ASSESSMENT OF THE COMPETITIVENESS OF INTERMODAL ROUTES FOR THE CASE OF THE SPANISH-FRENCH ATLANTIC COASTS

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ABSTRACT

The aim of this paper is to propose a tool to identify the most suitable maritime route (a priori) to articulate an intermodal transport chain able to compete with the freight road transport. This will be done through a case study: the choice of a pair of ports to articulate a Sea Motorway between the Atlantic coast of Spain and France. The analysis is carried out in terms of time and cost through a mathematical model which simulates the point of view of a loader that has been operating between these countries from 2006 to 2009. To evaluate the risk assumed with the choice of ports, we use a Monte Carlo simulation. Its results make it possible to identify the indexes more adjusted to the mean of the distribution simulated varying the values of the variables used to calculate them.

KEYWORDS

Maritime route choice; Sea Motorways; Short Sea Shipping; Transport model choice; Intermodal transport;-Indexes of relevance.

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1. INTRODUCTION

The congestion level that some of the main land transport corridors have reached in the EU territory suggests diverting the traffic from the roads to alternative transport modes. This aims at reducing the costs derived from the high traffic concentration they bear. This reduction would affect both social costs (related mainly to the accident levels and the environment degradation) and private costs (longer travel time).

To achieve this objective the development of the Short Sea Shipping (SSS) has been contemplated in the European Transport Policy. Although the definitions given for the SSS are numerous, according to the European Comission it refers to "the movement of cargo and passengers by sea between ports situated in geographical Europe or between those ports situated in non-European countries having a coastline on the enclosed seas bordering Europe".

The main advantages associated to SSS in comparison with the road transport are: its lower number of accidents, its low infrastructure costs, its capacity to reach ultra-peripheral regions and its lower impact on the environment (authors as Vanherle et al. (2010) have pointed out important clarifications regarding this subject). But in spite of all these advantages, road transport continues to be predominant for channeling the intra-communitarian freight trade flow. The main reasons why transport decision makers are reluctant to the intermodal transport is related to the perception of the SSS as an outdated, slower, rigid and complex alternative from an administrative point of view, in addition to being less reliable. So, the potential users tend to consider that the SSS is a less satisfactory option than road transport to offer a door-to-door service see Medda et al. and Triunfante Martins et al. (2010).

To try to reverse this perception, the White Paper of Transport (2001), introduced the concept *Sea Motorway* as a tool to develop the SSS. Sea Motorways are maritime corridors; a network of ports and intermodal services that offer a SSS transport in a particular zone of the EU. In 2003, the European Commission revised the Trans-European Network of Transport (TEN-T) including as an objective for 2020 the implementation of the Sea Motorways in 4 corridors (TEN-T Project 21): i) Motorway of the Baltic Sea; ii) Sea Motorway of Western Europe; iii) Sea Motorway of South-East Europe; and iv) Sea Motorway of South-West Europe, connecting Spain, France, Italy and Malta, and linking with the Sea Motorway of South-East Europe, including links to the Black Sea.

The articulation of Sea Motorways requires, aside from the election of ports of call, the establishment of frequency of service for the connections among them. This will make possible to offer a door-to-door service in similar conditions of cost and quality to those given by the road transport González Laxe et al. (2007). In other words, the success of the Sea Motorways depends on their capacity to integrate their services in an intermodal chain of transport without additional costs due to the bureaucracy or an inefficient port service Paixao Casaca et al. (2010). All this makes critical the selection of the port for the success of the Sea Motorway. Notwithstanding, the papers dedicated to port selection in the SSS framework are very scarce and tend to be limited to the shipping companies perspective. We propose to adopt the perspective of the transport service as a whole.

This work tries to develop a tool able to identify the ports that articulate the best maritime route to support an intermodal chain competitive with road transport. In order to do so, we propose as a case study the implementation of a Sea Motorway that connects the Atlantic Coastline of Spain and France. The structure of the paper is as follows: in section 2 we define the framework; the port alternatives taken into consideration to establish an intermodal alternative to road transport. In section 3 we analyse each of them, comparing their potential competitiveness in terms of cost and time. In section 4 we assess the results obtained in terms of risk assumed with respect to the hypothesis carried out to analyze the competitiveness of the different alternatives proposed. Finally, in section 5 we present the main conclusions of the paper.

2. CHOICE OF ROUTE ENDINGS

The amendment of the TENT-T originated the signature of a bilateral agreement between Spain and France in 2006 to promote the development of Sea Motorways to join their respective Atlantic coastlines. As a result, an intergovernmental commission was created with the aim of elaborating a proposal for the selection of Sea Motorway projects. The requirements are: i) a minimal service frequency of 4 departures per week each way during the first two years of exploitation operation; ii) a minimal frequency of 7 departures per week each way once those 2 years have elapsed; iii) minimal annual traffic of 350.000 semi-trailers should have been reached at the end of 5 years; and iv) 850.000 after 10 years. The projects selected would receive additional resources to the ones stated in the Marco Polo II Programme. The main parameters to assess them are: the traffic volume attracted (and diverted from the road), the quality of the project (according to the number of ports joined, service frequency and quality of the infrastructure) as well as the expected economical and financial results see Baird and Aperte (2010).

The purpose of this paper is not to identify which ports fulfill better these requirements, but to determine which ones have a better disposition to articulate an attractive intermodal chain versus the road alternative. The analyzed ports were firstly chosen due to their location, their relevance within their port system, and their potential to establish a Sea Motorway. All of them have an important hinterland; they are considered as Ports of category A (they have international relevance and an annual traffic volume of more than 1.5 million tons of freight or 200,000 passengers). They also fulfill the dock draft and surface requirements needed for the demands of the service for the Ro-Ros see Henesey and Mbiydzenyuy (2010).

Taking all these aspects into account, in this paper the Spanish ports of Vigo, Ferrol, A Coruña, and Gijón along with the French ports of Saint Nazaire, Le Havre and Calais were considered as possible endpoints of the Sea Motorway. These last three ports are the best located to connect with Rennes, Paris and Lille; the three most important cities in the country accesible from the Atlantic coastline, and consequently, the 3 french endpoints of the respective intermodal chain. In the Spanish case, the port itself has been considered as the endpoint of the route. This is due to two reasons. Firstly, these ports are located in the same provinces as the most important population/activity centres of their hinterland see García-Alonso and Sánchez-Soriano (2007). Secondly, those centres are the main traffic generators on the Spanish northern coastline. It should be pointed out that the inland provinces of Madrid and Zaragoza also channel an important volume of traffic through the Northern coastline, but they were ruled out as a possible route endpoint for the intermodal chain. This is because both use the port of Bilbao to channel to the North the bulk of their traffic see García-Alonso and Sánchez-Soriano (2010), and we discard this port for this study.

The port of Bilbao is ruled out as a possible maritime route endpoint because the Sea Motorways through Atlantic ports prove to be interesting for maritime inter-port distances ranging between 834 and 1400 km., in according to the conclusions of previous researches (see Emma project, from the fourth Framework program of the European Commission, or the INECEU project, funded by the Ministry of Development). Likewise, from the EU (COM-1999) it is also recommended to respect the minimum threshold of 1385 km of land distance to establish an intermodal chain of transport (these references were established for the European case. For other contexts, see for example Brooks and Trifts (2008).

Table 1: Distance of alternative routes (km)

Spanish port	French port	Maritime distance	French endpoint	Land distance
Vigo	Calais	1390	Rennes	1453
	St. Nazaire	915	Paris	1577
	Le Havre	1232	Lille	1793
Ferrol	Calais	1206	Rennes	1412
	St. Nazaire	717	Paris	1553
	Le Havre	1049	Lille	1751
A Coruña	Calais	1225	Rennes	1392
	St. Nazaire	717	Paris	1514
	Le Havre	1217	Lille	1731
Gijón	Calais	1156	Rennes	1061
	St. Nazaire	563	Paris	1184
	Le Havre	1152	Lille	1400
Santander	Calais	1164	Rennes	892
	St. Nazaire	508	Paris	1015
	Le Havre	1006	Lille	1231
Bilbao	Calais	1206	Rennes	795
	St. Nazaire	522	Paris	917
	Le Havre	1049	Lille	1134

Source: Spanish Civil Navy Association.

Considering the previously mentioned thresholds, the ports of Santander and Bilbao are ruled out for their land proximity to the final French destinations. Likewise the Ferrol, A Coruña and Gijón with Saint Nazaire combinations are ruled out due to their maritime proximity. Nevertheless, the alternatives of Gijón-Calais and Gijón-Le Havre have been considered as the maritime distance between them is adequate and both options respect the land distance threshold for one of the chain endpoints (Lille). Hence, in table 2 the port combinations analyzed in this paper to create a Sea Motorway can be seen.

Table 2: Possible maritime routes for the implementation of a Sea Motorway.

Spanish port (*l*)	French port (*k*)
Vigo	Calais
	St. Nazaire

	Le Havre
Ferrol	Calais
	Le Havre
A Coruña	Calais
	Le Havre
Gijón	Calais
	Le Havre

A multicriteria decision method has been used in order to analyze the success possibilities of the resulting intermodal chain. This type of analysis allows to evaluate which one of the alternatives considered accomplishes better a series of objectives, taking into account pre-established criteria. The identification of the best option is made by aggregating the assessment of the achievement of each criterion, normalized for each alternative. The double aspect of the multicriteria analysis accomplished in this paper drives to a complex matrix of decisions. In this particular case, the final objective is to identify which one of the Sea Motorways articulates the intermodal chain with better chances of success against road transport to connect the Spanish endpoints to the three French (Rennes, Paris and Lille).
In order to choose among the alternative Sea Motorways, the different transport modes have been also compared previously considering the established criteria (see figure 1). Firstly, for every three possible French route endpoints, both transport alternatives are evaluated observing the criteria. This is done for all possible intermodal chains, derived from the alternative Sea Motorways (port combinations shown in table 2). Having done this, and after having added the assessment of the criteria for each alternative transport mode, the Sea Motorway offering bigger chances for success to the resulting intermodal chain can be identified.

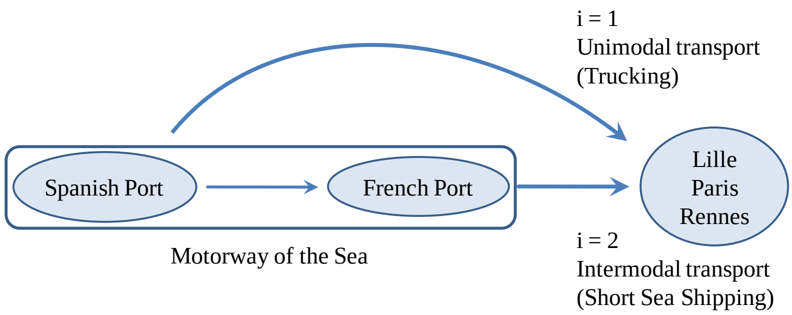

Figure 1: Alternative transport options for each combination of ports (table 2)

Therefore, the objective is not to analyze neither the intermodal competence between both options, nor which ports can articulate an optimal maritime route from the shipping companies point of view (vehicle route problems) or even the design of a ports network (commodity problems), but to identify which one favors the offer of a competitive door-to-door service with respect to the unimodal service.

3. ASSESSMENT OF THE ALTERNATIVES

As we know that the volume of trade and the evolution of transport costs are inversely related, the flows of freight could benefit from a reduction of these. Such a reduction could be in monetary terms or in terms of time see Limao and Venables (2001). Likewise, the *time* and *cost* variables are decisive factors in the selection of the -transport mode for freight see Garcia-Menendez et al. (2004). Therefore, the criteria taken into account in this paper are two: the time and the costs expended on each route. We propose an index to assess each of them, as we show in (1) and (2).

$$I_{ijkl}^{T} = 1 - \frac{Time_{ijkl}}{\sum_{i=1}^{2} Time_{ijkl}} \tag{1}$$

$$I_{ijkln}^{C} = 1 - \frac{Cost_{ijkln}}{\sum_{i=1}^{2} Cost_{ijkln}} \tag{2}$$

Where (1) is the *time index* and (2) is the *cost index*. The sub- indexes represent:
i) transport alternatives (i: road or SSS);
ii) the route endpoint in France (j: Rennes, Paris or Lille);
iii) the considered French port (k: Saint Nazaire, Le Havre or Calais); and
iv) the port and route endpoint in Spain (l: Vigo, Ferrol, A Coruña and Gijón).
v) The year in which the trip takes place is also considered for the calculation of the cost index (n): 2006, 2007, 2008 or 2009.

Both indexes are normalized according to the two transport alternatives taken into consideration (i) to reach a route endpoint (j) leaving from the other (l). So they respectively fulfill (3) and (4). Hence, the closer is the index value to 1, the less time/cost will be needed with respect to its alternative.

$$\sum_{i=1}^{2} I_{ijkl}^{T} = 1 \tag{3}$$

$$\sum_{i=1}^{2} I_{ijkln}^{C} = 1 \tag{4}$$

As seen before, the cities of Rennes, Paris and Lille are the references considered to calculate the corresponding indexes for each transport mode. Once the indexes have been calculated, the assessment for every alternative of Sea Motorway is aggregated. This aggregation is done using the *Relevance indexes*, defined according to (5) and (6). In this case, they are interpreted as the probability (the relevance) of that the decision maker chooses a particular transport option (mode and route) taking into account the access conditions (in terms of time and cost) to the three cities (which are the French endpoints of the route).

$$RI_{ikl}^{T} = \sum_{j=1}^{3} \left(I_{ijkl}^{T} \times \alpha_j \right) \tag{5}$$

$$RI_{ikln}^{C} = \sum_{j=1}^{3} \left(I_{ijkln}^{C} \times \alpha_j \right) \tag{6}$$

Where I^{T}_{ijkl} y I^{C}_{ijkln} are respectively the indexes in terms of time and cost of each modal alternative (i) associated to the French port (k). This port will be the hub among the French endpoints (j) and the Spanish one (*l*). Finally, αj is the weighting factor, calculated in according to the population of the end points in France, according to (7).

$$\alpha_j = \frac{Population_j}{\sum_{j=1}^{3} Population_j} \quad (7)$$

In order to calculate the maritime time of travel, we have considered a speed of 35 Kn and a load/unload time at the port of 34 units/hour. While for road haulage the European legislation (Regulation 561/2006) and a lorry average speed of 90 km/h have been taken into account. Likewise, to calculate the cost indexes corresponding to the maritime distance the estimations used in the INECEU Project have been replicated. Meanwhile for the road distances, the annual data given by the Observatory of Road Freight Transport Costs (General Department for Road transport of the Transport Secretary of State for the Ministry of Public Works and Infrastructure) have been considered. The same port rates have been assumed for all facilities.
The results are shown in tables 3 and 4. The Table 3 collects the *relevance indexes* in terms of time for all the routes analyzed in this paper. Table 4 collects the corresponding costs indexes for every endpoints of the Spanish route.

Tabla 3: Relevance indexes in terms of time

	Vigo		**Ferrol**		**A Coruña**		**Gijón**	
	Truck	SSS	Truck	SSS	Truck	SSS	Truck	SSS
French port	RI^T_{1k1}	RI^T_{2k1}	RI^T_{1k2}	RI^T_{2k2}	RI^T_{1k3}	RI^T_{2k3}	RI^T_{1k4}	RI^T_{2k4}
Saint Nazaire	0.45	0.55	---	---	---	---	---	---
Le Havre	0.47	0.53	0.45	0.55	0.45	0.55	0.49	0.51
Calais	0.50	0.50	0.48	0.52	0.48	0.52	0.52	0.48

Tabla 4: Relevance indexes in terms of cost

	2006		**2007**		**2008**		**2009**	
	Truck	SSS	Truck	SSS	Truck	SSS	Truck	SSS
Vigo	RI^C_{1k11}	RI^C_{2k11}	RI^C_{1k12}	RI^C_{2k12}	RI^C_{1k13}	RI^C_{2k13}	RI^C_{1k14}	RI^C_{2k14}
St. Nazaire	0.43	0.57	0.43	0.57	0.42	0.58	0.43	0.57
Le Havre	0.43	0.57	0.43	0.57	0.42	0.58	0.43	0.57
Calais	0.46	0.54	0.45	0.55	0.45	0.55	0.46	0.54
Ferrol	RI^C_{1k21}	RI^C_{2k21}	RI^C_{1k22}	RI^C_{2k22}	RI^C_{1k23}	RI^C_{2k23}	RI^C_{1k24}	RI^C_{2k24}
Le Havre	0.42	0.58	0.41	0.59	0.40	0.60	0.41	0.59
Calais	0.45	0.55	0.44	0.56	0.43	0.57	0.44	0.56
A Coruña	RI^C_{1k31}	RI^C_{2k31}	RI^C_{1k32}	RI^C_{2k32}	RI^C_{1k33}	RI^C_{2k33}	RI^C_{1k34}	RI^C_{2k34}
Le Havre	0.42	0.58	0.42	0.58	0.41	0.59	0.42	0.58
Calais	0.45	0.55	0.45	0.55	0.44	0.56	0.45	0.55
Gijón	RI^C_{1k41}	RI^C_{2k41}	RI^C_{1k42}	RI^C_{2k42}	RI^C_{1k43}	RI^C_{2k43}	RI^C_{1k44}	RI^C_{2k44}
Le Havre	0.47	0.53	0.46	0.54	0.46	0.54	0.47	0.53
Calais	0.50	0.50	0.50	0.50	0.49	0.51	0.50	0.50

Taking as a criterion the time involved, we can see that the Sea Motorways Vigo–St. Nazaire, Ferrol–Le Havre and A Coruña–Le Havre articulate the most competitive intermodal chains against to the road transport. In addition to this, the intermodal chains through the French port of Calais offer the worst results. In this sense, it is worth emphasizing the case of the maritme routes of Vigo–Calais, where the intermodal alternative is equivalent to the unimodal; and Gijón–Calais, where the unimodal option is the most suitable. With regard to the cost criterion, we can see that all the intermodal

chains are preferable to unimodal transport except for the chains that use the Gijón–Calais maritime route. In this case a tie occurs between both-modal alternatives. Likewise, the Calais option also turns out to be the least advantageous for the rest of the Spanish ports. On the other hand, it is worth noticing the advantage that the intermodal alternative offers with regards to the road when this is articulated on the Sea Motorway Ferrol–Le Havre.
In order to facilitate the comparison between the different Sea Motorways we define the *Differential indexes of relevance* in terms of time and cost, according to (8) and (9).

$$DIR_k^T = RI_{2k}^T - RI_{1k}^T \quad (8)$$

$$DIR_{kn}^C = \left(RI_{2kn}^c - RI_{1kn}^c\right) \times \beta_n \quad (9)$$

Where RI^T_k and RI^C_{kn} are respectively the relevance indexes in terms of time and cost, and β_n is the weighting factor regarding the annual traffic between France and the corresponding Spanish port, according to (10):

$$\beta_n = \frac{Traffic_n}{\sum_{n=1}^{4} Traffic_n}, \forall\, n = 2006\ a\ 2009 \quad (10)$$

The *Differential indexes of relevance* reflect the appeal of each Sea Motorway against the road alternative for transport users. The higher the value of the index, the higher is the appeal of the intermodal option. From these the port indexes can be defined. In terms of time, they match the respective Differential Index of Relevance. But in terms of cost it is necessary to take into account the year, as shown in (11)

$$\mathrm{IP}_k^C = \sum_{n=1}^{4}\left(\mathrm{DIR}_k^C\right) \quad (11)$$

Table 5 collects the *Port indexes* according to both criteria for all the maritime routes analyzed. According to these data, the most competitive intermodal chains in terms of time are the ones articulated on the motorways of Vigo-Saint Nazaire and Ferrol-Le Havre. While the maritime routes which include the port of Calais turn out the worst option for three of the four Spanish ports considered.

Tabla 5: Port indexes in terms of time and cost

	Vigo		**Ferrol**		**A Coruña**		**Gijón**	
	PI^T_k	**PI^C_k**	**PI^T_k**	**PI^C_k**	**PI^T_k**	**PI^C_k**	**PI^T_k**	**PI^C_k**
Saint Nazaire	0.10	0.14	---	---	---	---	---	---
Le Havre	0.06	0.15	0.10	0.18	0.09	0.17	0.02	0.00
Calais	0.01	0.09	0.05	0.12	0.04	0.11	0.07	0.00

In terms of cost, the competitiveness of the intermodal transport is even more interesting than regarding the time criterion (higher values). The option Ferrol-Le Havre stands out above the rest as the most competitive against the road. At a similar level is the option A Coruña-Le Havre, followed by Vigo-Le Havre and Vigo-Saint Nazaire.

4. RISK ASSESSMENT IN THE CHOICE OF ALTERNATIVES

To assess the goodness of the selection of a particular Sea Motorway, it has been carried out a risk analysis of the port indexes values taking into account the variation of the variables considered for its calculation. In order to do so, Monte Carlo simulation has been used. It allows varying simultaneously the values of the variables selected to calculate the port indexes. From these simulations the probability distributions for the indexes have been obtained. If these distributions are good estimators for the corresponding port index, the value of such port index will be considered well-grounded and, consequently, the decisions made from it should be reliable.

The simulations have been carried out to each one of the 9 possible routes. As it is a past scenario study case (already known), triangular probability distributions were used with a variation range of 20% between the most and least probable values. The amount of tests carried out in each simulation has been 1.600.000, with a 100% certainty for all results obtained. The mean, the median, the standard distribution of the probability distribution for each route and the theoretical distribution that best fits each one of the simulated distributions have been obtained.

The results of the probability distributions simulated were compared to the base values, which are the values of the Port indexes. The distance between both values has been assumed as the risk associated to the index. Therefore, the closer to the mean the index is (the shorter the distance is), the lower the risk assumed in the selection is. Given that the distance has been assumed as an absolute assessment of the risk, the coefficient of variability (standard deviation regarding the mean) has been used to compare the efficiency of the different indexes. The consistency level of the port index was assessed taking into account the gap between the value of the maximum probability in the correspondent simulated distribution and the value of the index.

4.1. Risk assessment in Port indexes in terms of time

The assumed speeds and population factor are the assumptions for the calculation of the port index in terms of time. Varying the values of these variables could change the value of the port index, and therefore the selected route. This is why these variables are the inputs considered in the simulation for this index.

Table 6 shows the obtained values from the simulations carried out using the Monte Carlo method. Figures 2 to 5 show the probability distribution of the simulations carried out for each port.

The difference between the index value and the mean reflects that the error assumed in the selection of the port is low. Also, the dispersion level of the data is high, with elevated standard deviations. Notwithstanding, the preferential order of the considered optimal routes remains the same due to the consistency of the index in all the cases and the distance in absolute values of the indexes among ports. Taking into account all these aspects, the alternatives of Ferrol-Le Havre and Vigo-St. Nazaire (both amongst the ones offering the best results to compete with unimodal transport) are chosen regarding the time factor (its port indexes are centred, efficient and consistent).

Tabla 6: Results from the Monte Carlo simulation (in terms of the time)

	Vigo			**Ferrol**		**A Coruña**		**Gijón**	
	SN	**LH**	**C**	**LH**	**C**	**LH**	**C**	**LH**	**C**
Port indice (PI^T_k)	0.10	0.06	0.01	0.1	0.05	0.09	0.04	0.02	-0.03
Mean	0.099	0.051	0.003	0.09	0.03	0.07	0.02	0.02	-0.03
Mediana	0.103	0.055	0.007	0.09	0.04	0.07	0.02	0.02	-0.03

Standar deviation	0.028	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02
Coeff. Of variability	0.28	0.58	9.55	0.34	0.86	0.42	1.5	0.78	-0.44

Where SN is Saitn Nazaire; LH, Le Havre; and C, Calais.

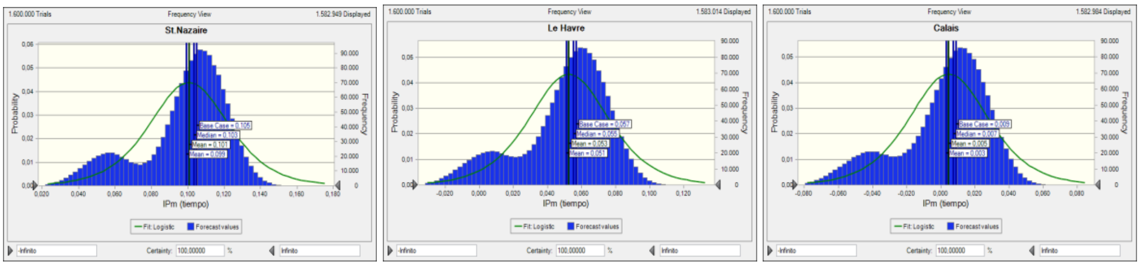

Figure 2: Probability distributions of the simulations for Port indexes (in terms of time) and the Spanish port of Vigo

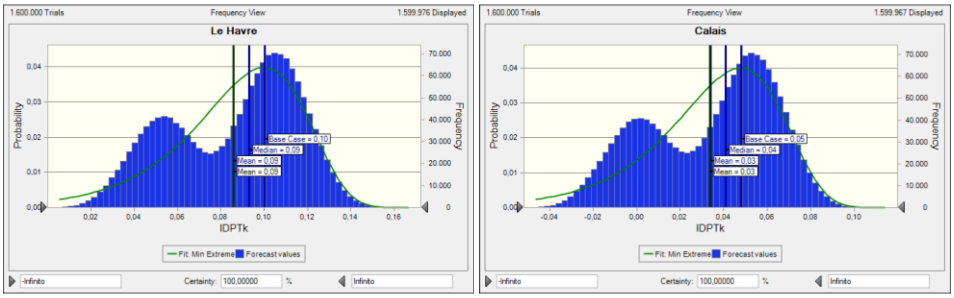

Figure 3: Probability distributions of the simulations for Port indexes (in terms of time) and the Spanish port of Ferrol

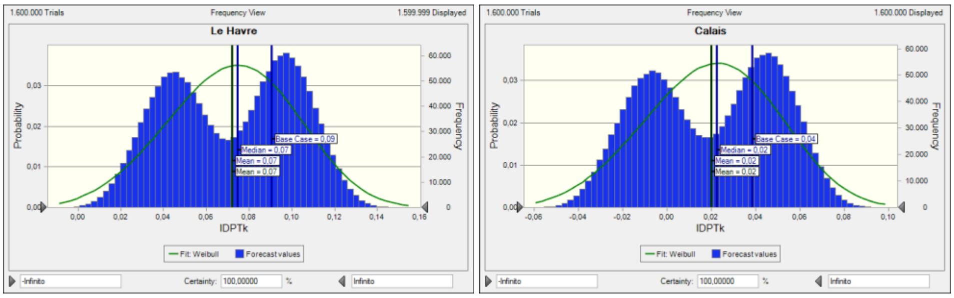

Figura 4: Probability distributions of the simulations for Port indexes (in terms of time) and the Spanish port of A Coruña

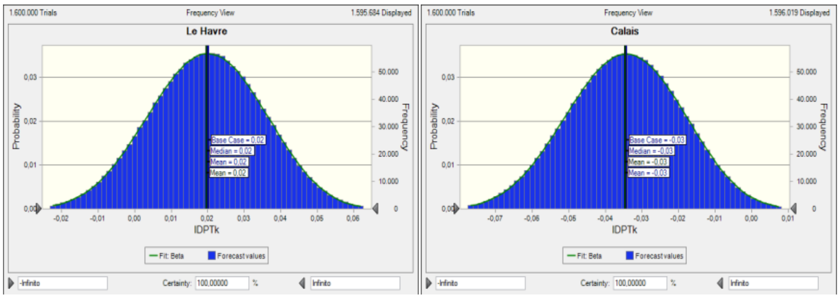

Figura 5: Probability distributions of the simulations for Port indexes (~~respect~~ in terms of the- time) and the Spanish port of Gijón

4.2. Risk assessment in Port indexes in terms of cost

For the risk analysis of this index, the assumptions taken into account have been: the population size in the French route endpoints, the weighting factor regarding the annual traffic volume recorded between France and Spain, the land transport cost per km and the freight per transport unit (considering independently the fuel cost and the capital cost). Table 7 shows the values derived from the simulations carried out, and the Figures 6 to 9 show their probability distribution. The results obtained show total coincidence between the respective value of the port indexes in terms of cost and the means of their simulated distributions. Furthermore, the indexes are efficient and consistent; therefore there should not be risk in the selection of the alternatives previously chosen: Vigo-St. Nazaire and Ferrol-Le Havre.

Table 7: Results from the Monte Carlo simulation (in terms of cost)

	Vigo			Ferrol		A Coruña		Gijón	
	SN	**LH**	**C**	**LH**	**C**	**LH**	**C**	**LH**	**C**
Port indice (PI^{T}_{k})	0.14	0.15	0.09	0.18	0.12	0.17	0.11	0.07	0.00
Mean	0.14	0.15	0.09	0.18	0.12	0.17	0.11	0.07	0.00
Mediana	0.14	0.15	0.09	0.18	0.12	0.17	0.11	0.07	0.00
Standard deviation	0.008	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Coeff. Of variability	0.06	0.07	0.1	0.06	0.08	0.06	0.08	0.17	2.97

Where SN is Saitn Nazaire; LH, Le Havre; and C, Calais.

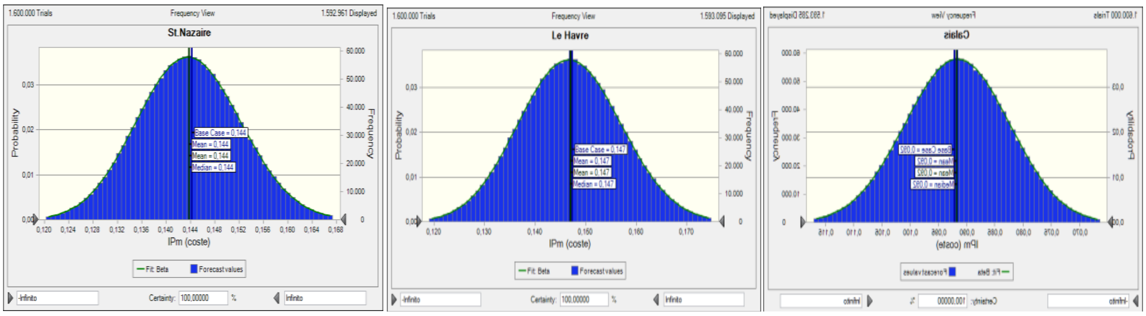

Figure 6: Probability distributions of the simulations for Port indexes (in terms of cost) and the Spanish port of Vigo

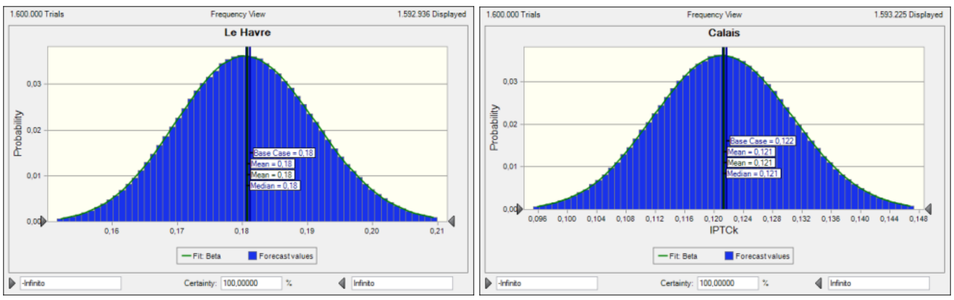

Figura 7: Probability distributions of the simulations for Port indexes (in terms of cost) and the Spanish port of Ferrol

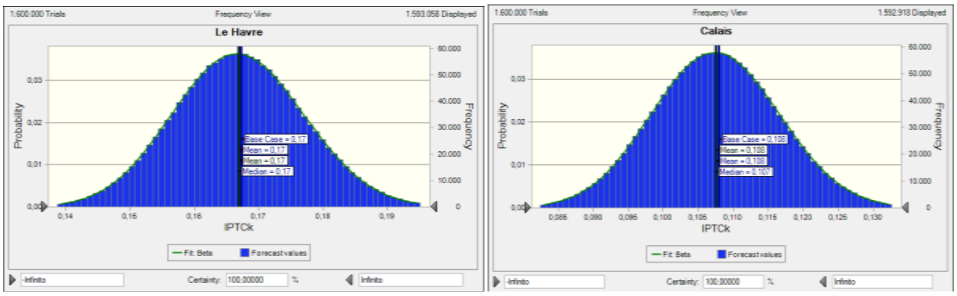

Figura 8: Probability distributions of the simulations for Port indexes (in terms of cost) and the Spanish port of A Coruña

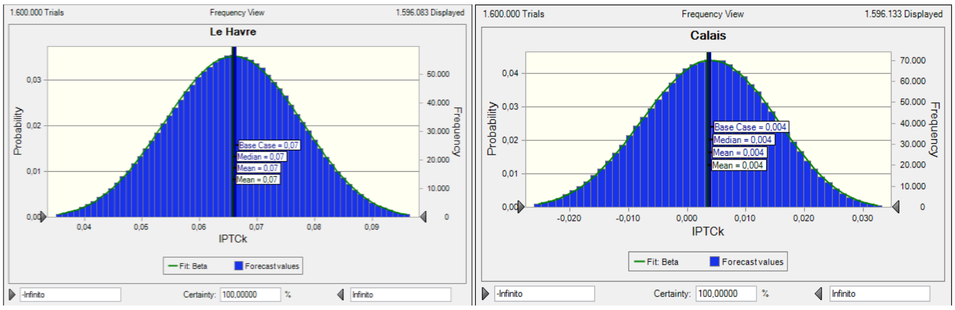

Figura 9: Probability distributions of the simulations for Port indexes (in terms of cost) and the Spanish port of Gijón

5. CONCLUSSIONS

The results achieved support the utility of the indexes presented. With them it is possible to make a first assessment of the potential of alternative routes to articulate a Sea Motorway competitive against the unimodal transport. Applied to the study case presented in the paper, we can be concluded that the intermodal alternative is preferable to the unimodal for practically the whole of the cases analylised. The advantage of the intermodal service versus the unimodal transport is noticed when attention is paid to the time criteria as to the cost of the service. However, such advantage is higher when attention is focused on the second aspect. Taking both perspectives together, the routes with highest potential of success are A Coruña-La Havre, Ferrol-La Havre y Vigo-Saint Nazaire.

As the value of the indexes depend on the assumptions considered in order to calculate them, it is convenient to analyse the risk assumed selecting or refusing a determined alternative. The tool selected for this is the Monte Carlo simulation. The results achieved from the simulations allow to note that the indexes are good estimators for two of the pre-selected routes: Ferrol-La Harvre y Vigo-Saint Nazaire. According to this, the risk assumed by accepting the advantage of the intermodal transport versus unimodal transport is low. Nevertheless, the A Coruña-La Havre option is rejected for the risk associated to its port index.

This paper leaves doors open to deepen in the analysis of the factors that determine the competitiveness of the intermodal transport against the unimodal. For example, issues as the influence of the reliability of the delivery times or the differences in the port costs. Maybe it could explain why the alternative Gijón-Saint Nazaire has entered into operation with success, but was rejected in this paper because the distance that separates their ports is out of the range considered desirable. Also it is interesting to analyse the sensitivity of the port indexes to variations in inputs such as the lorry speed, the ship speed, the loading and unloading time or the cost/km covered.

ACKNOWLEDGEMENTS

The authors thank the support provided by the Department of Applied Economics of the Oviedo's University. Also we gratefully acknowledge the financial support of the Government of Spain, FEDER and the Government of Generalitat Valenciana, under projects MTM2008-06778-C02-01, ACOMP2010/102 and ACOMP/2011/129.

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