

ASSESSMENT OF THE FACTORS INFLUENCING ON A SMART PORT WITH AN ANALYTIC HIERARCHY PROCESS

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1.- INTRODUCTION

The ports have always been strategic centres of economic activity that link the maritime and land transport, being considered engines of the economic development. It could be said that the containers transport is the first industry truly global in the world [1]. Currently in Europe, such transport head for a model which in 2020 will be smarter, sustainable and integrated. Due to this fact, is a priority to have information in order to know in what situation are the Mediterranean container ports and planning actions for its development [2].

In this line, there are many initiatives on literature, among those highlighted [3] for its holistic and integrated approach. The authors analyse the “smart-port” (SP) concept from three perspectives: operational, energy and environmental. About a bibliographic analysis and consulting experts, it assesses 23 factors that define the SP level of a Mediterranean container port (Table 1):

Areas	Factors
Operational	Quay length
	Storage area (patio area)
	Capacity to receive large vessels
	Size and maximum capacity use
	Technological level
	Automation level
	Intermodality level
	Lines which stopover in the port
	Quality management, security and health systems
Energy	Total energy consumption (primary energy)
	Energy consumption on the part of the containers
	Energy consumption of the internal fleet of vehicles
	Energy consumption on the part of the offices
	Energy consumption on the part of the light system
	Energy consumption on the part of the team dedicated to the container's movement (cranes, etc.)
	Use of renewable energy
	Energy management system
Environment	Environmental management systems
	Waste management
	Water management
	Emissions to air
	Noise pollution
	Leaks and spillages of substances into the sea

Table 1: Areas and factors of the SP model. Source: Authors [3].

On the other hand, AHP is a technique which: a) allows to determinate alternatives or elements when several criteria should be considered and determine priorities among these. [4]; b) is based on the knowledge and the experience of an expert group which should make comparisons between element pairs.

There are numerous studies where AHP is applied to assess factors related to the port management. In this way, the references are provided:

- [5]: Identifies efficiency, the frequency of vessels and the location as the main factors that influence logistics operator in choosing a port.
- [6]: Analyse eight Asian ports and establish that the most commonly used assessment include, among others, the quality of the labour force, internal productivity, average time of service to the vessel in the port, load and unload ratio, movement capacity in the terminal, operation cost of freight forwarding and the relationship between the input and output streams.
- [7]: It explores the relative importance of the factors which determine the competitiveness of a container port from the user's perspective. It finds that the factor "cost in the port" is which determines the competitiveness in the port from the shipping line perspective and the "port localisation" it does it from the freight forwarders and loaders.
- [8]: It analyses the factors which influencing the use of a determined shipping line in a port on the part of consignees or container operators. It concludes that these factors include the transshipment times and efficient operations in the terminal.

In the energy and the environmental field, the literature, didn't show evidences of the AHP implementation in the port area. An example could be the reference [9] that formulates a diffused AHP model as a guide for a port operation "green" identifying as a priority the management of dangerous waste, air and water pollution, among others.

In line with the latest research and trends, this work aims to contribute to guide the container port of the Mediterranean towards "smart" criteria. To this end, a) Adopts the concept SP as starting point, analysing the operational, energy and environmental perspective; b) Implements AHP, with the participation of European experts to determinate the relative importance of each of these perspectives, as well as, the determining factors; c) Enunciates suggestions for the port authorities and terminal managers of containers create strategies which increase it SP consideration and improve its competitiveness in an integral and balanced way.

The SP concept used is based on linked factors to non-confidential information, consequently it measurement it should be possible using public sources or by resorting to the ports directly. This enables that the results of this work can serve for the measurement of single level indicator "smart" of a port facilitating its comparison with others.

2. MATERIAL AND METHODS

Our study applies AHP, a technique which uses the matrix algebra about comparisons between pairs of elements carried out by experts.

Among the reasons which support the choice of this method, it highlights:

- Is a simple, logic and structured method based on the decomposition of an objective or a problem in a hierarchical structure of factors or subproblems.
- Facilitates the work of the expert participants, to allow assessing elements more easily, comparing to each other.
- It allows measuring the coherence of the expert's opinions. Thus, if its matrix is unconscious, the expert must rethink its opinion. If is not possible to redirect the degree of unconsciousness to acceptable values, its opinion of the study is removed.
- There are different softwares for its implementation. An example is an Expert Choice, used in this study for being easy use and for existing several tutorials and free versions.

The steps taken for implementing AHP are:

- a) Experts choice which will issue its opinions: the study joins forces with the collaboration of 16 experts of Mediterranean countries (Greece, Spain, Italy and Slovenia): Selected by its experience in European projects and studies related with the addressed topic; Participants directly or indirectly in the study of the SP concept on which is based the present study and with wide knowledge about the situation of the Mediterranean ports and its future expectations; owned by port authorities, regional governments, container terminals and other organisations linked to the port sector.
- b) It has been passed a questionnaire to each expert who includes the 4 assessment matrices of the study which should fill. They all are square matrices as many rows as columns and elements to compare:
 - Matrix 1, where the elements to compare are the three most considerate areas (operational, energy and environmental) on the basis of its influence on the SP level of a port.
 - Matrix 2, where the elements to compare are the factors which determine the operational perspective, according to [3] its influence in the SP Operational Area.
 - Matrix 3, where the elements to compare are the factors which determine the energetic perspective [3] based on its influence in the energy area of an SP.
 - Matrix 4, where the elements to compare are the factors which determine the environmental perspective [3] based on its influence in the environmental area of an SP.

The c_{ij} elements of each matrix (hereinafter, comparison matrix) reflect the value judgments of each expert, expressed in the numerical scale of [4].

- c) Once these individual assessments of the experts have been carried out, it has been analysed the consistency of all the comparison matrices generated (four of each expert).

For this, the Expert Choice IT support has been used, with which firstly, the hierarchy subject of study has been modelled. The higher node of the hierarchy is the mission pursued (for instance, become an SP) and the next nodes the alternatives which are assessed (for instance, Operational, Energy and Environmental). Similarly, it has been designed the hierarchy for the Operational, Energy and Environmental Area, taking into account the identified factors to each of them in [3].

Once the modelling has been made, it has been introduced in Expert Choice the comparison matrices of each expert, obtaining for each one:

- The consistency ratio (CR). AHP measure the consistency through the CR and validate that the judgments by the experts do not contain contradictions. Usually a CR minor or equal than the 0, 11 is considered acceptable, although some authors such as [4], recommend until 0, 9. In practice, a threshold of 0, 1 is considered as good and is adopted in the present study. When the limit was exceeded, a new assessment to the expert has been requested. Despite this review, the answers in the matrices 2, 3 and 4 of two experts had to be rejected to remain inconsistent (higher than 0, 11).
 - A vector whose components reflects the weight it has from the perspective of each expert, each element it has been compared.
- d) Applying the guidelines given by [10], the priorities of each element have been determined considering in an aggregated way the opinions of all the experts. It has been calculated:
 - Four decisions matrices, whose columns are the priorities calculated for each element and expert.
 - Four symmetric matrices of correlation coefficients of the experts and the exponential matrices corresponding through Ec. (1) and Ec. (2):

$$c_d = [\sum_{l=1}^t \exp(r_{dl})] - \exp(r_{dd}) \quad (1)$$

$$w_d = \frac{c_d}{\sum_{l=1}^t c_l} \quad (2)$$

where r_{dl} is the correlation coefficient between the expert d and the l , w_d is the weight of each expert and t is the number of experts.

- Weights of each element according to the Ec. (3):

$$w_{jg} = \left[\sum_{d=1}^t (w_d w_{jd}) \right] \quad (3)$$

where w_{jd} is the weight of the element j with regard to the expert d .

- e) Finally, it has been calculated the global priority of each factor in the model proposed by applying the principle of hierarchy composition, that is, multiplying the priority of each area (Operational, Energy and Environment) by the priority of each factor which determines it.

As validation tool the method of Thrustone binary comparisons is applied [11]. Once the factors are compared in pairs, it is calculated the proportion of times in which each one has been preferred towards another and this proportion is divided by the number of judges participating. To each of these proportions are assigned a typical score Z whit which the corresponding scale of intervals is obtained.

3. RESULTS

The table 2 shows the local priorities of each studied area:

Area	Local weight
Operational	0,62
Energy	0,19
Environmental	0,19

Table 2: Weights of each studied area in a SP. Source: Authors.

It can be seen how the experts consider the Operational Area as the most important and the most influential in the SP level (62%). The two other areas (Energy and Environment) have the same relative weight each other. The weights obtained by factor in the Operational, Energy and Environment areas are shown in the Table 3:

Studied areas in a "smart port"	Local weight
Operational area	
Quay length	0,10
Storage area (patio area)	0,10
Capacity to receive large vessels	0,07
Size and maximum capacity use	0,06
Technological level	0,16
Automation level	0,15
Intermodality level	0,15
Lines which stopover in the port	0,11
Quality management, security and health systems	0,10
Energy Area	
Total energy consumption (primary energy)	0,20
Energy consumption on the part of the containers	0,08
Energy consumption of the internal fleet of vehicles	0,19
Energy consumption on the part of the offices	0,07

Energy consumption on the part of the light system	0,12
Energy consumption on the part of the team dedicated to the containers movement (cranes, etc.)	0,17
Use of renewable energy	0,08
Energy management system	0,09
Environment area	
Environmental management systems	0,21
Waste management	0,12
Water management	0,11
Emissions to air	0,17
Noise pollution	0,15
Leaks and spillages of substances into the sea	0,24

Table 3: weights of the factors which influence in a SP in the framework of its areas. Source: Authors.

It can be seen how the technological level, of automation, and of intermodality are the ones which have a greater influence in the Operational Area.

The energy consumption of the internal fleet of vehicles and the teams dedicated to the container's movement are perceived as the most influential factors in the Energy Area. They are followed by the energy consumption of the lighting system.

In the Environmental Area, the leaks and the spillages of substances into the sea and the environmental management systems standardised are the two most important factors. The waste and water management are the least important.

The implementation of the Thurstone method allows us to know the distances between each of the factors, checking that exists differences between them, which is not appreciated when implementing AHP where all the factors are highly concentrated.

Finally, the Table 5 shows the overall weights of each influential factor in a SP as a consequence of the last step to implement AHP. It can be seen that the most important factor is the technological level, followed by the automation and intermodality level. The least important is the energy consumption of the offices.

Factors	Overall weight	Order of importance
Quay length	0,06	4°
Storage area (patio area)	0,06	4°
Capacity to receive large vessels	0,05	5°
Size and maximum capacity use	0,04	6°
Technological level	0,10	1°
Automation level	0,09	2°
Intermodality level	0,09	2°
Lines which stopover in the port	0,07	3°
Quality management, security and health systems	0,06	4°
Total energy consumption (primary energy)	0,04	6°
Energy consumption on the part of the containers	0,01	9°
Energy consumption of the internal fleet of vehicles	0,04	6°
Energy consumption on the part of the offices	0,01	9°
Energy consumption on the part of the light system	0,02	8°
Energy consumption on the part of the team dedicated to the containers movement (cranes, etc.)	0,03	7°
Use of renewable energy	0,01	8°
Energy management system	0,02	8°

Environmental management systems	0,04	6°
Waste management	0,03	7°
Water management	0,02	8°
Emissions to air	0,03	7°
Noise pollution	0,03	7°
Leaks and spillages of substances into the sea	0,05	5°

Table 5: Overall weights of the factors which influence in a SP. Source: Authors.

4.- DISCUSSION

The literature submit different studies highlighting priorities of the port sector with regard to the operational, energy or environmental area, as well as the studies about which aspects are most important by the economic operators or other entities in this decision making about a port. The present study goes one step further and it focuses on determining which factors would be the most important for a container port to be close to the SP concept. For this reason, it considers factors in the operational, energy and environmental areas and it is based on the sector expert's opinion.

The technological level is the factor which determines the SP configuration, followed by the automation level. This is in accordance with different studies which are in the literature, in so far as these establish as key factors of the competitiveness of a port the "cost", the "operating efficiency", the "internal productivity" or "the operation times" which could be linked to a high technological and automation level. Additionally, all of this is aligned to the latest international trends in the sensing and the big data area.

The intermodality is configured as one of the key factors. It reflects that the ports should not be considered isolated nodes in the logistics chains, but part of them, contributing to its optimization. This can be accomplished mostly based on technology and the automation, essentials to achieve the synchronization necessary between the different means of transport.

The factors relating to the environment and energy are pushed with regard to the operational factors in the Framework of an SP. This is in accordance with the perception of the sector in general, reflects in the conclusions of the reference [3].

Is the factor "Leaks and spillages of substances into the sea" the most important in this area, but always behind the operational factors. The emissions to air are considered a key aspect in the maritime operations. However, they are to be found explicitly in a seventh place in order to his importance in the SP concept. In any case, undoubtedly, is an aspect implicit in the implementation of an environmental management system (factor with the sixth place in the table 4). Despite of the existence of studies which determine the energy consumption of the refrigerated containers as relevant, at the level of an SP; this factor has not been specially emphasized by the experts. In any case is essential that the present study takes place periodically, not only for the evolution which can experiment the SP concept, but for the changes which may take place on the importance perceived by the experts about the determining factors.

Through the validation it has been established that the factors are not as close as it seems to indicate to implement AHP, but in fact they exist different groups which the expert participants discriminate. Additionally, has allowed checking the validity of contents based on the proximity of the factors in the scale.

The general conclusions are alienated by others reached in initiatives as [12] where the Operational Area are better valued against the Energy and Environmental areas and it obtained greater significance the technological level and the factors related to the infrastructure management.

The outcome of the present study is of high interest for those ports that aspire to become SP, as it provides relevant information to establish the strategic plan which allows them to reach this objective.

As the main limitation of the studio it should be stressed that it is focused on the port activity in relation to the goods transported in containers in the Mediterranean. On the other hand, AHP make it possible to reach a prioritisation based on a thorough analysis of the problem and the knowledge, experience and experts opinion, with the limitation that entails.

The use of a regression analysis or structural equation modelling could contribute to know better the causal relationships among the factors of the SP concept.

As other future work lines it intends to extend the study to contemplate the overall activity of the ports, and not only in relation to its activity associated to the container traffic. Additionally, should be considered the inclusion of other areas which we sense as very influential in the SP concept, as the socio-economic, using the weights obtained for each factor, in order to define a mathematical function to facilitate the calculation of the SP index for each port.

FOR DEEPER KNOWLEDGE

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