile access to information for night and weekend on-call waterway coordination.
B2. Port and Vessel Operations	*B2.1. List and Confirmations*	B.2.1.1 DISCHARGE CONFIRMATIONS: Record and confirm discharged cargo, for example: commodity, quantity, marks. B.2.1.2 LOADING LISTS: Submit cargo to the terminal operators for vessel loading along with the cargo location. B.2.1.3 UPDATED LISTS: Track cargo as it is loaded onto the vessel, for example: know what cargo still remains to be loaded. B.2.1.4 UPDATED STOCK: Track cargo that was unable to be loaded onto the vessel, for example: inoperable cargo needing repair. B.2.1.5 LIST CONFIRMATIONS: Provide the ability to confirm vessel loading is complete.
	B2.2. Maritime Reports	B.2.2.1 DAMAGE REPORTS: Record damages to discharged cargo. B.2.2.2. CLEANING REPORTS: Record whether cleaning was required. B.2.2.3 EMERGENCY REPORTS: Record and follow up emergencies.
C. Gate		
C1. Gate In and Gate Out Management	*C.1.1. Gate In and Gate Out Management*	C.1.1.1 DELIVERY MANAGEMENT: Create and manage truck delivery appointments. C.1.1.2 MOVEMENT TRACEABILITY: Notify terminal gate personnel of pending truck arrivals after a truck is received at the gate. C.1.1.3 PRIOR APPOINTMENTS: Notify longshore personnel of pending truck and rail arrivals and cargo to be loaded after a truck is received at the gate. C.1.1.4 Notify PENDING rail ARRIVALS. C.1.1.5 GATE OPERATIONS: Submit dispatch and retrieval requests to gate operations. C.1.1.6 VERIFY GROSS MASS at gate. C.1.1.7 Manage and control dynamic terminal CAPACITY LIMITS.
D. Master Data		
D1. Vehicle and Equipment Management	*D.1.1. Vehicle and equipment Management*	D.1.1.1 TIME CONTROL: Integrated measurement of time by activity and by operative. D.1.1.2 INCIDENCE TRACEABILITY: Measure of efficiency by individual and task. D.1.1.3 Customer KPIs/SLAs. D.1.1.4 TIME allocated PER TASK (from customer). D.1.1.5 EQUIPMENT AVAILABILITY. D.1.1.6 Ability to support/use QR CODES. D.1.1.7 RESOURCE REQUESTS: Equipment and resource requests handled by the system.
D2. Human Resources	*D.2.1. Human Resources*	D.2.1.1 EFFICIENCY REPORTS: Record man hours (labor per shift) for labor efficiency reporting. D.2.1.2 CAPACITY ISSUES: Analyze forecasted work orders/maintenance requirements from range of customers, match these to workshop/workforce capacity (±), and flag up capacity issues. D.2.1.3 Match available hours with work order components allowing for RAMPING UP AND DOWN. D.2.1.4 WORKER COMPETENCIES: Match operative competencies/experience with work order requirements.

Table A1. *Cont.*

		D.2.1.5 Accommodate customer KPI/SLA REQUIREMENTS. D.2.1.6 Incorporate known ARRIVAL AND DISPATCH SCHEDULES. D.2.1.7 Incorporate EMPLOYMENT LEGISLATION.
D3. Inventory and Warehouse Management (Not Cargoes)	*D.3.1. Inventory Management*	D.3.1.1. Provide the ability to track and MANAGE INVENTORY. D.3.1.2 INVENTORY DISCREPANCIES: Perform a physical inventory count and reconcile inventory discrepancies. D.3.1.3. Detail every INVENTORY item BY DESCRIPTION and reference number. D.3.1.4. Visibility of every INVENTORY item BY ARRIVAL/DISPATCH or fitting dates.
	D.3.2. Automation	D.3.2.1 Direct REAL TIME ORDERING and order visibility. D.3.2.2. REAL TIME PARTS availability updates. D.3.2.3 Pre-advised PICKING LIST to match work orders. D.3.2.4 OPTIMIZED STOCKHOLDING.
D4. Document Management	*D.4.1. Document Management*	D.4.1.1 FILE REPOSITORY: Upload/attach files, for example: pictures and documents, and associate with a booking number, bill of lading, or cargo item. D.4.1.2 DATE/TIME STAMP all documents and reports produced by the system. D.4.1.3 Generate and PRINT signed and time stamped DOCUMENTS.
D5. Customer Relationship Management	*D.5.1. Customer Relationship Management*	D.5.1.1 CREATE and manage QUOTES. D.5.1.2 QUOTE performance REPORTING capability: • Turn-around time (request received and quote delivered). • Quote conversions to actual business. • Actual cost compared to the quoted cost. D.5.1.3 RECORD TRACEABILITY: Provide the ability to submit customer records (new and changes) to the system.
D6. Invoicing and Purchasing	*D.6.1. Invoicing*	D.6.1.1 SPECIFIC TARIFFS: System automatically assesses storage charges for export and import cargo according to applicable tariff item parameters and rates as well as customer-specific parameters. D.6.1.2 BL MANAGEMENT: Add a customer to a BoL who is not the notified party or consignee. D.6.1.3 EVALUATE ORDERS: Submit import/export cargo billing to the system when cargo loading/discharge has been confirmed. D.6.1.4 Associate a CUSTOMER with the BOOKING, including labor time/tracking. D.6.1.5 Handle SPECIAL BILLINGS. D.6.1.6 Capture customer-specific BILLING REQUIREMENTS in the TOS, for example: associated BoL on all invoices.
	D.6.2. Cost Analysis	D.6.2.1. COST REPORTS: Accumulate all costs associated with a billable transaction. D.6.2.2. BILLING INTEGRATION: Interface with the customer's existing financial systems to transfer costs for final invoicing and billing.
E. ERP Dashboard		
E1. Data Analytics and reporting	*E.1.1. Data Reporting*	E.1.1.1 STANDARD REPORTS: Standard reports out of the box for all core system functions and activities. E.1.1.2 Ability to develop CUSTOM REPORTS. E.1.1.3 Ability to REPORT on all data fields WITHIN the SYSTEM. E.1.1.4. Allow reporting by THIRD PARTY REPORTING applications. E.1.1.5. AUTOMATE the DISSEMINATION of reports via email. E.1.1.6. HISTORICAL REPORTING. E.1.1.7 FILE EXPORT: Download reports to other formats, for example: Excel, PDF, etc.
	E.1.2. Data Queries	E.1.2.1 Ability to perform DATA QUERIES.
E2. Performance Analysis	*E.2.1. Performance Analysis*	E.2.1.1. ACTIVITIES LOG: Log all activities performed in the system, that is, who performed the activity and when. If data were changed by the activity, report the previous and current values. E.2.1.2 Record and track TERMINAL OPERATING EXPENSES. E.2.1.3 Select and show REAL TIME KPI STATUS. E.2.1.4 Configure and customize PERFORMANCE DASHBOARDS. E.2.1.5 COMPARE WITH OBJECTIVES.

Table A1. *Cont.*

F. Communications		
F1. Communications and Messaging	*F.1.1. Communications and Messaging*	F.1.1.1 PCS INTEGRATION: Integration facility for bi-directional automated data transfers between the TOS and other port systems that maintains business rules and application logic. F.1.1.2 PUBLISHED API's to allow the port to develop application integrations that maintain business rules and application logic. F.1.1.3 EDI COMMUNICATIONS: Automate the population of third-party data into or out of the system (including EDI, XML, XLS, etc.). F.1.1.4 ELECTRONIC AUTHORIZATIONS: Provide the ability to electronically receive authorizations or approvals from brokers, freight forwarders, truckers, etc.
F2. Partner and Client Notification	*F.2.1. Partner and Client Notification*	F.2.1.1 VISIBILITY AND ETA for customers and partners. F.2.1.2 Electronic PROOF OF DELIVERY. F.2.1.3 Customer/dealer/carrier ALERT FLAG. F.2.1.4 CUSTOMS CLEARANCE. F.2.1.5 CHANGE THIRD PARTY DATA populated in the system.
F3. Track and Trace	*F.3.1. Track and Trace*	F.3.1.1 Full VEHICLE movement TRACEABILITY by vehicle identification and location. F.3.1.2 TRACK/LOCATE CARGO as it is moved throughout the terminal/yard. F.3.1.3 DAMAGE REPORTS: Track and report damaged/inoperable cargo associated with a vessel voyage and booking number (exports) or BoL (imports).

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