Proposal of a Costs Simulator, for Traffics between Spain and the Black Sea

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Abstract: - There is a strong imbalance in EU transport mode share. In addition issues like road congestion, noise, accident rate and especially pollutant emissions result not only in external costs to society but also in high logistical costs to customers of transport services. The present paper proposes an assessment model to evaluate final internal and external costs of transport chains served by road and short sea transport as an efficient, fast tool to help customers decide on the most convenient transportation mode for a specific trade link. The links in this work connect Spanish Mediterranean coasts and the Black Sea with up to 19 Spanish provinces, with freight being imported and exported from/to Barcelona and Valencia and the main ports of Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine

Key-Words: - Short Sea Shipping, Simulator, Costs, Spain and Black Sea

1 Introduction
Both Spanish and European economies are immersed in the globalization and integration context. The current state of road transport requires a search for alternatives involving other methods of moving freight, as well as a previous analysis of crucial elements such as transport costs and times, not forgetting overruns associated with environmental damage. Current European and Spanish modal patterns have limitations hindering a balanced, environmentally-friendly freight distribution. Most import and export cargo [1] between Spain and Europe is transported by road, with numbers increasing over the last few years, thereby resulting in a polarization of the European pattern (Ministerio de Fomento, 2001; Richardson and Schwartz, 1999) [2]. This trend is leading to rising accident rates and road congestion which, in turn, generates serious environmental externalities. Excessive levels of pollution and traffic make it necessary to relief transport by promoting intermodality and Short Sea Shipping (SSS) as an alternative to road transport, thus establishing the basis for trade growth between Spain and Europe, especially in the face of the imminent entrance of candidate East and Middle European countries into the European Union. Much debate is currently taking place within the Union in order to draw up an action plan. The current state of Spanish transport is a consequence of the evolution and interaction of several internal and external factors, the most influential being transport policies, as well as Spain’s territorial and economic characteristics, e.g. orography and geographical location, distribution of population and economic activity and their peculiarities. To begin with, the Spanish terrain is highly mountainous, hindering the development of the transport network and affecting possible solutions. Specifically, the Pyrenees pass is the most critical point as it emphasizes Spain’s intrinsic peripheral nature with respect to the main economic interests and external markets within the Union or other countries having trade relations with Spain. The future development of transport will be mainly determined by sustainability and efficiency requirements such as the limit to the relative growth rate of mobility with respect to the Gross National Product, reduction in environmental impact and accident rates and improvements in safety, among others. The analysis in [3] revealed that the number of volumes exchanged between Spain and the Black Sea Region shows an upward trend. The data were obtained from figures regarding Spanish import and export operations with Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine, although the countries with the highest number of exchanges with Spain are Greece, Turkey, Russia and Ukraine (in the case of the last two as a result of Spanish crude oil imports). It is worth noting that trade operations with all these countries open the door to two big markets, i.e. Central Asia and the Middle East. Data from the Agencia Tributaria (Inland Revenue) and the
In order to calculate the number of trailers required to move the total volume of cargo, we apply the following formula:

$$N_{tr} = \frac{T_{Imp} + T_{Exp}}{18 Ton}$$  \hspace{1cm} (1)$$

where $N_{tr}$ = Total Number of tractor heads with trailers. The total volume of freight, i.e., 28,840.212,3 tons, can be converted into an approximate value (Ntr) of 1,602,234,01 (tractor heads with trailers). The daily number of tractor heads with trailers necessary to manage the total volume of freight is 4,389.68. To obtain the number of tractor heads with trailers required annually, expression (2) is applied:

$$N_a = \frac{N_{tr}}{365}$$  \hspace{1cm} (2)$$

where $N_a$ = Total Number of tractor heads with a trailer needed daily.

### 1.2.2 Analysis by countries

Exports with Bulgaria divided by sectors for all the provinces of the Spanish territory are mainly commodities, industrial products and capital goods, accounting for 68.8% of total exports and with a value of 244,461 €. On the other hand, agrifood products lead the import list with a share of 49% and a value of 167,504.34 €, followed by commodities, industrial products and capital goods, accounting for 26.7% of the total volume and with a value of 91,133.67 €.

![Export volumes share](diagram)

Figure 1. Shares of exportation volumes between Spain and the Black sea countries. Source own based on TARIC 2009.

In the case of Georgia, the main exports for all the provinces of the Spanish territory are consumer goods, accounting for 36% of the total and with a value of 5,820.31 €; agrifood products, representing 32% and with a value of 5,171.64 €; and commodities, industrial products and capital goods, accounting for 31.28% and with a value of 5,127.26 €. As for imports, commodities, industrial products etc.
and capital goods account for 93.4% of the total volume, with a value of 64,659.33 €. Commodities, industrial products and capital goods represent the largest volume of exports with Greece, with 50.4% of the total and a value of 52,972.38 €, while agrifood products account for 34.3% with a value of 42,045 €. With regards to imports, commodities, industrial products and capital goods, and agrifood products account for 49.6% and 30.3% of the total volume, with values of 13,953.27 € and 6,910.68 €, respectively.

The main exports to Russia are commodities, industrial products and capital goods, which account for 44.9% of the total with a value of 663,261.25 €, and consumer goods, representing 30% of the total volume, with a value of 442,869.87 €. As far as imports are concerned, commodities, industrial products and capital goods account for 97.6%, with a value of 4,474,967.80 k€. In the case of Turkey, consumer goods are at the top of the export list with a share of 56.3% and a value of 1,482,900.13 k€ and commodities, industrial products and capital goods represent 1,044,551.33 k€, while imports of commodities, industrial products and capital goods account for 83.8% of the total, with a value of 2,176,678.47 k€. Exports to Romania are mainly commodities, industrial products and capital goods, accounting for 61.5% of the total volume and a value of 412,431.01 k€, and consumer goods, with 23% and a value of 153,942.17 k€. Commodities, industrial products and capital goods lead the import list with a share of 51.8% and a value of 408,725.77 k€, followed by agrifood products, with a share of 28.9% and a value of 227,814.93 k€.

![Import volumes share](image-url)

**Figure 2.** Shares of importation volumes between Spain and the Black sea countries. Source own based on TARIC 2009.

Finally, exports with Ukraine are divided between 45.9% for commodities, industrial products and capital goods with a value of 86,576.38 €, and 34.5% for consumer goods and with a value of 65,044.69 €. Agrifood products account for 65.8% of the total import share with a value of 10,564.36 € while commodities, industrial products and consumer goods have a share of 30.6% and a value of 12,043 €.

## 2 Description of Main Objective

The main objective of this work is to obtain a calculation method of all costs and times associated with freight distribution. Overall costs (in €) will be calculated with results provided by a single variable, i.e. Gross Tonnage (GT), for all transport modes. The time (in hours) spent by the modes of transport to move freight between an origin and a destination will strongly depend upon the physical and operation speed of the modes employed. The obtained formulation will be subsequently validated with actual data from freight transport between Spain and Italy by SSS (since prices for these links are known). In theory, we will not accept calculation errors exceeding 10%. Validation will be performed with other simulators currently in operation. All required data will be computed by an engine generated by an Excel spreadsheet and a computer program compiled in Visual Basic, and then presented in tables and graphs. Cost-Time Simulator users will simply need to introduce an origin (o) and a destination (d).

### 2.1 State-of-the-art

After analysing all available simulators, they were divided into two groups. The first includes simulators of a practical nature and based on companies or private institutions keeping a web page where only a few variables are necessary (typically origin and destination) to determine cost or time without specifying the calculation formula or method used as the software is closed source. Two clear examples are Shortsea Promotion Centre-Spain and Rette Autostrade di Mare. Simulators in the second group calculate external costs based on theoretical studies which have had an impact on the society, such as RECORDIT and REALISE [8]. Our proposal is to bring together internal and external cost simulation.

## 3 Previous modelling work

First, functions for modelling time and cost of stages involved in the SSS logistic chain will be developed.

### 3.1 Background

The determination of cost functions and variables is crucial to analyze the feasibility of a process. Historically, the empirical estimation of port cost
functions started in the 60’s with Wanhill’s work (1974) [9], which aimed to design a model for determining the optimal number of berths in order to minimize total costs derived from port dues, in other words, berth and port time. The works by De Monie (1989) [10], Dowd and Lechines (1990) [11], Talley (1994) [12] and Conforti (1992) [13] proposed a cost analysis to appraise port performance and output by calculation of 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) [14]. The doctoral thesis of Ametller Malfaz, X. (2007) [15] describes the development of cost and time evaluation under the hypothesis of freight distribution based on population density.

3.2 Logistic chain components
In order to design the simulation model, the behaviour of freight distribution systems must be known. As is usually the case, actual systems are complex; a simple, straightforward mathematical representation therefore requires a simplification of such systems. Road haulage, port operation and maritime leg must be modelled to assign costs derived from each of the parts or components of the logistic chain. The possibility of a shift from pure road transport to a multimodal chain like SSS will depend on its particularities and conditions. At this point it is worth mentioning that the case under study is an SSS logistic chain where the truck driver does not travel on the ship during the sea leg. This situation is more likely to succeed than pure 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.

4 Methodology
The simulator is based on calculations whose results will provide a basis to the computer program and the engine for the computation of costs and times to, in turn, determine “direct” and “indirect costs” and times. Much mathematical and programming work is required, but field work is also essential to obtain real data of shipping lines, 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 “direct costs”, and costs and amount of emissions for “indirect costs” associated with each mode of transport.
2- Analysis of values of variables and determination of possible reasons for an inefficient freight transport to eventually establish its level of competitiveness.
3- Design of the program in Visual Basic to create a direct and indirect cost simulator.
4- Gathering and final analysis of obtained data.
5- Design of a mask to introduce inputs and receive the necessary outputs to serve a route and estimate direct and indirect costs of a freight transport.

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

4.1 Internal cost calculation
With regard to haulages, 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; that is, they are sometimes at a considerable distance, perhaps hundreds of kilometres, from ports. The terminal may even be located outside the port facilities. Haulage time depends mainly on trip distance and statutory driver breaks (Table 2).

<table>
<thead>
<tr>
<th>Driving time (h)</th>
<th>Rest time (h)</th>
<th>Trip time (h)</th>
<th>Trip time + 3 h Stw/Unst.</th>
<th>Trip done (km)</th>
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</table>

Table 2. Time of each process according to current legislation. Source: 2002/15/CE Directive

As far as port operations are concerned, SSS is conceived as an intermodal transport alternative where sea transport is involved at some point between the origin and destination (i, j). In terms of maritime intermodality, the Port Terminal is the key element. It seems only logical that port terminals are
one of the first elements to be known when exploring SSS operation logistics. The distance from the port of origin \((i)\) to the port of destination \((j)\) travelled by a Ro-Ro vessel is the so-call sea leg. Transport companies must pay charter fees established by the shipping company. These include transport of the platform to its destination, surveyor fees, extra charges derived from increases in fuel or trip ticket prices, and consignee services. All costs derived from operation and management of vessels will also be analyzed.

4.2 External cost calculations
The evaluation of costs derived from internal combustion gas emissions from fossil fuel engines requires a model to explain a linear regression between travelled distance and cost or gas emissions into the atmosphere. The best possible explanation is that transport, whether by road or sea, has an economic cost, as well as an environmental cost in the form of released gases. Thus, it can be deduced that the variable that best explains the reliability of the obtained expression is distance \((d_{ij}, dm)\). The cost and time calculation method will be applied again to determine costs and gas emissions into the atmosphere by a set of formulas. The final objective is to show transport-related direct and indirect costs on a simulator screen mask.

5 Conclusions
An external and internal cost simulator has been designed to allow the estimation of road and sea transport-related costs by operators interested in the Black Sea market. The simulator assumes that the European legislation on driving times is observed, and is based on a fleet of Ro-Ro vessels with similarities which enable linear regressions to be performed where tonnage is the variable to be considered.

References:
[1] Introducción y expedición constituyen conceptos análogos a los de importación y exportación respectivamente para flujos de comercio intracomunitarios.
[2] Frente a un incremento del 26% en toneladas-kilómetro entre 1990 y 1997 experimentado por la carretera, el transporte marítimo de corta distancia aumentó un 23%, según datos de la Comunicación presentada por la Comisión Europea en 1999 sobre transporte marítimo de corta distancia.
[7] ICF (Intermodal Comparative Framework); Task 3.2 of the REALISE project. Project funded by the 5th Framework Programme of the EU 2005
[8] RECORDIT: Real Cost reduction of door-to-door intermodal transport project. 4º Programa Marco de la UE and REALISE Regional Action for Logistical Integration of Shipping Across Europe. 2005. 5º. Programa Marco de la UE.