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Application of a model based on the use of DELPHI methodology and Multicriteria Analysis for the assessment of the quality of the Spanish Dry Ports location

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Abstract

Not all the potential of Dry Ports is used because there is no planning methodology to help decision-making. The aim of this research is to provide a decision-making methodology based on the use of DELPHI methodology and Geographic Information Systems. Firstly, all the factors influencing the choice of Dry Ports are compiled and the weightings of each factor are set using the DELPHI methodology.The results give greater importance to the aspects considered in the classical theories of industrial location. However, setting the most appropriate location to place a Dry Port is a geographical multidisciplinary problem, with significant economic, social and environmental implications. With this data, we present a practical case consisting of an evaluation of the location quality of Spanish Dry Ports based on the result of DELPHI and Geographic Information System Transparencies Method which use a linear weighted Scoring Multicriteria Decision Analysis.

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Keywords: Logistics; Intermodal Transport; Sustainability; Dry Ports; Industrial Location

1. Introduction

Dry Ports are designed as a solution to increasing road congestion, lack of open spaces in port installations and the significant environmental impact of seaports, due to the complexity of the transport sector and the increased volume of transported goods (Camarero and González, 2005; Rodrigue, 2006). In addition, Dry Ports are also

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presented as an opportunity to strengthen intermodal solutions as part of an integrated and more sustainable transport chain for transporting goods by rail (Roso, 2009).

There is also a widely held view that the railroad is the most sustainable inland transport and its use should be increased (González et al., 2012; HesseandRodrigue, 2006; Roso, 2008; Rodrigue et al., 2009). That way, Dry Ports are also presented as an opportunity to strengthen intermodal solutions as part of an integrated transport chain. In this sense, implementation of logistic platforms offers the opportunity to discretize each of the links of the transport chain. Thus, more polluting means of transportation, which have a lower transport capacity, can make several itineraries on the road which are as short as possible (Roso, 2007).

The competition of the different modes of transport and the difference in the interests of the various stakeholders involved in the Dry Ports have led to a situation of disorder in the distribution of goods that reflects the need for a referee in the planning of these facilities and a decisive commitment to rail freight transport, even with separate infrastructure from passenger transport (Roso, 2008). However, until now, there has not been a suitable tool for planning the location of nodal exchange infrastructure in generaland particularly for Dry Ports.

2. Territorial planning and infrastructure planning models

The decision between purely technical considerations and the project costs has traditionally been made by means of Cost-Benefit Analysis (Aparicio, 2010). Since the last decades of the 20th century, the environment as a variable has gained importance in the planning and construction of transportation. An Environmental Impact Assessment was added to the Cost-Benefit Analysis, which contributed decisively to the formalization of a decision-making system based on the use of multi-criteria analysis systems (Forester, 2008). While some of these effects are sometimes included within the Cost-Benefit Analysis or contained within the Multi Criteria Analysis, there is still a lack of systematic analysis (Aparicio, 2010). The effects on the territory therefore become the most uncertain aspect of major transport infrastructure. There are also some newer techniques that attempt to solve the problems of localization. The most important that have been implemented are: Cluster analysis, Classification Trees and Decision Trees, Future Scenario Analysis (Simulation), DELPHI, Expert Systems (Bayesian Networks and Neural Networks) and Geographic Information Systems (Soler, 2013).

2.1. DELPHI methodology

In this paper we use a DELPHI method to establish the weights of each of the factors that have an influence when deciding the location of a Dry Port. The DELPHI method is based on the analysis of the ideas of a group of experts who are specialized in a field of knowledge in search of a consensus of opinion (LinstoneandTuroff, 1975). As a result of the weights, we present here an analysis of the location of Spanish Dry Ports with the results of weights obtained using the DELPHI method.

2.2. Multicriteria Analysis

In this paper, we present a method to consider decision problems with multiple objectives with quantitative information. These problems can be solved with Multicriteria decision analysis.

In our research, we decided to use a Scoring methodology based on a Multicriteria decision analysis whose structure algorithm is:

$$S_j = \sum w_i \cdot r_{ij} \qquad (1)$$

whereS_j are the scores of each alternative, w_i are the weights of each factor and $r_{ij}$is the rating of each alternative according to different variables. Equation (2) shows the algorithm used in the research.

3. Dry Port location

Movement of goods and freight distribution are widely underrepresented in regional science and geographical research (Hormigo, 2006). This is surprising since a large body of traditional spatial theory was developed with respect to transportation costs or to trade areas: those aspects that were originally closely connected with the exchange of goods. More attention is now being paid to these related subjects in geography (HesseandRodrigue, 2004) and the progress of the theory has been evolving with the changes in economic theory.

In most analysis of the implementation of a new infrastructure or incorporating technical improvements in the transport system, it is usually assumed that a number of positive effects, both socially and economically, will happen. Consequently, it is usual to analyze the transport policy as a relatively autonomous policy, ignoring the broader territorial context in which it is applied.

Obviously, the development of transport has produced changes in location patterns. Thus, industrial locations have evolved in parallel with the development of transport, from industrial stages marked by the location in ports and along navigable rivers, to more flexible locations because of the railways. In recent times, other transport (motor vehicles, aviation) have generated a more autonomous industrial location and decentralized (Pons, 2008). According to Brown (2005), there is the need to achieve a situation that has the best accessibility to and from the centers of origin and destination of the various flows, which is achieved by means of the connection with the transport and communication systems. Good accessibility means access to wider distribution markets (access to a greater number of suppliers and distributors) and new niche market. Also assumes savings of time and costs producing a higher productivity and increasing competitiveness (Camarero et al., 2007). Therefore, industries are generally located near transport facilities. It can be said that accessibility increases around major urban centers and decreases as distance increases.

As proposed by Rodrigue et al. (2009), Dry Ports exert a significant influence over neighboring land uses. This is due in part to the intense linkages they generate with other urban functions, but it is also due to externalities that are frequently negative. Thus, industrial land is commonly associated with terminal sites, which are among the most important industrial zones in a city. Inland terminals in many cases have witnessed a clustering of logistics sites in the neighboring; leading to a process of logistics polarization and the creation of logistic zones (Hormigo, 2006).

In addition, these terminals must have the least impact on people, with minimum disruptionand minimizing lifestyle changesand always seeking the welfare of the community. So, this planning process requires taking into consideration the possible impact on the territory (Quijada-Alarcón et al., 2012).

4. DELPHI questionnaire

Following the literature review summary in the preceding section, it was possible to identify the factors that influence the determination of location of Dry Ports in terms of their characteristics and assess the constraints faced by the location. Furthermore, as proposed by Azcárate (2007), in the design of a methodology for location of an unwanted plant, a series of steps are carried out: 1. Exclusion phase: define a set of exclusion criteria, 2. Definition phase: the definition of a set of factors that allow us to measure the adequacy of the different places that have passed the previous restriction criteriaand 3. Selecting assessment phase.

In this paper we only consider factors related to the use of restrictions which correspond to the phases of exclusion and definition. These factors are presented in Table 1.

The DELPHI questionnaire results show the importance of several variables that this study proposed for the exclusion and definition phases of the problem of Dry Port location.

Table 2 shows the final results of the DELPHI questionnaire. These results are represented in Fig. 1.Awad et al. (2013) present a detailed analysis of the DElPHI questionnaire result.The most important factors indicated are related to the accessibility of the facilitiesand present a near-consensus. In particular, the most important factors considered by the expert panel are: accessibility to the rail network, accessibility to high-capacity main roads and accessibility to seaports. However, accessibility to airports was hardly given any importance. Also, the experts reached the least agreement on this factor after the second round.

Table 1. Factors related to the use restrictions.

no.	Factor name	Observations
*	Environmental Protection	Binary variable automatically discarded protected areas
1	Noise on natural environment	Noise level measured in dB (A) on the natural environment
2	Noise on urban environment	Noise level measured in dB (A) on the urban environment
3	Hydrology	Presence of vulnerable areas such as rivers, streams or lakes
4	Land price	Measurement of investment to make
5	Hosting municipality range	Considering the size of the municipality, the future development of urban centers and centers nearby and the demographic and economic potential
6	Accessibility to the rail network	Accessibility to freight and passenger transport networks
7	Accessibility to high capacity roads	Accessibility to high-capacity motorway networks
8	Accessibility to airports	Accessibility to air cargo terminals
9	Accessibility to seaports	Connection with one or more Seaports
10	Accessibility to supplies and services	Accessibility to communication networks and the electrical grid and any other necessary utilities such as water, sanitation, etc
11	Weather	The climate's appropriateness for the activities in the greatest number of days per year.
12	Orography	The orography is used to understand the topographic relief of the area on which the facility is located. This factor is commonly used to plan infrastructure s.
13	Geology	Mechanical characteristics of the land on which the facility is located
14	Distance to other logistics platforms	Overlap between hinterlands and the agglomeration of industries

Table2. Delphi questionnaire results.

	First round results			Second round results		
Factor number	Arithmetic Mean (R1)	Median (R1)	IQR (R1)	Arithmetic Mean (R2)	Median (R2)	IQR (R2)
1	4.80	5.00	3.25	5.00	5.00	1.00
2	6.30	7.50	3.25	7.05	7.25	1.63
3	5.80	6.00	2.25	6.08	6.00	1.63
4	6.80	7.00	4.00	7.10	7.00	1.25
5	5.40	5.00	3.25	5.30	5.00	1.00
6	9.05	10.00	0.25	9.85	10.00	0.00
7	9.05	10.00	1.25	9.75	10.00	0.25
8	6.15	5.00	3.25	5.75	5.00	2.00
9	8.95	10.00	1.25	9.58	10.00	1.00
10	7.60	8.00	2.00	7.88	8.00	0.63
11	4.05	3.00	2.00	3.35	3.00	1.00
12	5.20	5.00	3.25	5.18	5.00	0.88
13	4.84	5.00	4.00	5.03	5.00	1.63
14	7.90	8.00	1.25	8.05	8.00	0.00

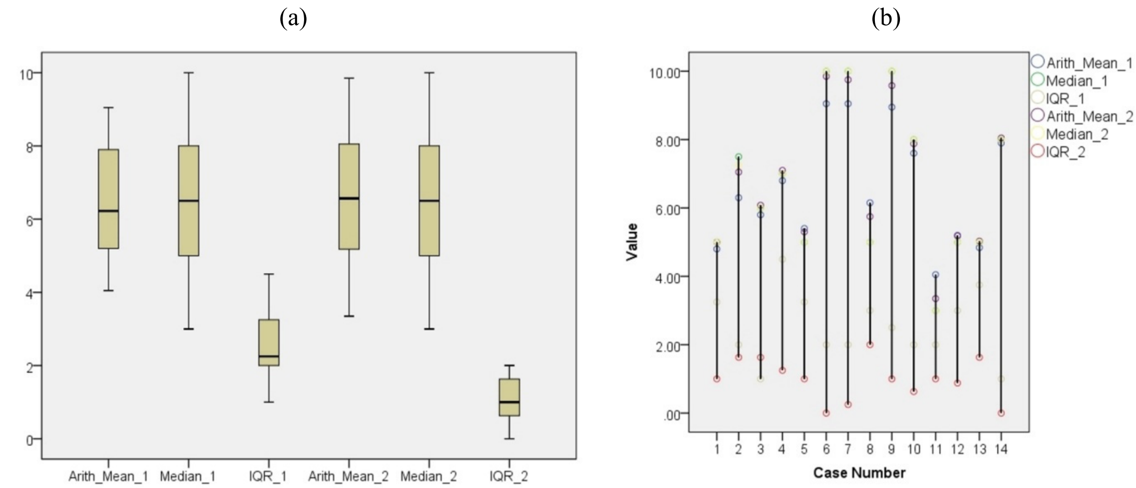

Fig 1. (a) Mean value and 95% CI deviation on weights Arithmetic Mean, Median and Interquartile Range of the first and second rounds. Source: Based on information gathered by the author. (b) Deviations above the Arithmetic Mean, Median and Interquartile Range comparing the results of the first and second rounds. Source: Based on information gathered by the author.

5. Case study: Spanish Dry Ports. Synthesis of results and discussion

Using the weights obtained from the DELPHIquestionnaire and applying them to Equation (2), we studied the quality of the location of the existing dry ports in Spain.

$$LQR_i = EP \cdot \sum(CAS_{ik} \cdot w_k) \quad (2)$$

where LQR_i is the Location Quality Rate for each location, EP is the binomial function "Environmental Protection" to eliminate the protected areas (Yes = 0, No = 1), CAS_{ik} are the Criteria Assessment Score of each factor and location and w_k are the weights of each factor. Thus, the case with a higher LQRvalue is the most appropriate for solving the problem.

Table3.Existing Dry Ports name and location.

Code	Dry Port name	Location
I	PS Antequera	Antequera (Andalucía)
II	PS Santander-Ebro	Luceni (Aragón)
III	ZAL Azuqueca A-2	Azuqueca de Henares(Castilla La Mancha)
IV	PS La Robla	La Robla (Castilla y León)
V	PS Toral de los Vados	Toral de los Vados (Castilla y León)
VI	PS Villafría	Villafría (Castilla y León)
VII	PS Venta de Baños Ventasur	Venta de Baños (Castilla y León)
VIII	PS Monforte de Lemos	Monforte de Lemos (Galicia)
IX	PS Madrid	Coslada (Comunidad de Madrid)
X	PS Abroñigal	Madrid (Comunidad de Madrid)

As can be seen in Table 3, most of the Spanish Dry Ports are located in the centre (n=3) and north (n=6) of the country. However, this distribution should not be understood as an absence of logistics facilities in the rest of the country.

In this paper, we decided to study only the Dry Ports with a specific name. Future research should include all the logistics facilities being Dry Ports but while taking other denominations.

We obtained an Assessment Criteria Score of each factor and location using the following conditions:

Noise scores are better for longer distances to protected natural media and urban areas. However, in this study we do not establish a minimum distance because it is a comparison between the distances presented by different Dry Ports.

Regarding hydrological conditions, high scores are obtained for locations far away from surface water courses, no aquifers in the environment and areas without potential risk of flooding.

Locations with a moderate price are of special interest because they reduce investment costs. However, cheaper land is often less accessible to other infrastructures. Therefore, we must reach a trade-off between not choosing cheaper ground but the location where the total land price and construction of access facilities is minimized.

In the case of Hosting Municipality Range a large population is valued positively because it will be an advantage for the demand of the goods stored in the Dry Port and availability of manpower. However, population density can also have a negative value for a Dry Port neighborhood because a high density is assumed to affect more people.

In assessing already built Dry Ports locations, we find that several of the examples presented here have rail, road and other service networks that have been developed in parallel with the construction of the facility.

To assess rail accessibility we took into account many different measures: type of access, number of tracks on the beach access, population of municipalities that are accessed directly by rail, proximity to an important railway junction, if bulk distribution shares the infrastructure with passenger transport, if the track is electrified and if the track is double or single. The best scores were obtained for locations with direct access, closer to railway junctions and best features of the track.

Accessibility to roads was also taken into account: type of road access (conventional, turnpike, highway), distance to the nearest highway, number of lanes of the access road, Average Daily Traffic (ADT) and Level of Service (LOS) of the path. The best locations have direct access to routes with good infrastructure conditions and a level of service that allows heavy vehicles to circulate efficiently.

Accessibility to airports is interesting because of the synergies that can occur with air cargo terminals. This is measured by the distance to the nearest airport, with the shortest distance having a higher value.

Accessibility of seaports was measured by the distance to the nearest Seaport and the number of ports at a distance not less than 200 Km or greater than 400 km. This distance was selected based on studies by (CAI, 2011 and Atlantic Transnational Network, 2006).

To evaluate climate the following factors are taken into account: climatic characterization, rainfall average, temperature deviation to 20° C, days with snowfall and wind speed average.

Topography is related to slope. We are interested in outstanding locations with very low requirements for rail freight transport. A flat location that requires very little ground preparation makes construction work cheaper. Geological factors must also be taken into account and this involves evaluating three steps: the nature of the material forming the floor of the area, excavability and compression strength.

The distance to other logistic platforms offers the possibility to assess the relationship between the Dry Port and the rest of the logistics system in the country. The hinterland concept can be extended to all logistics platforms. Adapting Notteboom (2002) for Dry Ports, the competitive hinterland reflects a place where a terminal competes with other terminals. Competitive hinterland is an area of a market where a port is forced to compete with other competitors in order to attract traffic and its market share. Obviously, the quality of services provided and charges to port are the main success factors in this hinterland. However, this system can generate a competitive geographic location disordered system that prioritizes economic management over other factors (Monios, 2011). In this sense, it is better to go to a collaborative-competitive model that generates economies of density, focus on spatial coverage and proximity. For Rodrigue et al. (2009), a core issue is the benefits derived from market density so that the same customer base can be reached (or serviced) with shorter distances and thus with fewer facilities. In such a circumstance, the location strategies are based on the relation with existing facilities, even if this implies the selection of sub-optimal locations.

Therefore, we are interested in locations that minimize the number of close logistics platforms (to control competition) and maximize the number of distant logistics platforms (integrating the entire collaborative logistics system).

Table 4 shows the results from the measurements discussed above. It is evident that the best locations are Villafría (Burgos), Abroñigal (Madrid) and Coslada (close to Madrid), mainly because of advantages in variables related to accessibility by rail, highways, seaports and a good relationship with the rest of the country's logistics system.

Table 4.Criteria Assessment Scores of each factor and location.

			DRY PORT											
	No.	w_k	I	II	III	IV	V	VI	VII	VIII	IX	X	Mean	IQR
FACTORS	1	5.00	0.74	0.10	1.58	10.00	5.45	1.39	1.58	0.00	3.47	6.04	3.03	4.50
	2	7.25	4.10	0.00	0.00	3.00	3.00	4.26	5.74	10.00	3.28	0.00	3.34	3.50
	3	6.00	4.93	1.00	3.06	0.00	8.20	5.93	2.34	10.00	4.55	4.55	4.46	3.40
	4	7.00	4.25	5.18	6.50	10.00	10.00	9.85	9.49	8.97	0.00	0.00	6.42	5.40
	5	5.00	6.76	0.00	3.06	4.50	4.45	10.00	3.91	5.57	2.26	5.70	4.62	2.30
	6	10.00	6.15	3.85	7.31	4.62	0.00	5.77	4.23	1.54	9.62	10.00	5.31	3.40
	7	10.00	3.82	3.42	10.00	3.82	4.61	9.21	4.87	0.00	9.74	9.47	5.89	5.70
	8	5.00	5.21	7.12	7.40	7.12	0.00	10.00	5.83	0.33	9.49	8.81	6.13	3.40
	9	10.00	8.33	8.33	0.00	8.33	10.00	5.00	5.00	8.33	0.00	0.00	5.33	7.10
	10	8.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	0.00
	11	3.00	10.00	9.00	7.20	3.00	6.40	5.80	7.20	0.00	7.40	7.40	6.34	1.50
	12	5.00	10.00	10.00	8.33	5.00	0.00	8.33	10.00	8.33	10.00	10.00	8.00	1.70
	13	5.00	7.74	0.90	0.00	8.91	1.16	0.28	0.63	0.28	10.00	8.91	3.88	8.60
	14	8.00	0.00	4.74	8.70	6.25	5.85	10.00	5.99	4.60	7.73	8.05	6.19	3.00
TOTAL(WITHOUT WEIGHT)			82.04	63.64	73.15	84.55	69.11	95.82	76.80	67.95	87.53	88.94	78.95	16.67
POSITION			5	10	7	4	8	1	6	9	3	2	-	-
SCORE (MÁX 140)			58.60	45.46	52.25	60.39	49.37	68.44	54.86	48.54	62.52	63.53	56.39	11.89
TOTAL(WITH WEIGHT)			534.37	433.80	510.04	576.05	488.29	662.62	522.30	483.36	584.71	585.97	538.15	88.82
POSITION			5	10	7	4	8	1	6	9	3	2	-	-
SCORE (MÁX 942.50)			56.70	46.03	54.12	61.12	51.81	70.30	55.42	51.29	62.04	62.17	57.09	9.42

The maximum score of the location of a Dry Port is 942.50 points. The maximum location score obtained is 70.30% of the points, with a huge advantage to the following locations. The average score is 57.09%, which means that the location of the Dry Ports has not been very successful until now. However, the low IQR value shows that the location quality is rather constant. These results show a lack of sensitivity by social and environmental factors. The total score of evaluating all the factors related with accessibility was jointly around 65.30% (64.17% using weights). This result would be even lower if the accessibility of the service networks was not taken into account. We conclude that the availability of the location of Dry Ports in Spain must be improved, especially in relation to rail networks, high capacity roads and seaports.

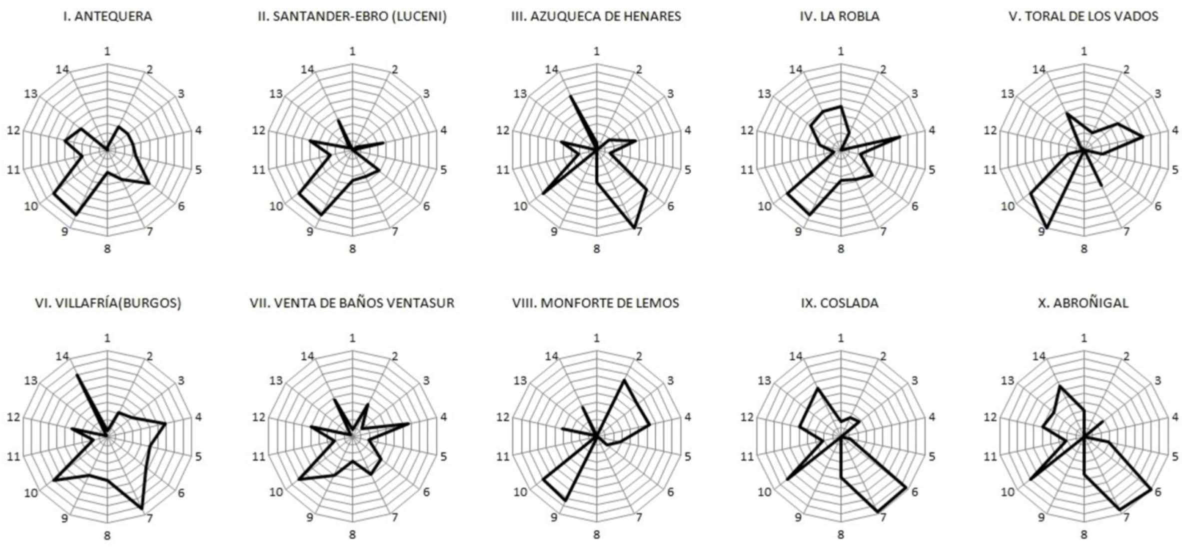

Fig.2. Results from the study after affect scores with weights

The results presented in Table 4 were given in the axis graphs as shown in Fig.2. These graphs represent the values of each variable along a separate axis that starts in the centre of the graph and ends at the outer ring. Axis graphs show changes in values relative to the centre point, making them especially useful for comparisons. They also show very clearly the strengths and weaknesses of each location. These diagrams do not have a geometric interpretation. That is, the inner area of the figure and the comparison must be made factor by factor because each variable has a different scale and is affected by a weight. However, by superimposing two or more of these diagrams, we obtain the strengths and weaknesses of one location over another.

Thus, we can establish preferences at the national level for the desirability of a location over another. Nevertheless, it is evident in the corresponding figures of Abroñigal and Coslada, with a distance of less than 10 kms, that it is difficult to establish a difference when the diagrams represent locations too close to each other.

6. Conclusions and future research

In this paper we have tried to convey the idea that the decision on the most appropriate location for Dry Ports is a geographic and multidisciplinary problem. It involves economic, social and environmental issues.

The results of the DELPHI questionnaire show that in the search for the location of a Dry Port, great emphasis is placed on the aspects considered in classical theories of industrial location. However, we should not lose sight of other aspects since no factor is so unimportant as to justify its exclusion. In this way, the results help to achieve sustainable development, yielding more satisfying locations in comparison to the ones when only using the aspects considered in classical theories.

An assessment of Spanish Dry Ports location was performed from the weights obtained for each factor in the DELPHI questionnaire. The DELPHI questionnaire enabled us to assess the quality of each location and to perform a national comparative study among the various locations.The evaluation shows that the location of the current Spanish Dry Ports has only a medium quality. Moreover, the spatial distribution of Dry Ports, mostly located in selected Autonomous Communities, seems to cater more to political decisions rather than technical criteria.

This is because there is no easy and clear planning methodology to help decision-making. There should be policies in place to generate a collaborative-competitive logistic model with the factors considered in this paper.

From the observed data about accessibility, we also conclude that the availability of the location of Dry Ports in Spain must be improved. So while Dry Ports are also presented as an opportunity to strengthen intermodal solutions as part of an integrated and more sustainable transport chain for transporting goods by rail, not all of its potential is used.

The presented methodology is a tool with great potential to assess the quality of the location of Dry Ports in a region and to establish strategies for national logistics systems. This in turn should help with the development of political policies.

Also, by incorporating a large number of factors this has meant simplifying the effect of each factor. Future research may include a detailed study of the effect of each of these factors. Other research may take into account all factors to develop the “selecting assessment phase” of Azcárate (2007), considering not only factors related to the use restrictions which correspond to the phases of exclusion and definition.

Furthermore, Scoring methodology is based on the establishment of the relative weight of each factor. The weights obtained through the DELPHI questionnaire are slightly arbitrary. So, future research will achieve more accurate weights. This aim is possible using an Artificial Neural Networks paradigm.

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