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A methodology for measuring sustainability of dry ports location based on Bayesian Networks and Multi-Criteria Decision Analysis

Samir Awad-Núñez*[,a], Nicoletta González-Cancelas[a], Francisco Soler-Flores[b], Alberto Camarero-Orive[a]

[a]*Department of Transportation, Technical University of Madrid, Spain*
[b]*Dept of Mathematics and Computer Science applied to Civil and Naval Engineering, Technical University of Madrid, Spain*

Abstract

The decision of where to locate a dry port requires the analysis of the whole logistics supply chain, with the objective of transferring the largest volume of goods possible from road to more energy efficient means of transport, like rail or Short Sea Shipping, that are less harmful to the environment. However, such decision ought to cope also with the sustainability of the site inland. The objective of this article is to investigate the variables influencing sustainability of dry port location and how this sustainability can be evaluated. We propose a methodology based on Multi-Criteria Decision Analysis (MCDA) and Bayesian Networks (BNs). MCDA is used as a way to establish a scoring, whilst BNs were chosen to eliminate arbitrariness in setting the weightings using a technique that allows us to prioritize each variable according to the relationships established in the set of variables. In order to determine the relationships between all the variables involved in the decision, giving us the importance of each factor and variable, we built a K2 BN algorithm. To obtain the scores of each variable, we used a complete cartography analysed by ArcGIS. As case studies, the sustainability of all of the 10 existing dry ports in Spain has been evaluated. In this set of logistics platforms, we found that the most important variables for achieving sustainability are those related to environmental protection, so the sustainability of the locations requires a great respect for the natural environment and the urban environment in which they are framed.

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Keywords: Dry ports; Industrial location; Sustainability; DELPHI; Bayesian Networks; Multicriteria Decision Analysis; Geographic Information Systems

* Corresponding author. Tel. +34 91 336 6657
E-mail address: samir.awad@caminos.upm.es

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1. Introduction

The global economic structure, with its decentralized production and the consequent increase in freight traffic all over the world, has led shipping to become the most suitable and cheapest way to transport goods. Ports are nodes of critical importance in the logistics supply chain as link between two transport systems: the sea-side and the land-side (Nuzzolo et al., 2013). The growth of the activities at seaports is producing three undesirable effects: increasing road congestion, lack of open space in port installations and a significant environmental impact. These adverse effects can be mitigated by moving part of the activities inland. In this respect, the implementation of dry ports is a possible solution and would also provide an opportunity to strengthen intermodal solutions as part of an integrated and more sustainable transport chain, acting as a link between road and railway networks. Moreover, it allows the separation of the links of the transport chain, thus facilitating the shortest possible routes for the lowest capacity and most polluting means of transport.

The dry port concept is based on moving intermodal terminals further inland from the port areas (Jaržemskis, A., Vasiliauskas, A. V. 2007). This logistics platform is presented as a solution to the most important problems arising from the accumulation of activities in port areas: increasing road congestion, lack of open spaces in port installations and the significant environmental impact of seaports (Rodrigue 2006).

Connecting cargo handling from the port to a logistics centre helps achieve a better port operation, which leads to a greater efficiency in ship operations (reduction in ship time in port) and to energy efficiency issues in shipping and, particularly, to operational issues such as the minimisation of fuel consumption and resulting greenhouse gas emissions (Moon, D.S.H.,Woo, J. K. 2014). It helps also to avoid traffic bottlenecks, which relates to a decrease in road and railway emissions. In addition, dry ports allow the separation of the various links of the transport chain. Thus, they are also presented as an opportunity to strengthen intermodal solutions as part of an integrated and more sustainable transport chain, allowing for the shortest possible routes for the lowest capacity and most polluting means of transport (Roso 2007; Regmi, M. B., Hanaoka, S. 2013).

All these conditions present dry ports as a solution that provides a more sustainable logistics supply chain. But while taking into account the sustainability of the logistics supply chain it is also necessary to ensure the sustainability of the site. The main goal of this article is to investigate the variables influencing the sustainability of dry port location and how this sustainability can be evaluated.

2. Factors influencing the location of dry ports

The diversity of factors involved in the location of industry has prompted economists over the last century to build models that try to explain the complexity of the real world. For Weber (1909), the main objective when deciding on the location for any industry is to reduce the transport and labour costs. Hotelling (1929) and Reilly (1931) include the presence of competitors. Christaller (1933) adds the “minimum demand threshold” in order for the location to be profitable. As a result of this threshold, the best locations are close to large population centres. But for Lösch (1940), the relationship between population size and type of industry is very important because the impacts on a big population density could lead to social problems. In 1979, Smith introduces the concept of “subtracted value”, which consists of the negative externalities that must be considered against the positive. According to Brown (2005), accessibility to and from the centres of origin and destination of the various flows should be maximised, which is achieved through the connection with the transportation and communication systems, generally located alongside transportation facilities forming hubs.

As can be seen, location problems are multi-objective problems and the implications on levels of economic growth, social welfare, environmental acceptability, accessibility and territorial conditions must all be taken into account. From the research of Pons (2008), and incorporating the elements described above, the set of variables of this study is presented in Table 1. These 41 variables are grouped into 17 factors which in turn correspond to 4 categories: environmental factors, economic and social factors, accessibility factors, and location factors (gathered in Table 1). The variables can be considered as either a Profit, when a higher value is better in geographical analysis, or a Cost, when a lower value is better, and where w_k are the weights of each factor and $W_{\overline{k}}$ are the weights of each variable.

Table 1. Factors influencing the location of dry ports

Category	Factor	w_k	Variable	Variable	Kind	$W_{\bar{k}}$
Environmental factors	Impact on natural environment	5.00	DNS	Distance to natural spaces	Profit	10.00
			CNE	Connectivity on natural environment	Profit	0.00
			NIS	Number of isolated spaces	Cost	9.10
			DFA	Density of the facility area	Profit	0.00
	Impact on urban environment	7.25	DUS	Distance to urban spaces	Profit	8.20
			CUE	Connectivity on urban environment	Cost	8.20
	Hydrology	6.00	DSW	Distance to surface water	Profit	7.30
			FL	Flooding level	Profit	7.30
			GP	Groundwater presence	Profit	6.40
Economic and social factors	Land Price	7.00	LP	Land price	Cost	7.30
	Potential Demand Growth	6.40	IPI	Industrial production index	Profit	6.40
			GDP	Gross Domestic Product	Profit	5.50
			EL	Employment rate	Cost	6.40
	Hosting municipality range	5.00	PL	Population level	Profit	4.60
			PD	Population density	Cost	5.50
Accessibility factors	Accessibility to the rail network	10.00	NRA	Number of railway accesses	Profit	5.50
			IRE	Importance of the railway environment	Profit	8.20
			CD	Centrality of demand	Profit	5.50
			QR	Quality of the railway	Profit	0.00
	Accessibility to high capacity roads network	10.00	DAHCN	Direct access to the high capacity network	Profit	4.60
			DHCR	Distance to a high capacity road	Cost	3.70
			NL	Number of lanes	Profit	3.70
	Accessibility to airports	5.00	DA	Distance to an airport	Cost	5.50
	Accessibility to ports	10.00	DP	Ports nearer than 400 Km	Profit	2.80
	Accessibility to supplies and	8.00	CSS	Currency of supplies and services	Profit	0.00
Location factors	Weather	3.00	CV	Climatic variety	Profit	5.50
			RL	Rainfall level	Cost	2.80
			WF	Winter frosts	Profit	2.80
	Orography	5.00	TC	Terrain curl	Profit	5.50
			SL	Slope	Cost	2.80
	Geology	5.00	EX	Excavability	Cost	8.20
			CS	Compressive strength	Profit	8.20
	Relation with other logistics platforms	8.00	NNLP	Number of nearby logistic platforms	Cost	1.90
			NMDLP	Number of middle-distance logistic platforms	Profit	3.70
			BICA	Belonging to an industrial consolidated area	Profit	1.00
	Integration into the main supply	5.50	DPFC	Distance to a principal freight corridor	Cost	5.50
	Potential optimization of the modal shift	5.05	DPPC	Distance to a principal passenger corridor	Profit	6.40
			NPT	Number of passenger trips	Cost	6.40
			NRADT	Nearest roads' ADT	Cost	1.00
			DTENT	Distance to the TEN-T Core Network Corridors	Profit	3.70

Impacts on natural and urban environments are better for longer distances to protected natural and urban areas. However, in this study is not established a minimum distance because it is a comparison between the distances presented by different dry ports. Impacts are also better when the land is cut the less as possible by the facilities.

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, must be reached a trade-off between not choosing cheaper ground but the location where the total land price and construction of access facilities are minimized.

The potential demand growth is measured by three economic values: Industrial Production Index, Gross Domestic Product and Employment Rate.

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, 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 are taken 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. Areas in which a port has noticeable contestable advantages is said to be the “captive hinterland”. Hinterlands are places in which a transport terminal and/or port, offers its services and deals with customers. The dry port location becomes a key issue when considering collaborative-competitive strategy of the logistics system of a country or region. By developing strong functional links with particular inland terminals a port might intrude in the natural hinterland of competing ports.

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. Outstanding locations with very low requirements for rail freight transport are required. 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. It is better to go to a collaborative-competitive model that generates economies of density, focus on spatial coverage and proximity. Therefore, 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), are preferable.

Integration into the main supply chain infrastructures is assessed by the distance to a principal freight corridor. The corridors taken into account are the important route of railway and roadway freight transport at the same time.

Location is a capital factor in adjusting the balance of the modal shift. The size of the potential transfer of road freight transport to the railway freight transport is measured by the distance to a principal passengers corridor, the number of passenger trips (in lines of mixed traffic), the nearest roads’ ADT and the distance to the TEN-T Core Network Corridors considered by the European Union.

3. Bayesian Networks and Multi-criteria Decision Analysis: a proposed mixed methodology

By triangulating different techniques we have established a methodology for assessing the sustainability of the location of dry ports that can also be used to evaluate their overall quality. To reduce the arbitrariness of the weightings of the Multicriteria Decision Analysis algorithm, we decided to use an Artificial Intelligence model based on Bayesian Networks that establishes the relationship between the variables for a given sample.

The proposed methodology has been developed with the following tasks (see Figure 1):

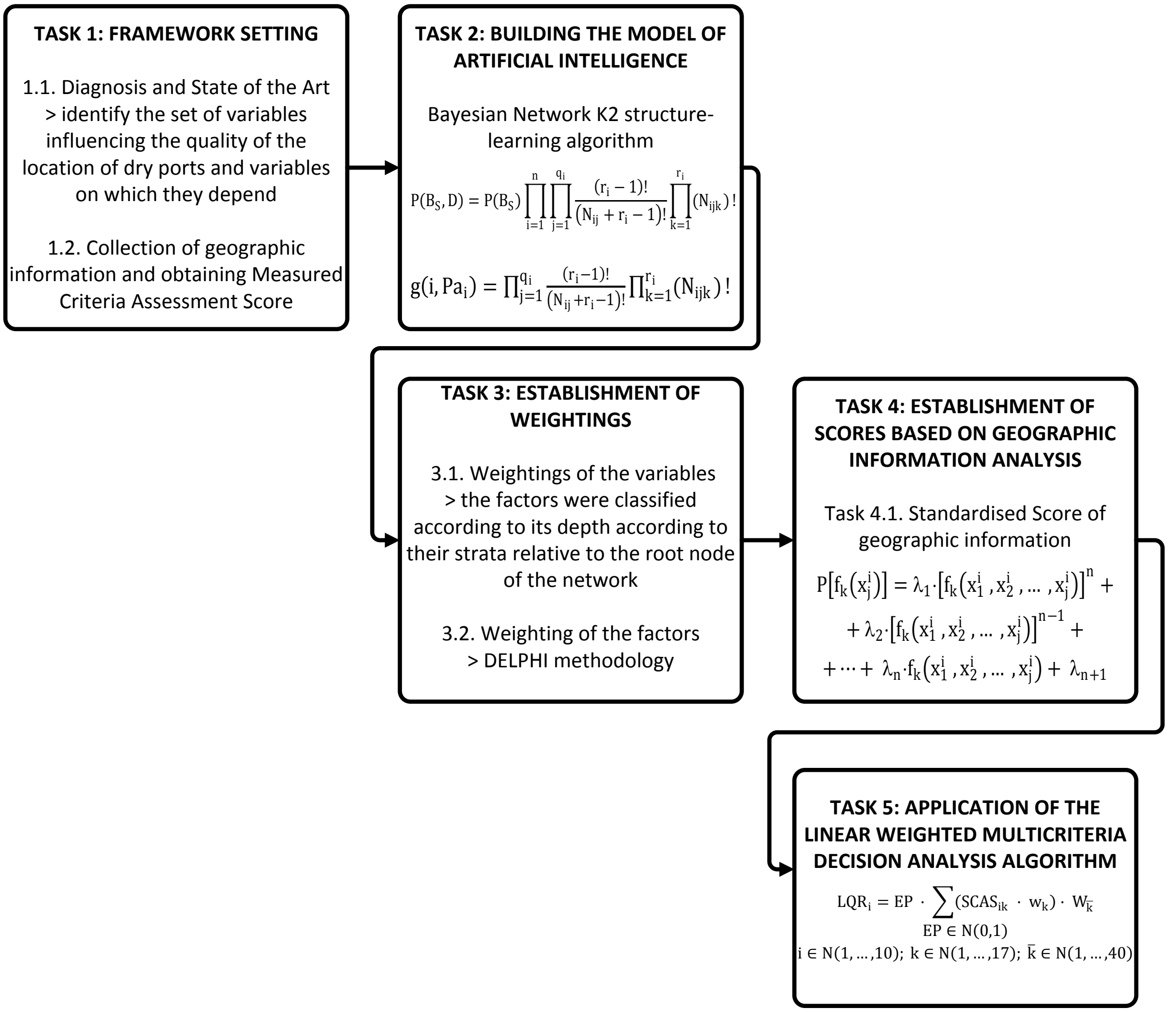

Fig 1. Schematic representation of the proposed methodology

Task 1: work setting

Task 1.1. Diagnosis and State of the Art: first step is reviewing the state of the art to identify the set of variables influencing the quality of the location of dry ports and variables on which they depend.

Task 1.2. Collection of geographic information: in this stage geographic information of each variable is gathered and entered in the Geographic Information System software.

Task 2: building the model of Artificial Intelligence

We have chosen to use Bayesian Networks for their ability to represent a causal model using a graphical representation of dependencies between variables that are part of the application domain. According to the type of structure of the data, different structure-learning methods can be applied. To build the Bayesian Network we chose a

K2 structure-learning algorithm (first equation in box of Task 2 in Figure 1), because it allows the variables to be ordered. This way, the network can be stratified.

In this kind of algorithm, all structures are equally likely at the start. The K2 algorithm begins by assuming that a node has no parents and at each step incrementally adds that node's parent whose inclusion increases $g(i, Pa_i)$. For each node, the algorithm searches for the K2 parents that maximize $g(i, Pa_i)$.

Task 3: establishment of weightings

Task 3.1. Weightings of the variables: to obtain the weighting of each variable, the factors were classified according to their strata relative to the root node of the network, and thresholds were defined based on the "depth" of the factor within the network.

Task 3.2. Weighting of the factors: these are established by applying the DELPHI methodology. It is based on the analysis of the ideas of a group of experts in the search for a consensus of opinion. Owing to the length limits of this document, it is advisable to look in the full working document for more information on any particular theme about the conducted methodology in Awad (2014).

Task 4: establishment of scores based on Geographic Information Analysis

Each variable is graded according to the value of geographic information, obtaining a Criteria Assessment Score. This value was normalized using a spline. Depending on the grade of the spline, there were 3 different kinds of boundary conditions. The kind of interpolation is selected by minimizing the distance between the Measured Criteria Assessment Score (MCAS) and the Standardised Criteria Assessment Score (SCAS).

Task 5: application of the linear weighted Multi-criteria Decision Analysis algorithm

Using the weightings obtained in Task 3 and the Standardised Criteria Assessment Score of Task 4, and then from the equation in box Task 5 in Figure 1, the quality of the location of dry ports is obtained, where LQR_i (Location Quality Rate) is the ratio of the quality of each location; EP (Environmental Protection) is the dichotomous function "Environmental Protection", which serves to exclude protected areas (worth 0 for protected locations and 1 for locations without environmental protection); $SCAS_{ik}$ (Standardised Criteria Assessment Score) is the score of the evaluation criteria for each variable and location. Finally, w_k are the weightings obtained in the DELPHI questionnaire to fix the importance of each factor and the $W_{\bar{k}}$ are the weightings of each factor. The locations with a higher LQR value will be most appropriate for solving the problem.

4. Case of study: sustainability of the existing dry ports in Spain.

Spain is a country located in southwestern Europe. Its network infrastructure is constituted as a mesh with a substantially radial orientation center in Madrid, both on the road and in the railway networks of general interest of the State.

The road and railway networks used in this paper corresponds to the existing as of 31^{th} December 2012, since these are the last cartographies published by the Dirección General de Carreteras del Ministerio de Fomento (General Direction of Highways of the Ministry of Public Works) and ADIF (the public railway administrator). Similarly, all other variables measurements have been conditioned by this and their values are taken for 31^{th} December 2012.

In the country there are different types of logistics facilities. However, the criteria used to define them are not uniform, since there is a fuzzy threshold between different types of logistic infrastructure. Looking ahead to this paper states we define dry ports as those logistical facilities that direct connect to seaports by a railway line, allows the possibility of customs clearance at the terminal facilities and have permanent facilities. In this case of study, after characterizing the infrastructures, the factors and the variables, the sustainability and the quality of the locations of the dry ports is assessed developing the presented methodology of the previous section.

5. Results and discussion

Equation 2 requires the following inputs: 1) the weightings of each variable and factor and 2) the Standardised Criteria Assessment Score of each variable and location.

Using the geographic information of the 10 existing dry ports in Spain, a K2 algorithm Bayesian Network has been built. The result determines the relationship between all the variables involved in the decision. The network obtained is represented in Figure 2.

As can be seen, DNS is the root node of the whole network because no path enters it. By assessing the importance of each variable by depth compared with the root of the network, a certain weighting is set for each variable.

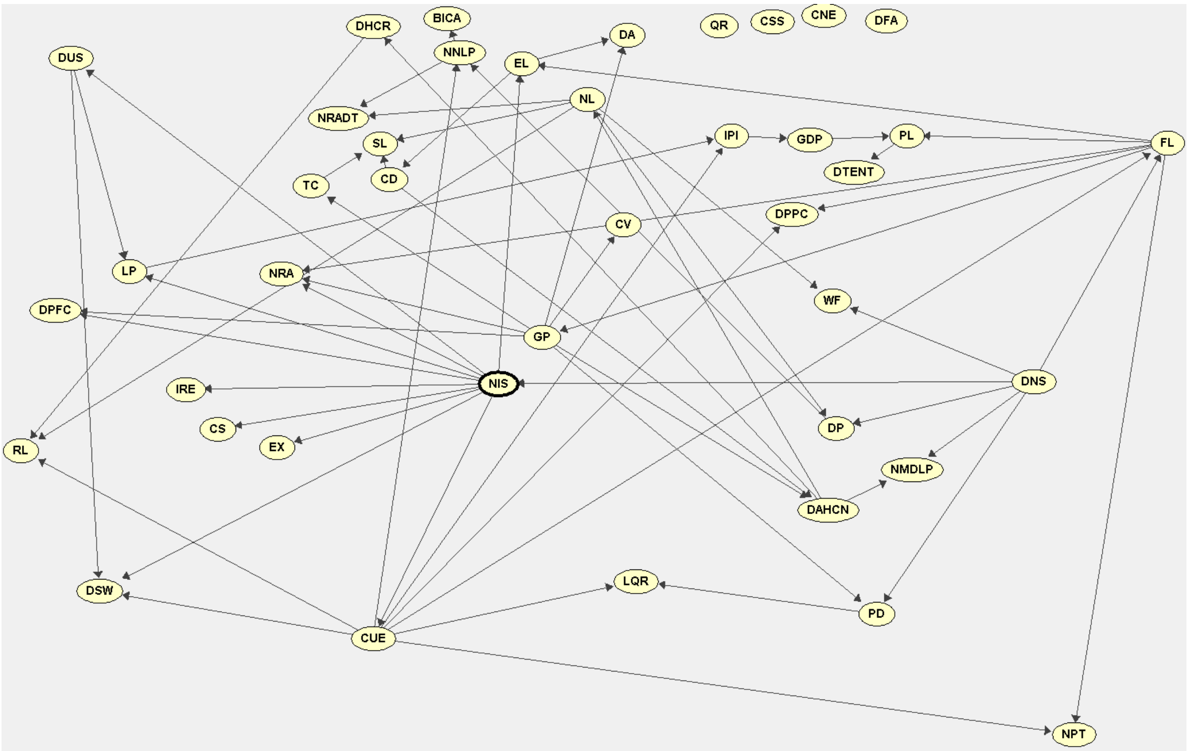

Fig 2. The network representing relationships between all variables involved in the decision using the K2 Bayesian Network algorithm.

Depth is related to the number of steps to reach DNS and the number of relationships between the evaluated variable and the other variables. As there are 11 layers: the layer 1 receives a weighting of 10; the layer 11, a weighting of 1; and intermediate layers, the corresponding linearly interpolated values. The variables that are outside the BN have a weighting of 0. Table 1 shows the weightings of the variables resulting of this procedure. The weightings of each factor are also compiled in this table. As shown in Awad et al. (2014), only 14 factors were employed, compared with 17 considered in this research. The weightings of the 3 additional factors were obtained through missing data analysis techniques (statistical inference), maintaining the weightings of the factors that are known and their importance as given by the questionnaire.

Applying Equation 3 with the weighting from Table 1 and the Standardised Criteria Assessment Score from the geographic information analysis using ArcGIS (see Table 2), we obtained the results reported in Table 3.

Each dry port presents a weighted score for each category: environmental, economic and social, accessibility, and location. Merging the results of the environmental, and economic and social variables, we obtained the sustainability of each dry port. Taking into account all the full set of variables, quality can be observed.

The most sustainable dry port is Monforte de Lemos, which scored well in terms of social and environmental factors and was balanced in the economic section, with 60.3% of the maximum possible score. Meanwhile, the least sustainable locations are Coslada, Abroñigal and Santander-Ebro, all of them with low social and environmental scores that are not compensated by the economic section.

For its part, Coslada has the best quality location if all the variables are taken into account, with 57.2%. These modest results show that both sustainability and quality of dry port locations in Spain is moderate. This can also be seen in the median values, of 41.3% and 48.8% respectively.

Analysing sustainability, scores in economic and social variables are much better than in environmental variables. As environmental variables appear to be the ones with the biggest weightings, this produces moderate sustainability ratings. Also the set of sustainability assessments of the locations has a standard deviation of 11.1%, so it can be considered that the quality of the locations is grouped around the central values.

Table 2. Compilation of Standardized Criteria Assessment Score

	Standardised Criteria Assessment Score									
Variable	I	II	III	IV	V	VI	VII	VIII	IX	X
DNS	1.5	0.9	2.3	10.0	5.8	2,1	2,3	0,8	4,0	6,4
CNE	0.0	0.0	0.0	0.0	0.0	0,0	0,0	0,0	0,0	0,0
NIS	0.0	7.5	5.0	2.5	2.5	7,5	5,0	5,0	0,0	0,0
DFA	10.0	10.0	0.0	0.0	10.0	10,0	10,0	10,0	10,0	10,0
DUS	2.5	0.0	0.0	2.0	2.0	0,0	3,5	6,1	2,0	0,0
CUE	6.7	0.0	3.3	6.7	8.3	0,0	3,3	6,7	0,0	0,0
DSW	0.8	2.0	1.6	0.0	0.0	4,6	4,7	1,8	9,1	0,0
FL	10.0	0.0	5.0	0.0	10.0	10,0	0,0	10,0	0,0	5,0
GP	0.0	0.0	0.0	0.0	10.0	0,0	0,0	10,0	0,0	0,0
LP	4.7	5.5	6.5	9.2	9.2	9,0	8,8	8,4	1,5	1,5
IPI	5.3	10.0	3.5	8.0	8.0	8,0	8,0	4,5	3,1	3,1
GDP	5.8	8.6	6.1	7.6	7.6	7.6	7.6	7.1	10.0	10.0
EL	0.0	4.5	4.7	3.5	3.5	6.5	4.6	5.1	5.6	5.6
PL	10.0	0.3	10.0	1.3	0.6	10.0	1.8	5.6	10.0	10.0
PD	9.4	9.6	0.0	9.5	9.1	0.0	5.5	9.0	0.0	0.0
NRA	10.0	3.0	8.0	10.0	8.0	10.0	5.0	5.0	10.0	10.0
IRE	6.0	2.0	4.0	6.0	6.0	2.0	8.0	4.0	10.0	10.0
CD	4.0	3.0	10.0	4.0	3.0	7.0	4.0	7.0	7.0	10.0
QR	10.0	10.0	10.0	10.0	5.0	10.0	10.0	5.0	10.0	10.0
DAHCN	0.0	5.0	10.0	5.0	5.0	10.0	5.0	0.0	10.0	10.0
DHCR	4.0	0.0	10.0	0.0	6.7	10.0	7.3	0.0	10.0	10.0
NL	10.0	10.0	10.0	10.0	10.0	10.0	10.0	0.0	10.0	10.0
DA	0.0	2.7	3.3	2.7	0.0	9.7	0.0	0.0	8.5	6.8
DP	8.8	8.8	2.5	8.8	10.0	6.3	6.3	8.8	2.5	2.5
CSS	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
CV	5.0	0.0	0.0	0.0	5.0	0.0	0.0	10.0	0.0	0.0
RL	4.5	6.9	5.5	2.3	3.3	4.5	5.5	0.0	5.6	5.6
WF	10.0	10.0	10.0	0.0	10.0	0.0	0.0	10.0	10.0	10.0
TC	10.0	10.0	10.0	2.0	2.0	10.0	10.0	2.0	10.0	10.0
SL	10.0	10.0	5.0	2.5	2.5	7.5	10.0	5.0	10.0	10.0
EX	6.4	0.4	0.0	8.3	0.9	0.4	0.0	0.4	10.0	8.3
CS	6.5	2.7	2.3	8.7	3.0	2.7	2.3	2.7	10.0	8.7
NNLP	8.0	5.0	0.0	6.0	0.0	3.0	2.0	8.0	0.0	3.0
NMDLP	2.8	5.9	10.0	7.0	7.0	10.0	6.0	5.0	10.0	10.0
BICA	5.0	10.0	10.0	5.0	5.0	10.0	5.0	5.0	10.0	10.0
DPFC	1.0	7.0	8.0	2.0	0.0	6.0	5.0	3.0	9.0	10.0
DPPC	8.6	2.9	6.4	4.7	7.3	3.7	0.0	6.7	4.6	1.7
NPT	8.9	4.0	6.6	7.8	9.1	7.9	5.5	8.7	7.2	0.0
NRADT	9.6	8.0	8.4	9.4	8.8	7.8	8.9	9.9	7.6	4.3
DTENT	10.0	5.0	10.0	10.0	5.0	0.0	10.0	10.0	10.0	10.0

I. Antequera; II. Santander-Ebro (Luceni); III. Azuqueca de Henares; IV. La Robla; V.Toral de los Vados; VI. Villafría (Burgos); VII. Venta de Baños (Ventasur); VIII. Monforte de Lemos; IX. Coslada; X. Abroñigal

By looking at the overall quality of the locations, we saw that dry ports have higher grades than 60% in accessibility and higher than 50% in location. However, as was the case for sustainability, these ratings are not able to pull up the overall rating because the environmental variables are the most weighted of the model. Again, we can say that there is little dispersion in the sample, in this case with a standard deviation of 6%.

Table 3. Multi-criteria Decision Analysis algorithm results

	Environmental		Economic and Social		Accessibility		Location		Sustainability		Quality (LQR)	
I	1091.2	32.1%	1152.8	52.7%	2025.0	55.1%	2224.2	67.8%	2244.1	40.1%	6022.0	48.0%
II	474.3	13.9%	1444.5	66.0%	1412.2	38.4%	1583.6	48.2%	1918.8	34.3%	4827.0	38.5%
III	827.5	24.3%	1116.3	51.0%	2679.9	72.9%	1839.0	56.0%	1943.8	34.8%	6174.5	49.2%
IV	1129.0	33.2%	1495.5	68.4%	2180.2	59.3%	1841.8	56.1%	2624.5	46.9%	6646.5	53.0%
V	1841.0	54.1%	1469.8	67.2%	2223.7	60.5%	1359.4	41.4%	3310.8	59.2%	6071.8	48.4%
VI	1085.3	31.9%	1548.9	70.8%	2741.3	74.6%	1561.6	47.6%	2634.1	47.1%	6297.6	50.2%
VII	953.2	28.0%	1423.9	65.1%	2197.3	59.8%	1363.8	41.6%	2377.2	42.5%	5732.5	45.7%
VIII	1928.2	56.6%	1445.4	66.1%	1233.0	33.6%	1635.4	49.8%	3373.6	60.3%	5341.2	42.6%
IX	719.2	21.1%	1017.7	46.5%	3257.7	88.6%	2622.8	79.9%	1737.0	31.1%	7217.0	57.5%
X	537.2	15.8%	1017.7	46.5%	3377.0	91.9%	2228.2	67.9%	1554.9	27.8%	6941.1	55.3%
Average	1058.6	31.1%	1313.3	60.0%	2332.7	63.5%	1826.0	55.6%	2371.9	42.4%	6127.1	48.8%
Median	1019.3	29.9%	1434.2	65.6%	2210.5	60.1%	1737.2	52.9%	2310.6	41.3%	6123.2	48.8%
Std Dev	373.2	11.0%	338.3	15.5%	662.2	18.0%	561.5	17.1%	623.0	11.1%	754.4	6.0%
Max	3404.0		2187.2		3675.0		3282.3		5591.2		12548.5	

6. Conclusions and future research

In this research we have tried to convey the idea that the determination of the most appropriate location to place dry ports is a geographic and multidisciplinary problem, with environmental, economic, social, accessibility and location repercussions.

Although the results of the DELPHI questionnaire show a greater importance in the search for the location of a dry port for the aspects considered in the classical theories of industrial location (accessibility to the rail network, accessibility to high-capacity main roads and accessibility to seaports), the DELPHI weightings are corrected according to the relationships established between variables by taking into account the Bayesian weightings. Ultimately, environmental variables prove to be the most important in deciding the location. Although four variables are unrelated to the rest of the network (Connectivity with the natural environment, Density of facility area, Quality of the railway and Currency of supplies and services), we must not lose sight of these variables in future evaluations since the lack of relationship is related to the inability to establish preferential relationships between them because their values are practically the same for all locations of dry ports in Spain.

A very important conclusion is that the satisfactory results allow us to confirm the great power of applying Bayesian Networks and Multicriteria Decision Analysis to the assessment of dry port location. In addition, the triangulation of different independent techniques provides greater confidence in the results, because the use of Bayesian Network and DELPHI methodology reduces the arbitrariness of the weightings of the Multicriteria Decision Analysis algorithm.

By implementing the Multicriteria Decision Analysis algorithm into a McHarg Geographic Information System, we will be able to develop a powerful decision-making tool. Furthermore, the versatility of the model will allow, with small changes in the variables, the location of other logistics platforms or NIMBY facilities other than dry ports.

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