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Cost Assessment Simulator for Transport Between Mediterranean Spanish Ports and the Black Sea

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ABSTRACT

There is a strong imbalance in EU transport mode shares. In addition, issues like road traffic, noise, accident rates, and especially polluting emissions result not only in external costs to society, but also in high logistical costs to transport service customers. The present paper proposes an assessment model to evaluate final internal and external costs of transport chains served by trucks and short sea shipping (SSS). An efficient and fast tool is presented to help customers decide on the most convenient mode of transportation for a specific trade link. The trade links in this paper connect 19 Spanish provinces to the main ports in the Black Sea region (Bulgaria, Georgia, Romania, Russia, Turkey, and Ukraine) through the ports of Barcelona and Valencia.

1. Introduction

The main objective of this paper is to obtain a calculation method of all costs and times associated with freight distribution. Overall costs (in €) are calculated based on the operational cost of a single truck and the variable Gross Tonnage *(GT)* for the marine transport mode. The time (in hours) required to move freight between a point of origin and a destination strongly depends upon the operational speed of the modes employed. The formulation is subsequently validated with actual data on freight transport by SSS between Spain and Italy (since prices for these links are known). Calculation errors exceeding 10% are not accepted. Validation is performed with other simulators currently in operation. All required data is calculated by an engine generated by an Excel spreadsheet and a *Visual Basic* program, and then presented in tables and graphs. Users of the proposed cost and time simulator will simply need to introduce an origin (*i*) and a destination (*j*), as well as other transport-related parameters.

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1.1. State of the art

After analyzing all available cost and time simulators, we found that they are divided into two groups. The first group includes simulators of a practical nature, based on companies or private institutions maintaining a website where only a few variables must be introduced (typically origin and destination) to determine cost or time, without specifying the calculation formula or method used. In these cases, the software is a closed source. Two clear examples are the Shortsea Promotion Centre-Spain, and the Rete Autostrade di Mare. On the other hand, several attempts have been made to estimate external costs based on theoretical

studies conducted in the transport sector. Some have been obtained through research projects, especially within EU-framework programs and EU initiatives like CAFE (2001). Other programs have had an impact on transport sectors, such as RECORDIT (2001), ENTEC (Whall, 2002), UNITE (2003), INFRAS (IWW, 2004), REALISE (2005), MOPSEA (Vito, 2006), EMMOSS (T&M Leuven, 2007), and iTREN-2030 (EU, 2009). For air pollution damages, studies have relied on the ECOSENSE model (often cited as the "ExternE model") developed by IER (2005) within the ExternE project series. Our aim here is to present a simulator of internal and external costs, which will also allow for the updating of cost data and the incorporation of new and different ships for the marine mode.The empirical estimation of port cost functions started in the 60's with the work of Wanhill (1974), which aimed to design a model to determine the optimal number of berths in order to minimize total costs derived from port dues, that is, berth and port time. The works by De Monie (1989), Dowd and Lechines (1990), Talley (1994), and Conforti (1992) proposed a cost analysis to appraise port performance and output by calculating several indicators. Cost analysis also allows comparison of productive efficiency over time in a company and between companies. Two techniques are useful here, i.e. data envelopment analysis (DEA) (Roll and Hayuth, 1993), (Martínez Budría *et al*, 1999; and Tongzon, 2001) and econometric estimation of frontier and distance functions (Liu, 1995; and Baños-Pino *et al*, 1999). The doctoral thesis of Ametller Malfaz (2007) describes the development of cost and time evaluations under the hypothesis of freight distribution based on population density.

The behavior of freight distribution systems must be known in order to design a simulation model. As is usually the case, actual systems are complex; therefore, a simple, straightforward mathematical representation requires the simplification of such systems. Road haulage, port operations, and maritime transport must be modeled in order to assign costs derived from each part or component of the logistics chain. The possibility of a shift from strict road transport to a multimodal chain like SSS will depend on route characteristics and conditions. The case under study here assumes a SSS logistics chain where the truck driver does not travel on the ship during the sea leg. This case is likely more competitive than strict road transport since the truck driver can perform parallel activities while freight is being transported by sea, resulting in increased productivity of transport companies and reduced operational costs. Note that an SSS chain can only be guaranteed if a trade agreement with the destination country covers the last stage of the transport chain.

1.2. The commercial scenario

The analysis below shows an upward trend in the volumes traded between Spain and the Black Sea region. Basic data obtained from the Spanish Institute for External Trade (ICEX) analyzes values (in Euro) and volumes (in metric tons) exchanged between Spain and the Black Sea region in 2009. Figures on import and export operations between Spain and Bulgaria, Georgia, Romania, Russia, Turkey, and Ukraine have been evaluated in previous works (Mihailovici, 2011; Rodríguez Nuevo, 2008). The largest number of exchanges occurred with Greece (not located on the Black Sea but included due to the amount of trade), Turkey, Russia, and Ukraine (in the case of the last two countries, as a result of Spanish crude oil imports). It is worth noting that trade operations with all these countries open the door to two large markets, i.e. Central Asia and the Middle East. Data from the Agencia Tributaria (Department of Revenue) and ICEX (Table 1) were used to create a framework to test the feasibility of selecting a transport mode according to physical and environmental costs. Data on (internal) truck costs were obtained from the yearly publication *Observatorio de costes del transporte de mercancías* (Observatory of freight transport costs, 2011), in which a set of model trucks is specified by the Spanish Ministry of Transport. As for vessels, Short Sea Shipping Ro/Pax ships were employed in Mediterranean routes (Martínez de Osés and Castells, 2009).

External costs arise when the social or economic activities of one group of persons have an impact on another group, and when this impact is not fully accounted or compensated for by the first group (ExternE, 2003). The environmental impact and external costs of each mode of transport are compared with the external cost pricing proposed by REALISE (Regional Action for Logistical Integration of Shipping Across Europe) thematic network carried out within the 5th EU Framework Program. The volume of exports and imports between Spain and the Black Sea region is approximately 3,941,806 and 24,898,406 tons, respectively. Thus, the total volume of freight moved from an origin in Spain (i) to a destination in the Black Sea (j) is about 28,840,212 tons per year, a value that justifies the interest in analyzing the viability of a trade route between both regions.

Table 1: Volumes in metric tons exchanged between Spain and the Black Sea.

2009	Exports		Imports	
	Value	Weight	Value	Weight
Bulgaria	355,232.53	211,267.70	341,875.66	1,200,411.60
Georgia	16,146.92	14,516.40	69,249.74	178,798.10
Greece	1,764,529.42	1,093,081.50	331,898.97	410,281.50
Romania	670,701.01	350,416.30	788,653.51	1,659,126.70
Russia	1,477,423.57	703,394.60	4,587,218.95	15,805,139.00
Turkey	2,597,335.18	1,457,645.50	2,632,495.76	2,144,425.60
Ukraine	188,606.24	111,484.00	582,248.73	3,500,273.60

Source: Authors

2. Methodological considerations

The simulator uses calculations whose results provide a basis for the computer program and the engine for the computation, in terms of costs and travelling times, that determines the internal and external costs, based on the previously mentioned projects. Substantial mathematical and programming work is required, but field work is also essential to obtain real data on regular shipping lines (limiting the study to Ro-Ro ships), port facilities, and vessels. In order to implement the simulator, the following methodological sequence is proposed:

1. Development of a formula and a mathematical model for determining costs and times for internal costs, and costs and amount of emissions for external costs associated with each mode of transport. We have used the REALISE (2005) project which provides statistics and a methodology to calculate environmental impacts and thus the external costs from both sea and road transport. The REALISE project used data sets, based on the COPERT III (EEA, 2002) calculation module. COPERT III was designed to evaluate polluting emissions from road

transport and was part of the EMEP CORINAIR (EEA, 2009) project. The EMEP CORINAIR (nowadays identified as the EMEP/EEA air pollutant emission inventory guidebook) provides guidance on estimating emissions for different modes of transport. The emissions factors of vessels, in g/kg fuel, were calculated taking fuel consumption into account. To evaluate the impact of transport emissions, the scenario considered here is a hypothetical improved future condition, resulting in a 10% decrease in the current emissions, except for SO_2 and NOx. The main engine fuel consumption rate is strongly affected by the propulsion systems installed, such as engine, gear, shaft, and propulsion arrangements. External costs evaluated in this simulator are SO_2, NOx, CO, nm-VOC (local contamination), and CO_2, CH_4 and S (global contamination). As regards haulage, road transport is the first and last stage of freight transport and distribution. It is evident that SSS always requires this component since origins and destinations are generally within port jurisdiction. The terminal may even be located outside the seaport facilities.

2. Create a database with information and characteristics of actual Short Sea Shipping vessels.
3. Analysis of the value of variables and determination of possible reasons for an inefficient freight transport mode to eventually establish its level of competitiveness.
4. Design of the program in *Visual Basic* to create an internal and external cost simulator.
5. Gathering and final analysis of obtained data.
6. Design of a mask to introduce inputs and receive the necessary outputs to serve a route and estimate internal and external costs of a freight transport mode.

When the program is running, freight transport costs and times, as well as costs and amounts of pollutant gases emitted during transport, are printed on the mask.

The calculation engine, which performs and works with formula and matrix data in Visual Basic, was designed on the basis on previously obtained formulations (Ametller, 2010), compared with previous existing calculation methodologies (COPERT for road transport or CORINAIR for marine mode). The steps involved in the simulator design are described in the following subsections.

2.1. Description of the data acquisition methodology

After an origin (*i*) and a destination (*j*) are proposed, the work methodology of the simulator is as follows:

1. Choose data from the "destination matrix" and find out whether there is a destination for the selected route (Bulgaria, Georgia, Greece, Romania, Russia, Turkey, and Ukraine).
2. Choose data from the "origin matrix" and find out whether there is an origin for the selected route (La Coruña, Almería, Asturias, Barcelona, Burgos, Cádiz, Cantabria, Castellón, Ciudad Real, Guipúzcoa, Huelva, Lugo, Madrid, Murcia, Tarragona, Valencia, Valladolid, Vizcaya, and Zaragoza).
3. Choose data from the "maritime distance matrix" Barcelona, Valencia and Bulgaria, Georgia, Greece, Rumania, Russia, Turkey, and Ukraine. Maritime distances were obtained from MAP24 and Via Michelin sources.

   At this point the executable program allows entry of variables like ship occupancy -as this is used to spread the total ship costs over the actual number of cargo units loaded-; type of freight, number of calls made and company profits only in the case the consignor would like to consider it, otherwise this value can be zero. These parameters are described below.
4. Print and display all solutions for the best ship (calculation of SSS and road transport costs, time, and pollutant emission costs).
5. Choose the best three ships for the selected route from the simulator's database which has been included in the simulator by selecting a number of Ro Pax ships used in SSS Mediterranean trade and provide their details (ship's name, year of build, length, beam, carrying capacity, lane meters, power, speed, and number of carried trailers.
6. Perform routines under the established formulation (for all destinations, origins, and ships).

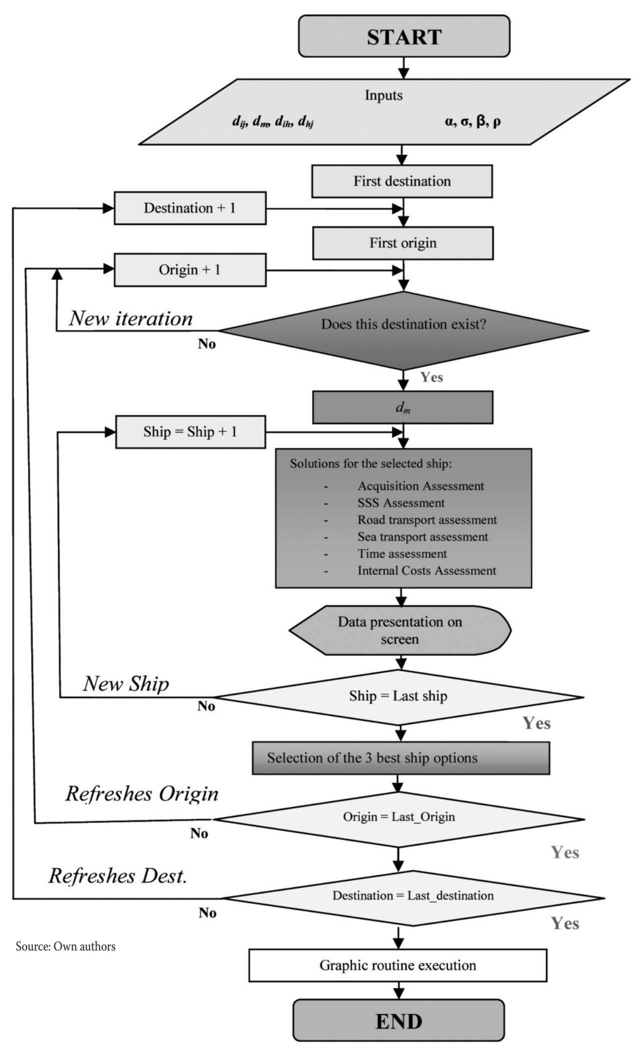

Figure 1: Work methodology diagram of the simulator.

2.2. Description of functionality

Because the land distance matrix coordinates are annexed to the program code that calculates costs and times for the ships and selects routes, road transport calculations are the least complex. This simplifies the relationship between formulas and distances since only road chain data and road leg (in multimodal chains) data are obtained using the same land matrix. The compiler proposes one ship from the database created in the simulator, which contains vessels currently (2010) serving SSS routes, as has been mentioned before. The ship is studied and initial calculations are made based on its details. The program then selects a destination and finds out whether there is an origin for it. If this is not the case, the compiler goes back to the previous step and starts again.

After identifying a ship, a destination and an origin, the program with a database with the existing shipping lines, confirms whether there is a shipping company on the established route. A port –Barcelona or Valencia in the case of Spain– where the consigner will ship the freight is selected. If no route is found, the simulator goes back to the previous step and makes calculations starting from the new origin. It is important to keep in mind that choosing shorter distances results in lower costs and shorter transport time.

When the program selects the most efficient ship in terms of costs, a destination, an origin and a route, it calculates the costs and times for that route.

Once data for the first selected ship is generated, the program goes back to "selection of ship" and makes and records the calculations for all the available vessels in the "ship list". The program allows the user to choose and save the three best ships to serve the selected route. This is important because the shipper can thus charter the ship, which implies optimal costs and transport times, as indicated by the simulator.

The penultimate level consists of choosing a new origin for the destination initially selected. This functionality is shown in order to provide an alternative origin, but the calculation process starts all over again while keeping the previous destination (in the opposite case, the program goes back and selects another origin).

The last step is to use up all the origin possibilities for the above destination and to start a new search for all possible origins for every selected destination. Finally, there will be as many results as pairs of destinations/origins. This way, data for every ship for all destination/origin pairs are obtained individually. The simulator can then describe costs and times for each ship and possible route, providing the user with the best choice. All data is interpreted by means of tables, charts, and the mask designed for the presentation of simulator data (Fig. 1).

Source: Own authors

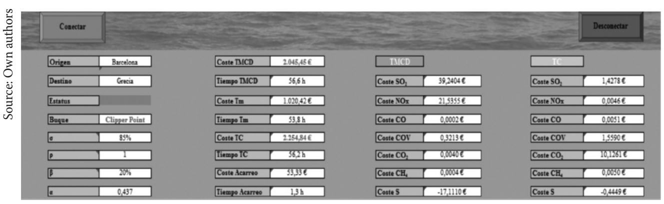

Figure 2: Example of the simulator mask, showing all the variables to be selected before the calculation process.

Table 2: List of ships inserted in the simulator database and regressions done with them.

Name of ship	Year of building	Lehgth (m)	Breadth (m)	Draft (m)	GT	Lineal metres (m)	Power (KW)	Speed (Knots)	N° of trailers	In de GT	In Trailer
Bouzas	2003	151,8	21	6,2	15.224	1.680	12.960	21	96	9,63062841	4,564348191
Catania	2003	179,5	25,6	6,8	25.995	2.230	18.900	23,5	127,4285714	10,1656595	4,847555984
Pilar del Mar	2008	187,4	25,6	6,85	26.904	2.300	21.600	23,5	131,4285714	10,2000303	4,878463521
Schieborg	2000	173,4	25,2	7,5	21.005	1.884	11.000	22,5	107,6571429	9,95251578	4,678951574
Ave Liepaja	1999	179,93	25,24	6,5	22.152	2.000	23.762	23,5	114,2857143	10,0056831	4,738701579
Ave Luebeck	1999	179,93	25,24	6,5	22.152	2.000	23.762	23,5	114,2857143	10,0056831	4,738701579
Zurbaran	2000	180	25	6,5	24.046	2.000	32.300	23,5	114,2857143	10,0877239	4,738701579
European Endeavour	2000	179,95	25	6,5	24.046	2.130	23.762	23,5	121,7142857	10,0877239	4,801676378
Midnight Merchant	2000	179,95	25	6,5	24.046	2.130	23.760	23	121,7142857	10,0877239	4,801676378
Murillo	2002	180	25	6,5	25.098	2.396	32.300	23	136,9142857	10,1305434	4,919355078
Clipper Point	2008	152	23,03	5,7	14.759	1.830	18.480	21,5	104,5714286	9,59960835	4,649870365
Superfast Galicia	2003	160	23,2	6,8	16.686	1.762	34.300	22,5	100,6857143	9,72232532	4,612003926
Superfast Levante	2001	158	25,2	7,2	17.391	1.905	34.300	22	108,8571429	9,76370811	4,690036407
Maria Grazia On	2004	179,8	25,6	6,5	26.302	2.230	21.600	24	127,4285714	10,1774003	4,847555984
Hoa Sen	2001	179,8	25,6	6,5	24.418	2.040	34.000	24	116,5714286	10,1030758	4,758504206
Trinacria	2002	179,8	25,6	6,5	24.409	2.040	34.000	24	116,5714286	10,1027072	4,758504206
Sorolla	2001	172	26,2	6,21	26.916	1.809	28.960	23,5	103,3714286	10,2004762	4,638328604

Source: Own authors

3. Preliminary results

We have designed a simulator of internal and external costs that provides marine stakeholders interested in the Spanish and Black Sea markets with very close estimates of the costs of using maritime or road transport.

The simulator considers European road transport regulations on driving times (2002/15/EC Directive) and costs of road freight transport (Spanish "Observatorio de costes del transporte por carretera", 2010). For marine transport, similarities in cost structures among the groups of ships selected, mainly Ro-Ro ships, make it possible to use linear regression in order to get formulae for marine internal costs, in which the variable to consider is gross tonnage.

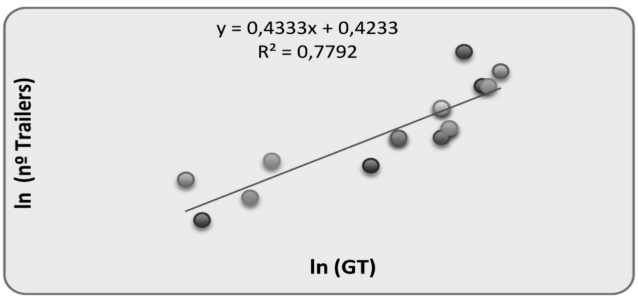

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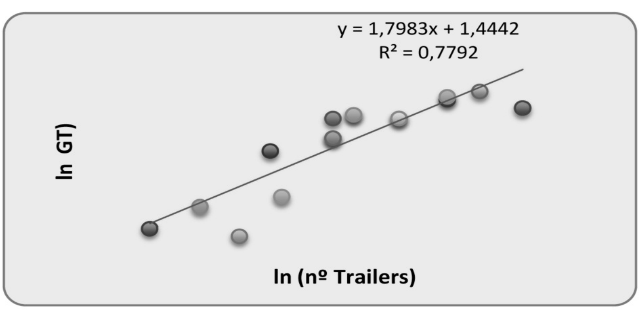
Figure 3: Example of regression of number of trailers/ GT.



Source: Own authors

Figure 4: Example of regression of GT/ number of trailers. Source own.

In order to validate the simulator results, these were compared with real costs and sailing times of SSS lines linking Spain and Italy. Finally, agents of import/export trade between Spain and the Black Sea region were consulted for getting a qualitative information to gether with the quantitative data coming from Spanish statistics (ICEX).

3.1. Design of cost and time simulator

The simulator was designed to compare freight transportation by road chains and by multimodal (with SSS leg) chains only.

Both internal and external costs can be calculated. Prime or internal costs are those derived from fixed and variable costs related to transport activities. External costs are environmental costs associated with estimated emissions considered in previously mentioned projects.

The simulator makes some assumptions regarding the time required for activities within the transportation chain, such as loading and unloading operations. The loading and unloading time varies according to the type of ship used and port handling operations. Considering 0.5 hours plus lading and discharging times.

3.2. Simulator technical specifications.

The simulator includes the following set of options, which can be optimized by the executable program:

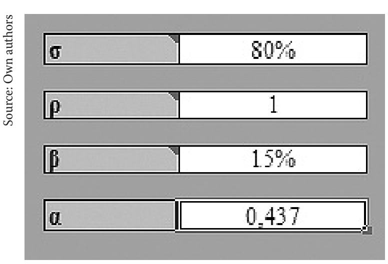
— Names of the best three ships. In any case, if the first ship is already chartered, there are second and third best options.

— Ship's cargo-carrying capacity (σ), that is, the actual load volume that a ship can carry in her holds. This is an important factor for shipowners, given the fact that profits strongly depend on the percentage of the total loading capacity actually used. The ship's profit depends on the ship's occupancy rate. If the ship occupancy rate parameter is not introduced in our program, the ship will have an occupancy rate of 100% and this is an unrealistic value, as an average the occupancy rate ranges around of 60-70%, thus affecting the real share of the ships' costs.

— Number of ports visited by a model Ro/Ro ship in each trip (ρ). Obviously, a higher number stops at ports leads to increased port costs for the shipowner.

— Specific profit margin of the shipping company (*β*), established as desired by the simulator user.

— Freight cost parameter (α) for determining inventory costs, id est the cost for the manufacturer of maintaining the freight in a warehouse waiting for it to be sold; for example, perishable or refrigerated goods require transport under more demanding conditions than other types of goods, resulting in higher costs.



Source: Own authors

Figure 5: Example of variables that can be optimized by the executable program.

The value of the previous variables can be modified by the user of the simulator, as the only independent variables. This is of great importance for shipowners because costs and service times can be adjusted by promoting certain variables. The value of the internal costs depends on the type of ship, thus on her tonnage or GT.

3.3. Reliability of the Simulator

The program's reliability was assessed during the design phase by comparing the obtained figures with real prices. The results, which were based on a sailing route served by a Western

Mediterranean company, were conclusive and satisfactory as the error or difference between the model data and real data did not exceed 10% (see Table 2).

Table 3: Summary of existing deviations between actual and estimated costs.

Route	Freight Cost (€) Tractor Trailer (17.5 meters)	Analysis Value (€)	Standard Deviation
Barcelona-Livorno	805	832	−3.4 %
Barcelona-Civitavecchia	787	861	−9.4 %
Valencia-Livorno	1.001	900	−10 %
Valencia-Salerno	989	1.017	−2.8 %

Source: Shipping companies (2010)

3.4. Display of Cost and Time Competitiveness Indexes

The simulator calculations can be displayed graphically. The costs and time required for freight transport from one province (origin) to another (destination) are determined by the simulator. Additionally, the external costs produced by the transport modes were calculated using the REALISE project formulae. Using the criterion of moved volume per province, a province table is used to find out which provinces are most likely to move more freight to the Black Sea region. For comparison purposes, the authors used the cost of embarking a trailer in Spanish-Italian trade. There are several options to be considered as an unaccompanied trailer, a complete truck (tractor plus trailer), and a complete accompanied truck. A volume ranking is established and reflected by the so-called Cost Competitiveness Index (CCI). This index determines the competitiveness of boarding the trailer throughout the journey against the road option with a single-driver truck. The mentioned index uses the following formula (Rodriguez Nuevo, 2011):

$$CCI = \frac{1.012 \cdot d_r + 96}{0.332 \cdot d_m + 1.012 \cdot d_h + 805}$$

d_r: Road distance, means the total distance covered by a road transport only

d_m: Maritime distance

d_h: Haulage distance, stands for the distance of road legs before and after a marine transport chain, within a multimodal transport chain.

If the value is more than 1, then the SSS alternative is more competitive with regard to costs than the road-only alter native.

The Time Competitiveness Index (TCI) determines the competitiveness in regard to time of boarding the trailer throughout the journey instead of the road option and the following formula is applied (Rodríguez Nuevo, 2011):

$$TCI = \frac{d_r - 108}{d_m + d_h - 56}$$

If this value is greater than 1, the SSS alternative is more competitive with regard to time than the road-only one.

A competitiveness ratio, which is different for each Spanish province, determines whether a route is competitive in terms of time and cost. As an example, the following figures show the trailer-only option.

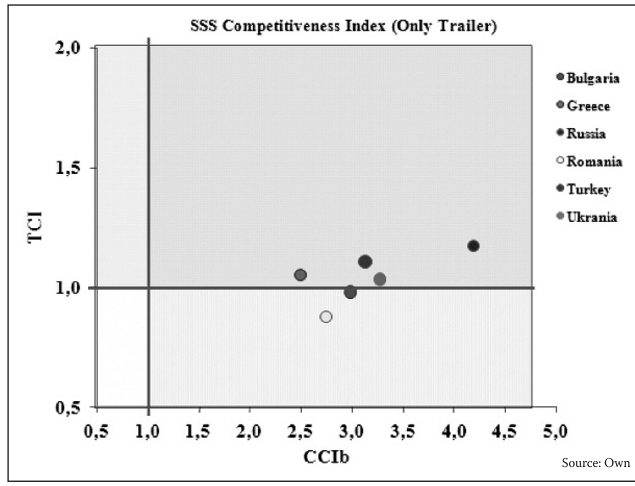


Figure 6: Cost Competitiveness Index of SSS versus road-only transport between Madrid and the Black Sea.

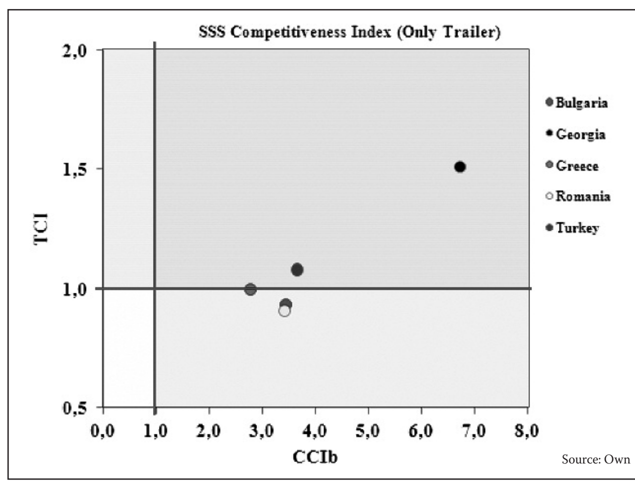


Figure 7: Cost Competitiveness Index of SSS versus road-only transport between Barcelona and the Black Sea.

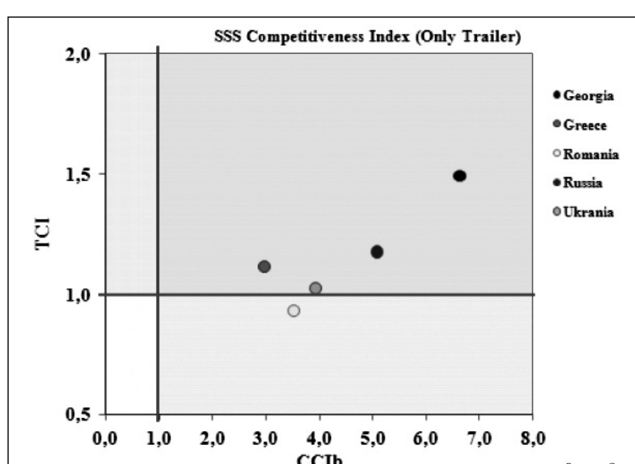


Figure 8: Cost Competitiveness Index of SSS versus road-only transport between Castellón and the Black Sea.

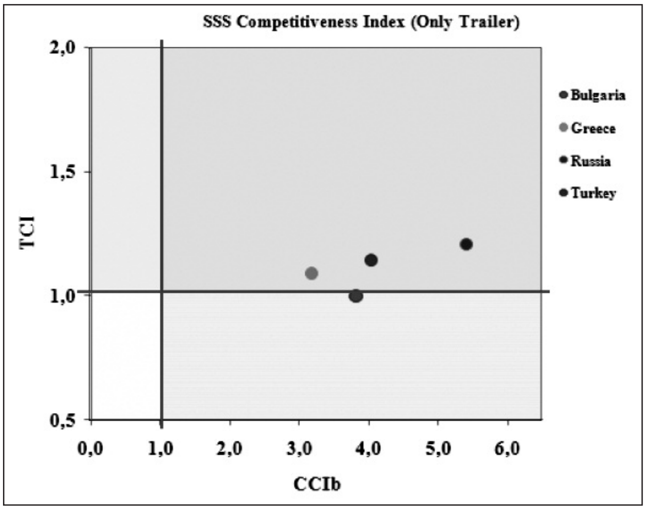


Figure 9: Cost Competitiveness Index of SSS versus road-only transport between Cádiz and the Black Sea.

4. Discussion of results

Regarding cost calculations, in all routes, road transport was found to be more expensive. The farthest destination (Ciudad Real in Spain to Poti in Georgia), reaches the cost of 7,299.98 €. This is the most expensive route between Spain and Georgia. The least expensive route costs 2,254.84 €, and reaches the Piraeus port from Spain.

The marine option is always more economical, the most expensive one being the one going from Spain to Russia (Rostov-na-donu) at 2,556.82 €, and the cheapest one to Piraeus costing 1,123.82 €.

Costs differ less for the route between Spain and Piraeus (less than 1,131.02 €). This last case is justified because of the similarities in distances travelled both by road and by sea. The biggest difference is in the route between Ciudad Real (Spain) and Poti (Georgia) at 4,987.82 €.

Table 4: Table showing the costs (in €) and time (in hours) between different origins in Spain and Poti (Georgia).

ORIGIN	SSS Cost	Road Cost	SSS Time	Road Time	**TMCD/TC Costs**	**TMCD/TC Time**
Barcelona	1,484.53	6,117.09	101.2047115	152.5510	**24%**	**34%**
Burgos	2,113.49	6,782.66	116.8899335	169.1494	**31%**	**31%**
Cádiz	2,338.17	7,299.98	126.4108305	182.0504	**32%**	**31%**
Castellón	1,572.82	6,401.88	107.3242665	159.6532	**25%**	**33%**
C. Real	1,870.57	6,858.39	114.7496565	171.0380	**27%**	**33%**
Lugo	2,419.71	7,198.65	128.4444005	179.5234	**34%**	**28%**
Murcia	1,753.66	6,761.33	111.8340305	168.6174	**26%**	**34%**

Table 5: Table showing the costs (in €) and time (in hours) between different origins in Spain and Piraeus (Greece).

ORIGIN	SSS Cost	Road Cost	SSS Time	Road Time	**TMCD/TC Costs**	**TMCD/TC Time**
Barcelona	2,148.78	3,282.00	85.18854600	81.8482	**65%**	**-4%**
Burgos	1,646.50	3,147.61	72.66260600	78.4966	**52%**	**7%**
Cádiz	1,123.82	2,254.84	56.60322692	56.2324	**50%**	**-1%**
Castellón	1,202.79	2,553.50	61.59700600	63.6804	**47%**	**3%**
C. Real	1,691.71	2,514.03	70.76559892	62.6962	**67%**	**-13%**
Lugo	1,504.15	2,900.15	69.11257000	72.3254	**52%**	**4%**
Murcia	1,155.37	2,617.50	60.41437000	65.2764	**44%**	**7%**

The assessed costs and time are shown in figure10.

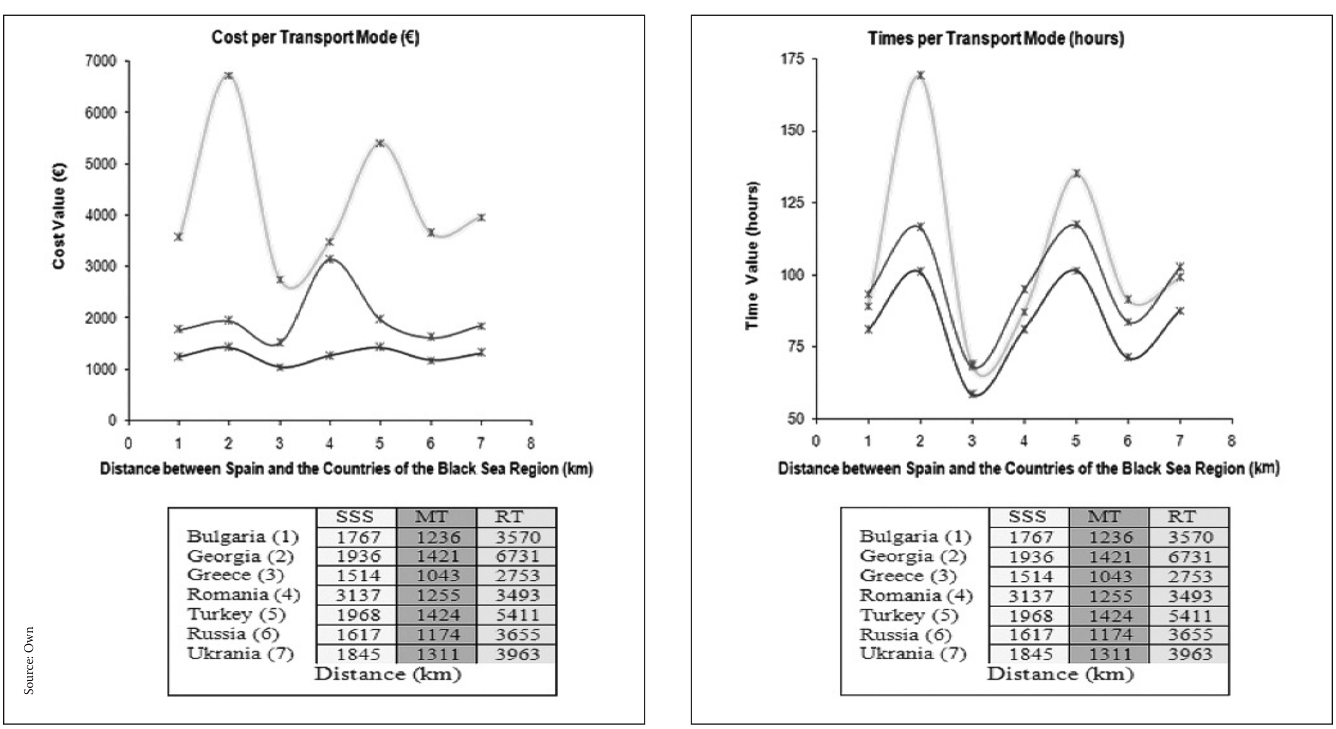


Figure 10: Graphical representation of costs and time required between Spain and the Black Sea.

6. Conclusions

A simulator for the evaluation and reporting of data to assess internal and external costs for a freight transport chain has been created. The calculation scenario is the route between Spain and the Black Sea region because of its potential in the near future.

In general terms, we found that SSS is more economical for all routes between Spain and the Black Sea region.

The "road only" option was found to account for 60% of the most favorable cases in terms of time. Routes between Spain and Bulgaria, Greece, Romania, and Ukraine take less time when using the road-only alternative.

The following results were obtained regarding the cost and time competitiveness indexes:

— The Time Competitiveness Index (TCI) determined that SSS routes between Spain and Georgia and Spain and Ukraine are the most efficient in terms of time.

— The Cost Competitiveness Index (CCIa) determined that SSS routes with the driver, truck, and trailer onboard the ship are more competitive in terms of cost than the above case.

— The Cost Competitiveness Index (CCIb) determined that SSS routes with only the trailer onboard the ship are the most competitive in terms of cost.

References

Ametller Malfaz, X. (2007): *Optimización del transporte de mercancías mediante el TMCD.* Universitat Politècnica de Catalunya.

Conforti, M. (2009): Productivity scrutinized. *7th Terminal Operations Conference. Cristoforo Colombo Congress Center*; 16-18 June, Genoa, Italy.

De Monie, G. (1989): *Medición y evaluación del rendimiento y de la productividad de los puertos*. Monographies of the UNCTAD on Port Management. 6, New York.

Dowd, T.J. and Leschine, T. M. (1990): Container terminal productivity: a perspective. *Maritime Policy and Management* 17(2): 107-112.

European Commission (2001) *The Clean Air for Europe (CAFE) Programme: Towards a Thematic Strategy for Air Quality*. COM (2001) 245.

European Commission. 2002/15/EC *Directive of the European Parliament and of the Council of 22 March, On the Organisation of the Working Times of Persons Performing Mobile Activities*, and Directive 561/2006 of the European Parliament and of the Council of 15th of March.

European Energy Agency (2002): *COPERT III,* is a project developed by the European Energy Agency in the framework of the activities of the European Topic Centre on Air and Climate Change.

European Energy Agency (2009): *CORINAIR, is an air pollutant emission inventory guidebook*, providing guidance on estimating emissions from anthropogenic and natural emission sources.

ICF (Intermodal Comparative Framework) (2005): Task 3.2 of the REALISE project *Project funded by the 5th Framework Program of the EU.*

IER: Institut für Energiewirtschaft und Rationelle Energieanwendung (2005): *Externalities of Energy*. 4th Frammework Programme of the EU. University of Stuttgart.

INECEU (2005): *Intermodalidad entre España y Europa.* Project developed under the Spanish Ministry of Transport.

ITREN-2030 (2009): Integrated transport and energy baseline until 2013 modeling project. 6th Framework Programme of the EU.IWW University of Karlsruhe (2004) *External Costs of Transport*. Update study Final report. Zurich / Karlsruhe.

Liu, Z. (1995): The Comparative Performance of Public and Private Enterprises. *Journal of Transport Economics and Policy*. September: 263-274.

Martínez de Osés, F.X. and Castells, M. (2008): Heavy Weather in European Short Sea Shipping: Its Influence on Selected Routes. *The Journal of Navigation*. 61: 165-176.

Martínez de Osés, F.X. and Castells, M. (2009): *Análisis de la aplicación del ecobono en los tráficos marítimos españoles*. Barcelona digital SL Publication.

Martínez de Osés, F.X. and Castells, M. (2009): Selection of Short Sea Shipping Transport Alternatives in SW Europe. *WMU Journal of Maritime Affairs*. Vol. 8. Nr.1: 27-45.

Mihailovici, C. (2011): Maritime Transport in The Black Sea – A Key of the Door of Europe. *Journal of Marine technology and Environment* 2(1): 67-70.

REALISE (2005): Regional Action for Logistical Integration of Shipping Across Europe. *5th. Framework Programme of the EU.* www.realise-sss.org

Recordit Project. Real Cost Reduction of Door-To-Door Intermodal Transport. (2001): *Supported by the Commission of the European Communities*. DGVII. R&D Project, Integrated Transport Chains.

Rodríguez Nuevo (2008): *Análisis medioambiental de la eficacia del transporte marítimo de corta distancia en las cadenas de transporte intermodal.* Revista del Instituto de Navegación de España 32 (2): 34-45.

Rodríguez Nuevo, M. (2010): *Diseño de un simulador de costes y tiempos, para evaluar el transporte rodado de mercancías versus transporte marítimo de corta distancia.* Thesis (PhD). Universitat Politècnica de Catalunya.

Spanish Ministry of Transport (2010): *Observatorio de costes del transporte por carretera.* Secretary of transports: 32-33.

Talley, W.K. (1994): *Performance Indicators and Port Performance Evaluation.* Logistics and Transportation Review 30(4): 339-352.

Transport & Mobility (2007): *Flemish Emission Model for Inland Shipping, Maritime Transport and Rail*. Leuven.

UNITE (2003): *Unification of Accounts and Marginal Costs for Transport.*

VITO Vision on Technology (2006): *Monitoring Programme On Air Pollution From Sea-Going Vessels*. Flanders.

Wanhill, Stephen R.C. (1974): Optimum Size Seaport -A Further Analysis.

Whall, C. et al. (2002): Quantification of Emissions from ships associated with ship movements between Ports in the Europeam Community, Report to the Europeam Commision, Entec, Northwich, UK.