GLOBALOG: A SIMULATION CASE OF FREIGHT MULTIMODAL TRANSPORTATION

Rosa Rios Prado[(a)], Diego Crespo Pereira[(b)], David del Rio Vilas[(c)], Nadia Rego Monteil[(d)]

[(a), (b), (c), (d)] Integrated Group for Engineering Research, University of A Coruna (Spain)

[(a)]rrios@udc.es, [(b)]dcrespo@udc.es, [(c)]daviddelrio@udc.es , [(d)]nadia.rego@udc.es

ABSTRACT
GLOBALOG is a Spanish multidisciplinary project aimed at promoting logistics as a competitiveness factor. This paper presents the work carried out for the modelling and long-term analysis of multimodal transportation networks, leading to the first complete multi-regional maritime-road multimodal freight transportation model in Spain. The classical four steps approach has been adapted to the specific characteristics of multimodal freight transportation and the available data sources. Road and maritime-road multimodal mode choices have been analysed and fitted to a model based on historical data. Along with provided origin-destination matrices, a model for mode distribution forecasting has been implemented in the TransCAD transport planning software. A set of scenarios of cuts in port services fees and reductions in maritime transportation times has been analysed. Although several data pitfalls raise concerns on the validity of the numerical results obtained, this paper demonstrates the potential of this methodology for the improvement of multimodal networks.

Keywords: logistics, freight transportation, multimodal, simulation, supply chain.

1. INTRODUCTION
Improving supply chain efficiency increases the companies' competitiveness in a globalized environment. The development of logistic know-how, methodologies and practices by the use of information and communication technologies is necessary to achieve this objective.

GLOBALOG (PSE-370000-2009-11) is a project promoted by the Ministry of Science and Innovation of the Government of Spain which aims at obtaining this goal. During four years (2006 – 2010) and with a total budget of €8 million, twenty seven agents including universities, public and private R&D centres, Port Authorities and important logistic companies are involved in its development (Globalog 2011).

The project involves research activities and methods for improving supply chains and transportation networks along the next 15 years. The scope of the project is shown in the organizational scheme in Figure 1. It comprises a series of subprojects addressing the improvement of the characteristic elements involved in the management of logistic processes of different types of supply chain.

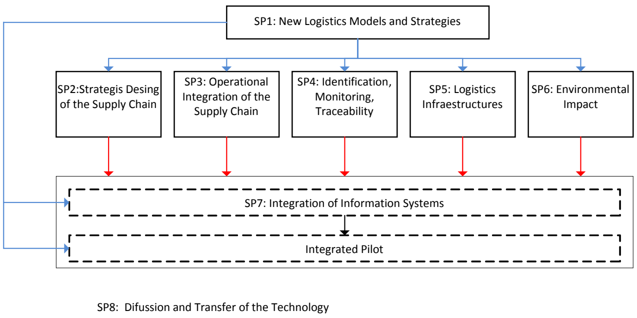

Figure 1: GLOBALOG Work Packages Diagram

This paper describes the work carried out within the Subproject 5 (Figure 1) by the Integrated Group for Engineering Research (GII) of the University of A Coruña (Spain). The objective of the SP5 is the assessment of new logistic infrastructures for the Spanish freight transportation between the Spanish Mediterranean and Atlantic regions. To do so, a simulation-based multimodal transport modelling has been developed.

The maritime-road multimodality option is the chosen one due to some reasons. On the one hand, in Spain most of the freight transport is carried out by road. This initiative will provide with recommendations in order to promote the use of alternative transport modes. As a consequence, it will reduce the possible road congestions and the CO_2, NO_x, and other emissions. On the other hand, the European Authorities specifically support this intermodality by means of several initiatives and legislation. The "White Paper- European Transport Policy for 2010: Time to Decide" (EC 2011) gathers the state of the transports nowadays and some objectives for the future of the transport. It highlights the problems of congestion and pollution among others, which would be prompted by an increase of 50% of road freight in 2010. The Marco Polo project (Marco Polo 2011) follows the objectives of the White Paper. This project attempts to reduce the congestion of the road infrastructures and to improve the transport effects on the environment by transferring part of the road freight to the Short Sea Shipping (SSS), railway and inland waterways.

Other initiatives related with the above mentioned are the promotion of the SSS and the Motorways of the Sea (MS) concept. SSS is the movement of cargo and passengers by sea between ports situated in geographical Europe or between those ports and ports situated in non European countries having a coastline on the enclosed seas bordering Europe (SSS 2011). A Motorway of the Sea is a sea length between ports that are also interconnected with transeuropean networks and intermodal corridors, safeguarding social cohesion, providing with an efficient intermodal system where goods are rapidly transferred between different modes through the optimization of port operations, overcoming natural barriers and sensitive areas and other geographical obstacles (MS 2011).

Finally, the opportunity of future exploitation has been considered. The strategic location of two new important port facilities on the Atlantic Spanish shore would play an active role in attracting freight flows from the Panama Channel extension, serving as hub ports for successive feeding operations.

All this expresses that the maritime-road multimodality is a highly opportune option, not only for the know-how improvement but the utility of the model to evaluate the options promoted by Europe.

The road-railroad multimodality has been also considered. However, nowadays railroad is losing market share and the Spanish infrastructure is insufficient. Besides, the current period of crisis does not seem to be the best moment to invest in those infrastructures. The present investments in this kind of transport have the goal of finishing the started building works related to high speed lines for passengers transport.

A Modelling and Simulation (M&S) approach for the multimodal freight transport is a total innovative initiative. As a consequence, a great previous data collection, infrastructure characterization and decision maker behaviour modelling have been developed. On section 2, those previous works will be described, together with the simulation tool and the methodology. In section 3, the scenarios and results of the experimentation will be explained. The lack of appropriate public data and other limitations that appeared during the study are provided in section 4. Finally future work lines and conclusions are described in sections 5 and 6.

2. THE MODEL.

2.1. Data collection.

A first phase in the model construction is to identify the possible sources of information and the available data.

As this is a transport model, it is necessary to know the freight flow. It will be considered the road freight flow, because it is the transport mode that is wanted to decongest. The Road Freight Transport Permanent Survey of the National Statistics Institute of Spain (INE) provides with the Origin-Destination (OD) Matrix, in thousands of tonnes, between Spanish Autonomous Regions. These goods are not separated by their nature.

A GIS (Geographic Information System) has been developed by other member of the subproject 5 providing the graphical part and geographical data needed to define the traffic analysis zones and the network used for the transport. The road lengths are an example of the data that can be obtained from the GIS.

Other source of data for road transport are the documents from the Observatory of Road Freight Transport of the Ministry of Public Works of Spain. These documents gather the road freight transport costs depending on the vehicle used, and also the terms of this cost chain.

In the maritime case the cost chain has been generated by the research group. Later on the paper, the construction of this cost chain will be described. The data needed come from official organizations related with the maritime realm. Particularly they come from Yearbooks of the State Ports, reports from Manager's Office of the Naval Sector, Ministry of Industry, Tourist and Trade, web sites of the shipping companies and legislation.

It is also necessary to know the sea lengths between ports, because although sea transport does not need physical infrastructures it follows the lines of the navigation charts. These lengths have been obtained on a website for merchant navy captains (Capitanes, 2011).

Finally the relevant legislation has been taking into account such as E.U. Regulation nº561/2006 that explains the break time for road transport.

2.2. The tool.

TransCAD is the tool chosen for the transport simulation. It is a software package that fully integrates GIS with demand modelling and logistic functionality.
This software has been specifically developed for passenger transport modelling.

2.3. Previous Steps: TAZs and Network definition.

As mentioned, the model is for freight transport so the first step is to decide the origin and destination of the flows. Then it has to be defined the network used for the transport.

These zones are the Traffic Analysis Zones or TAZs. They have to be capable to generate or to attract significant amounts of goods, so two criteria are used to choose them. A first criterion is the relation with the supply chain. Freight terminals, Logistic Centres and Ports are important points of generation and attraction of goods. But the population also consumes and generate freight, so the second criterion is related with the number of inhabitants in a zone. Figure 2 shows the TAZ used in GLOBALOG.

Figure 2: TAZs for GLOBALOG.

As stated in the introduction, the road and multimodal (road-maritime) options will be modelled; therefore the needed network must include the Spanish roads and a set of maritime lines to build the multimodal chain. The roads used (motorway, dual carriageway, main national roads) come from the developed GIS for the project.

For the maritime net, the GII has carried out a layer with the maritime legs. The proposed maritime lines come from the reutilization of the regular commercial routes and the routes of internal cabotage approved by the Ministry of Public Works which exist nowadays. The length of these legs is the real distance by sea between ports, obtained in the before-mentioned website for merchant navy captains.

2.4. Transport unit.

The transport unit chosen has to be compatible with all transport modes. So TEU (Twenty Foot Equivalent Unit) is the transport unit chosen.

This unit is a container of twenty feet, widely used in maritime transport, and that can be used in road transport by a container vehicle.

2.5. Transport Modes Characterization.

The characterization of the transport modes is a function of two main characteristics: time and cost per transport unit.

Besides, time and cost are a function of the travel length so these lengths are calculated. TransCAD is used to obtain them, by short path methods.

2.5.1. Road time:

It has a part function of the speed and length and another function of the break time regulation (E.U. Regulation nº561/2006).

This allows us to build a function for road time. As it can be seen for a particular stretch, time is the addition of the time $t_{ij} = \frac{l_{ij(km)}}{v_{(km/h)}}$, where l is the length in kilometres and v the speed in kilometres per hour, and the break time derived of the regulation. In this case the speed is 80 km per hour. The travel distance versus the real time is represented on Figure 3. As a result, the time function is obtained (Equation 1).

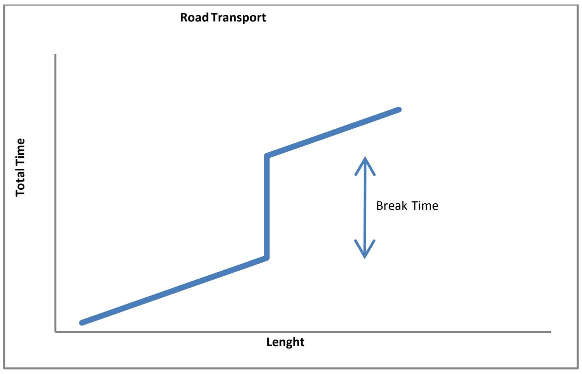

Figure 3: Total Road Time

$$t_{ij} = 0.0254 \times d_{ij} \qquad (1)$$

2.5.2. Road cost.

Data of the Observatory of Road Freight Transport is used to obtain the road cost. This Observatory gives the cost per km and per type of vehicle. It is calculated as an addition of the following elements:

- Vehicle amortization.
- Vehicle financing.
- Staff.
- Insurance.
- Fiscal Cost.
- Allowance.
- Fuel.
- Pneumatics.
- Maintenance.
- Repairs.

This division allows building the cost which directly depends on the distance and the one that depends on the time.

2.5.3. Multimodal Time.

The multimodal chain is made up of road and maritime transport. So the total time is the sum of both of these times. The road time is calculated as previously shown.

The travel time by sea is calculated by the following expression:

$$t_{ij} = \frac{l_{ij(km)}}{v_{(km/h)}} \qquad (2)$$

where v is 33.3 km/h=18 knots, that is the average of the speed of the vessels working in regular lines that have been employed to build the maritime geographic file. The vessel loading and unloading times and the routes scheduling are related to the waiting time in port when transhipment operations are required.

Table 1: Summary of Costs.

Type	Cost	Formula	Unit
Road	Travel	$C_{ij} = 1.167 \times d_{ij}$	Euros
	Inventory	$C = \propto \times 0.0254 \times d_{ij}$	€/TEU
Port	Operations	$C_{op} = 43.26 \times S^{0.847}$	€
	Inventory	$C_{inventory} = \propto \times T_{op}$	€/ TEU
Sea	Capital	$C_{capital}(S) = 0.22 \times S$	€/day
	Maintenance, Insurance, Repairs	$C_m = 0.008 \times S$	€/ day
	Crew	$C_m = 322.61 \times S^{0.094}$	€/ day
	Taxes	$C_{taxes}(S) = 1.58 \times \frac{S}{100} + 57.69 \times 0.347 \times S^{0.84771} + 0.80 \times \frac{S}{100} + 0.7199 \times S^{0.6204} + 67.03 \times T_{op}$	€/stop
	Fuel	$C_{fuel} = 0.10 \times S^{0.738}$	€/ day
	Inventory	$C_{inventory} = \propto \times \frac{d_m}{v}$	€/TEU

2.5.4. Multimodal cost.

As is the case of time, the multimodal cost is the sum of maritime and road cost. Road cost is calculated as said before.

The cost chain for maritime transport has been determined. This chain includes the following elements:

- Cost of Capital.
- Maintenance, Insurance, Administrative Taxes.
- Crew.
- Port Taxes.
- Fuel.
- Inventory.
- Port Operations.

These costs are calculated as a function of the Gross Tonnage, GT, (S, in Table 1) of the vessel.

2.6. Methodology.

The following task is the construction of the simulation model. The Four Steps Model is the methodology used to build the transport model. This is frequently used for passengers transport but not for freight transport, so some approximations had to be done in order to use it for freight transport simulation.

The four steps are:

1. **Trip Generation**. Estimates the extent, for a given spatial unit, for which it is an origin and destination of transport movements.
2. **Trip Distribution**. Commonly a spatial interaction model that estimates movements between origins and destinations and which can consider constraints such as distance.
3. **Modal Split**. Movements between origins and destination are then disaggregated by modes. This function depends on the availability of each mode, their respective costs, and preferences.
4. **Traffic Assignment**. All the estimated trips by origin, destination and mode and then "loaded" on the transportation network, mainly with the consideration that users want to minimize some kind of "cost" ("cost" = length, for example).

This approach starts by considering a zoning and network system and the collection and coding of planning, calibration and validation data (Ortúzar and G. Willumasen 2011), as shows in Collection Data and Previous steps sections.

As said before, this methodology is widely used for passengers transport but not for freight transport. So an original approach has to be made to use it. Figure 4 depicts this approach.

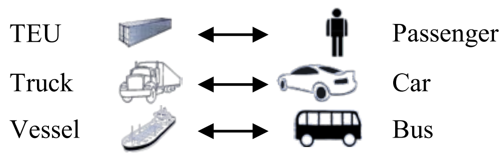

Figure 4: Similarity Relationship between Passengers and Freight Transport.

2.6.1. Trip Generation.

In this case the OD matrices are known, so the Trip Generation Modelling is not necessary.

These matrices are data of freight transport from National Statistics Institute of Spain, and their units are thousands of tonnes. The flows are between Autonomous Regions.

The definition of the project marks the election of the TAZs. In the Previous Steps point appears the TAZs chosen and the criteria for the election.

2.6.2. Trip Distribution.

The TAZs represented a level of aggregation lower than Autonomous Regions. Accordingly, a population criterion is used to disaggregate the data of the OD matrices. A population weight, for every pair Origin-Destination, is calculated in the following way:

$$w_{ij} = \frac{p_i \times p_j}{\sum_A p_i \times \sum_B p_j} \quad (3)$$

Where:

p_i TAZ Origin Population
p_j TAZ Destination Population
A Autonomous Region of the TAZ Origin
B Autonomous Region of the TAZ Destination

These weights multiply the flow between *A* and *B* and give the flows between *i* and *j*. It can be seen easily with an illustrative example.

$$w_{Vigo\_Oviedo} = 0.114$$
$$T_{Galicia\_Asturias} = 2694.10 \cdot 10^3 \, tonne / year$$
$$t_{Vigo\_Oviedo} = 0.114 \times 2694.10 \cdot 10^3 = 307.13 \cdot 10^3 \, ton / year$$

The transport unit is not tonne but TEU. To convert tonnes in TEU, the flow between TAZs is divided by 20 tonnes (average weight of a TEU). The data are per year, so these data are divided by 365 days per year to obtain values per day.

All of this allows building the OD Matrices between TAZ per day and with units in TEUs.

2.6.3. Modal Split.

The Modal Split is a key part of the model. It determines which fraction of the flow between each origin-destination pair uses each mode. A widely employed statistical model is the Multinomial Logit Model (MNL). It consists of a logit function that weights the attractiveness of each transportation mode given by a utility function. Standard methods for fitting MNL rely on datasets of paired observations of utility drivers and single realizations of the chosen mode. They are usually gathered by means of a Mobility Survey or a Market Research.

However, as it was not within the original scope of the Globalog project, the lack of a market research or survey task to provide us with has significantly hampered our advancements. Also, as many other European countries, Spain lacks of a nationwide survey to cope with this point as well. Historical data of flows by mode were employed instead. This raises two issues. The first is that the model's ability to forecast results out of the historical data range is severely harmed. The second is that the MNL fitting method implemented in TransCAD could not be applied to data in which the mode choice variable is a fraction instead of a binary variable, so it had to be fitted by means of an external tool (the R free statistical software environment, 2011).

A simpler logistic regression model (Equation 4) was selected instead of an MNL due its lower number of parameters for an obtained similar quality of fit. The one utility function per mode approach of MNL was replaced by a single utility function that represents the *relative* attractiveness of multimodal transportation compared to that of road transportation. The selected utility drivers were the relations between road and multimodal costs and times.

$$p(U_{MM/R}) = \frac{1}{1+e^{-U_{MM/R}}} \quad (4)$$

Several different utility functions were tested. The one found to be more statistically significant was a linear model that includes a first order interaction effect as well. Equation 5 shows the fitted model

$$U_{multimodal,q} = \beta_0 + \beta_1 \times \frac{C_r}{C_m} + \beta_2 \times \frac{T_r}{T_m} + \beta_3 \times \frac{C_r T_r}{C_m T_m} \quad (5)$$

Table 2 presents the parameters values and their significance levels. It can be seen that all the selected factors are useful for predicting the mode choice. The negative value of β_2 implies that, within this model, an increase in multimodal transportation times would increase its utility. This is a hardly reliable result. However, this term is dominated by the interaction term so that an increase in multimodal time leads to an overall reduction of its utility. Figure 5 shows a surface response curve for the predicted multimodal absorption rate versus the costs and times relations. It can be noted that cost and time relations that are separately favourable to multimodal transport, lead to low multimodal rates. It is the combination of favourable time and cost relations that poses a noticeable effect in multimodal flow absorption rates.

Table 2: Results of the Logistic Regression.

Coef.	Value	Std. Err.	t-value	p-value	S.L (†)
β_0	-3.948	0.260	-15.209	< 2e-16	***
β_1	1.161	0.545	2.130	0.0340	*
β_2	-3.794	0.974	-3.895	0.0001	***
β_3	8.955	1.928	4.644	5.02E-06	***

(†) Significant Level codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '1

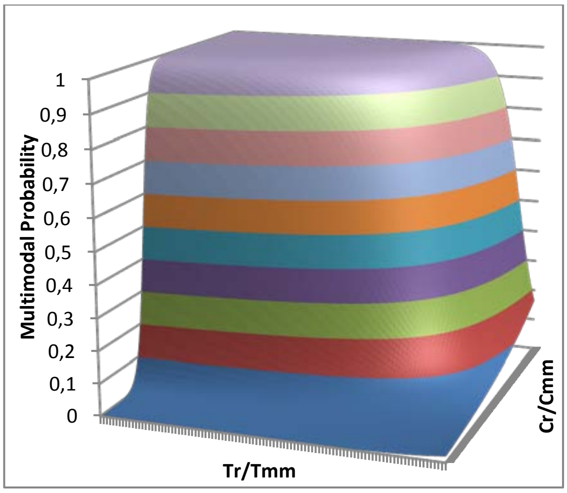

Figure 5: Multimodal Probability.

Then the multimodal utility function is:

$$U_{multimodal,q} = -3.948 + 1.1606 \times \frac{C_r}{C_m} - 3.7944 \times \frac{T_r}{T_m} + 8.955 \times \frac{C_r T_r}{C_m T_m} \quad (6)$$

Where C is the cost (in €/TEU) divided by 100 and T is the time divided by 10 (in h/TEU), both for the same trip between Origin and Destination.

Concerns on model's validity are raised by the negative value of β_2 and the trend for the model to predict multimodal absorption rates near 100% for OD pairs favourable to multimodal in terms of cost and time. This absorption rate is not realistic since there are non-accounted factors in the model that would restrain the flow of certain types of freight through the multimodal network. However, given the limitations in the provided data, a greater effort in this modelling step was disregarded. The only way for improving model's validity would be by means of a larger dataset. Still, the model is useful for estimation of model choice as far as the studied scenario keeps close to the historical data employed, which fits relatively well.

2.6.4. Traffic Assignment.

The last step of the model is the Traffic Assignment Modelling. The traffic assignment model predicts the network flows that are associated with future planning scenarios.

The method used in the project is the "All or nothing" one. This method assigns all traffic flows between Origin and Destination pairs to the shortest paths connecting them. Yet this is not the most appropriate method as it ignores the fact that link travel times are flow dependent, the lack of data -like road capacity- prevents the use of more accurate methods.

In the Model Split point the obtaining of the probabilities of every transport mode was presented. Multiplying these probabilities by the OD Matrices, the OD Multimodal and OD Road Matrices are obtained. These are the matrices that we have to use in the Traffic Assignment. Figure 6 shows an example of this assignation.

Figure 6: Traffic Assignment Example.

3. EXPERIMENTATION

3.1. Scenarios.

Once the transport model has been built, it allows doing a set of simulations. The objective of these simulations is to evaluate the influence of the changes on the transport variables over the decision makers' choice.

The variables that characterize the transport are time and cost. So these are the variables which could be varied. Time only changes if changes in technology, infrastructure or legislation occur.

For road transport, we suppose that the changes in technology will not be as important as for entailing a large decrease on the travel times. Furthermore it would have to go accompanied by a legislative relaxation in terms of transport, in clear opposition with nowadays restrictive trend. So we will not vary the road time in the scenarios.

But in the case of maritime time the speed used in the model is the average speed of the vessel that operated in the regular lines used. This speed is 18 knots, but the speed of this kind of vessels varies between 15.5 and 26 knots. Another variable time in the maritime transport is the waiting time, whenever transhipments of containers are carried out.

Another issue that give us the framework to define the scenarios is that provided by the Spanish law 33/2010 about the liberalization of port management. In other countries this kind of initiatives has led to the decrease in port taxes, so the decision of scenarios with this kind of decrease seems to be justified.

The work strives for identifying the conditions that increase the multimodal transport choice. As a result, the scenarios to assess are due to variations in multimodal cost and times.

The first proposed five scenarios involve a proportional decrease of the taxes, as shown in Table 3.

Table 3: Scenarios Variables.

Scenario	Annual Decrease	Total Decrease	Vessel Speed (knots)	Max Waiting Time (days)
E1	0.67%	10%	18	--
E2	2.00%	30%	18	--
E3	2.67%	40%	18	--
E4	3.33%	50%	18	--
E5	4.67%	70%	18	--
E6	4.67%	70%	26	1
E7	--	--	26	1
E8	--	--	22	3

In terms of time, two scenarios are evaluated. The first one jointly considers a maximum waiting time for a container of one day, and a vessel speed of 26 knots (E7). The second one supposes a maximum waiting time in port of 3 days and 22 knots of vessel speed (E8).

The last scenario (E6) is a combination of 70% taxes decrease, 1 day for maximum waiting time and 26 knots of speed.

3.2. The Results.

The work aims at assessing the possible absorption of road flows by multimodal transport. So the freight that is being distributed between both modes is the forecast of the road freight. Thus, two ways for the assessment of the obtained results are proposed.

The first one takes into account all the containers moved between TAZs, except those ones moved within a TAZ. Figure 7 and Figure 8 show the percentage of multimodal and road transport for this option.

In all cases time and taxes cuts cause increases on the multimodal flows, but limited to a 3.1% for the best scenario in the last year of the simulated period. Probably these poor values are because of the considered multimodal network, as the sea legs of the multimodal route are not specifically designed for it and the waiting times and lengths are too long for a short shipping operation.

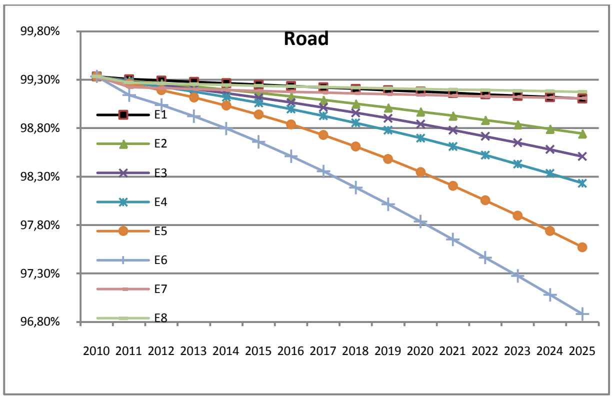

Figure 7: Road Percentage.

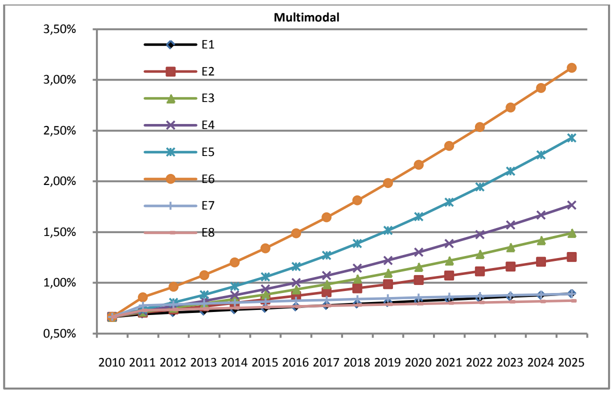

Figure 8: Multimodal Percentage.

The second option to evaluate the results comes from the EMMA study (European Marine Motorways Study) which states that the optimal distance between ports for Short Sea Shipping is between 500 km and 1400 km. So this second option takes into account the flows between TAZs separated by sea distances higher than 500 km. So we consider the flows between the TAZs in the Atlantic cost and the TAZs in the Mediterranean. Figure 9 and Figure 10 show these second values.

In this case the values are a slightly better than in the previous one. The better scenario (E6) allows reaching a multimodal quota near to the objectives of the National Strategic Plan for Freight Transport (PEIT). PEIT pursues a participation share for multimodal transport of 8-10% in 2020.

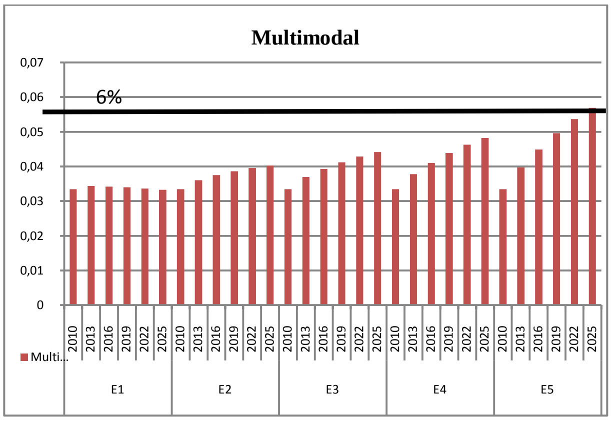

Figure 9: Second Option. Multimodal Absorption Percentages (a).

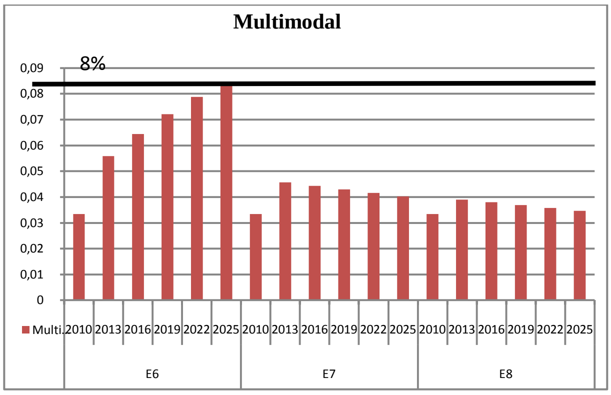

Figure 10: Second Option. Multimodal Absorption Percentages (b)

Another observed result from the experimentation is the variation of the multimodal transport absorption with the accumulation of the taxes reduction. In the following table we can see the increase on the flows respect the initial one corresponding to a 1% increase in the taxes diminution.

Table 4: Flow Increment.

Scenario	% Flow Increase Over Initial Year
E1	6.05
E2	3.21
E3	2.91
E4	2.76
E5	2.62

4. LIMITATIONS FOUND.

The development of the project shows a set of limitations in the freight transport theme, in the Spanish case.

4.1. OD Matrix:

Available data are between Autonomous Regions and without distinguishing the nature of the goods transported. OD Matrices for every kind of good are important. Also the origin and destination should be considered in a spatial level lower than Autonomous Regions, as province or municipality.

4.2. Characterization of the transports:

Cost chains could not be found for each of the transport models used in the model, particularly multimodal cost chain has been an original development of this work. Another type of problem is the graphic documentation. The geographic layer of the maritime transport has been also specifically developed by the GII research team.

4.3. Mobility Survey and Market Research:

The choice model requires a set of data to be introduced in order to create the decision function. These data assess the decisions taken by a number of components with certain features on a range of means of transport, from which their characteristics are known. They are usually obtained from a survey of mobility in the case of passenger transport, and in a market study, for freight transport.

- These market studies are not available. Therefore, to solve this absence a "survey" with the available data has been generated. Thus, we have characterized the transport time and cost.
- A complete study would take into account a number of variables that would make the model more robust. There are features of transport, more qualitative than quantitative, which greatly influence the decision, such as perceptions of risk. There are also very important reliability data, difficult to quantify and obtain.

4.4. Geographic Information System.

Although the GIS has not meant a limitation - as it has been developed for the project- it is desirable the availability of a general nature GIS adapted for analysis tasks and not only for graphical representation. It should collect data on all existing transportation infrastructure in the country, as well as demographic, economic, travellers and goods data available.

5. FUTURE WORK.

As a consequence of the project development, some future works are intended.

- Development of specific routes designed for multimodal transport. Routes used in the model are existing regular routes, and therefore the vessels and waiting times are not specifically designed for multimodal operation. This is in line with initiatives such as motorways of the sea, for example Vigo-Saint Nazaire or Gijón- Saint Nazaire, but limited to national territory. The development of such routes would be clearly consistent with the objective of improving the companies' supply chains.
- Environmental impact assessment. The use of multimodal chain removes items of road transport. This implies a reduction of emissions from the combustion process. The development of emission models for these modes of transport would assess the amount of emissions savings.
- Intensive study of the elements of cost chains. A particular example of this is fuel costs. In the current situation of rising oil costs is very important to study the plausible scenarios of evolution.
- Development of multimodality option with the railroad. The establishment of multimodal model and the needs of its construction lay the foundations to develop the rail option. This is limited by the possibility of acquiring all the necessary data from this transport.

6. CONCLUSIONS.

This paper presents the first comprehensive and effective approach to the development of a simulation model of multimodal freight transport in Spain for the evaluation of interregional flows. The classical four steps approach has been adapted to the specific characteristics of multimodal freight transportation and also to the available data sources. Road and maritime-road multimodal mode choices have been analysed and fitted to a model based on historical data. Along with provided OD matrices, a model for mode distribution forecasting has been implemented in the TransCAD transport planning software. A set of scenarios of cuts in port services fees and reductions in maritime transportation times has been analysed.

ACKNOWLEDGMENTS

We wish to express our gratitude to the Ministerio de Ciencia e Innovación of the Government Of Spain and the European Union which funded this project through the European Regional Development Fund.
(PSE-370000-2009-11)

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Project Part-Financed by the European Union
European Regional Development Fund

REFERENCES

Ametller Malfaz, X, 2007. *Optimización del transporte de mercancías mediante el transporte marítimo de corta distancia.* Minor Thesis. Universitat Politécnica de Catalunya.

Capitanes, 2011. *Capitanes website*. Available from: http://www.capitanes.com [accessed 1 July 2011]

García Menéndez,L. and Feo Valero, M, 2009.European Common Transport Policy and Short Sea Shipping: Empirical Evidence Based on Modal

Choice Models. *Transport Reviews,* 29(2),239-259.
Globalog, Official Project web. Available from: http://www.pse-globalog.org/category/sobre-globalog/ [accessed 1 July 2011]
Ortúzar, J. D and Willumsem., 1994. *Modelling Transport.* 3nd ed. Wiley.
Port Authority Of Gijón, 2008. *Annual Report.*
Port Authority Of A Coruña, 2008. *Annual Report.*
Port Authority Of Vigo, 2008. *Annual Report.*
Port Authority Of Marín, 2008. *Annual Report.*
Port Authority Of Bahía de Algeciras, 2008. *Annual Report.*
Port Authority Of Alicante, 2008. *Annual Report.*
Port Authority Of Valencia, 2008. *Annual Report.*
Port Authority Of Barcelona, 2008. *Annual Report.*
Port Authority Of Tarragona, 2008. *Annual Report.*
R, 2011. *What is R?.* The R Foundation for Statistical Computing. Available from: *http://www.r-project.org/* [accessed 1 July 2011]
Washington, S.P, Karlaftis, M.G. and Mannering, F.L. 2003. *Statistical and econometric methods for transportation data analysis.* 1st edition, ed Chapman & Hall books.

AUTHOR BIOGRAPHIES

Rosa Rios Prado works as a research engineer in the Integrated Group for Engineering Research (GII) of the University of A Coruna (UDC) since 2009. She holds an MSc in Industrial Engineering and now she is studying for a PhD. She has previous professional experience as an Industrial Engineer in an installations engineering company. She is mainly devoted to the development of transportation and logistical models for the assessment of multimodal networks and infrastructures.

Diego Crespo Pereira holds an MSc in Industrial Engineering and he is currently studying for a PhD. He is Assistant Professor of the Department of Economic Analysis and Company Management of the UDC. He also works in the GII of the UDC as a research engineer since 2008. He is mainly involved in the development of R&D projects related to industrial and logistical processes optimization. He also has developed projects in the field of human factors affecting manufacturing processes.

David del Rio Vilas holds an MSc in Industrial Engineering and has been studying for a PhD since 2007. He is Adjunct Professor of the Department of Economic Analysis and Company Management of the UDC. He has been working in the GII of the UDC as a research engineer since 2007. Since 2010 he works as a R&D Coordinator for two different privately held companies in the Civil Engineering sector. He is mainly involved in R&D projects development related to industrial and logistical processes optimization.

Nadia Rego Monteil obtained her MSc in Industrial Engineering in 2010. She works as a research engineer at GII of the University of A Coruna (UDC), where she is also studying for a PhD. Her areas of major interest are in the fields of Ergonomics, Process Optimization and Production Planning.