ROAD TRANSPORT VS. RO-RO: A MODELLISTIC APPROACH TO FREIGHT MODAL CHOICE

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1. INTRODUCTION

During the last years, due to the rapid growth in transportation demand (both in freight and passengers traffic) and because of the prevalent use of road transport, in some of the most important highways and state roads a frequent situation of congestion is visible, with low level of service and high social costs. This is one of the reasons why research has been carried out on freight traffic and modal choices to find some measures that can switch lorry traffic from roads to alternative modes or routes, both traditional (maritime and railway transport) and combined ones.
In every type of combined transport the co-ordination between all the operators from the origin to the final trip destination is one of the most important conditions to improve the service; the presence of an operator that could plan the whole "supply chain" is particularly important, in order to make the combined transport similar to a mono-modal one. In this context recent studies, focused on the Italian national freight movement, proved that the progress of short sea shipping (in particular in the form of combined Ro-Ro transport), depends on the presence of a Multi-modal Transport Operator (M.T.O.).
Recently, in Italy road-sea combined transport supply system has improved rapidly; some private shipping companies are introducing new vessels for freight movement and a large part of lorry-drivers consider Roll-On/Roll-Off (Ro-Ro) lines particularly useful to avoid congestion roads or some critical situations. Some haulage companies have also created new logistic solutions, such as the "non-accompanied" combined transport and the loading of the semi-trailers only. In the Tyrrhenian Sea national Ro-Ro lines are prevalent, and in the Adriatic Sea the international relations with Turkey, Greece and the Balkan Countries in general are rapidly increasing.
This increasing combined transport demand points out all the structural and operational limits of maritime transports and, in particular, of port services for these reasons:

- lack of operating areas near and behind the port wharfs;
- lack of controlled areas for trucks and trailers before the next departure or after the last arrival;
- lack of connections between the port and the inland road supply system.

Despite of these difficulties, in Italy and in particular across the port of Trieste there are some efficient examples of transport alternatives using Ro-Ro technology. One of the most important is the regular maritime liner service between some Turkish ports and Trieste, both for the increasing success of

the service and for the total freight movement. This one represents a particular example of integration between all the transport operators.
This system has been studied to understand the innovative elements of the maritime supply underling the factors that guaranty the competitively of this complex service.
This one and other national and international Ro-Ro lines in the Mediterranean Sea can prove the possibilities of this alternative transport mode, as it is sustained from the E.U. and, in Italy, from the last P.G.T.L. (Transport and Logistic General Plan). In Italy, for example, the development of the so-called “Sea Highways” (national Ro-Ro routes across the Tyrrhenian and the Adriatic Sea) is one of the most important and current projects within the planning process of national freight movement.
Recent studies, based on different approaches, have been carried out in order to analyse the opportunity to insert combined alternatives (or to improve the existing ones) in the reference transport scenario. In the technical and scientific literature on this topic, two main approaches may be found to study the freight modal split between a combined transport mode and a traditional one: the first one consists in the analysis focused on the economic feasibility of some particular routes in a limited transport area (this is required in a executive level of any project), while the second one focuses on the same problem from a general point of view and lacks of a practical application.
The paper presents and discusses the process for the construction of an aggregate modal choice model between two transport modes for freight flows; the study aims to understand which attributes of the supply system are really important to measure the preferences of users and so to simulate modal split of freight flows. The proposed approach permits to:

- estimate the variations in demand and the preferences of users with regard to changes in the transport system characteristics;
- propose some possible scenarios verifying the opportunity to insert combined alternatives in the Adriatic Area and across one of the most important port (Trieste).

The study is composed of four principal steps:

1. analysis of freight transportation demand in road transport and in Ro-Ro lines in 1998, with no distinction between different types of goods. This leads to three O/D matrices: a national one, another one about the route between Turkey and Central-Western Europe and the last one referred to the road transport demand from the Centre and the South of Italy to the Central and Oriental Europe;
2. analysis of the attributes of the present transportation system for all O/D couples given from the study on the demand; the attributes of each level of service are macroscopic ones, such as the frequency of the service, the total travel time from origin to destination, the operating costs.
3. given the transport demand and the relative supply level of service, a binomial logit expression has been used to simulate modal choices through random utility models; some different utility functions have been obtained after a detailed calibration process. These mathematical expressions differ for the attributes considered.
4. given the utility functions, new possible improvements in the transport system characteristic have been proposed and a new split of freight

has been estimated (for example the average increase of lorry journeys through the port of Trieste).

2. DEMAND ANALYSIS

The analysis of freight demand depends of course on the target of the work. In this case the aim is to analyse the possibilities of the combined road-sea transport in the Adriatic Sea and mainly across the port of Trieste, for both national and international traffic flows. So, all freight flows realised in 1998 in the two transport modes (road and combined road-sea transport) have been analysed in three principal areas:

- exportation from Turkey to the European Countries;
- Italian freight flows;
- exportation from Central and South Italy to the Central and Eastern European Countries.

These data have been collected and analysed with reference to a particular zoning that again depends on the aims of the paper. The considered zoning is related to the reference market of Trieste port, as reported in the figure below.

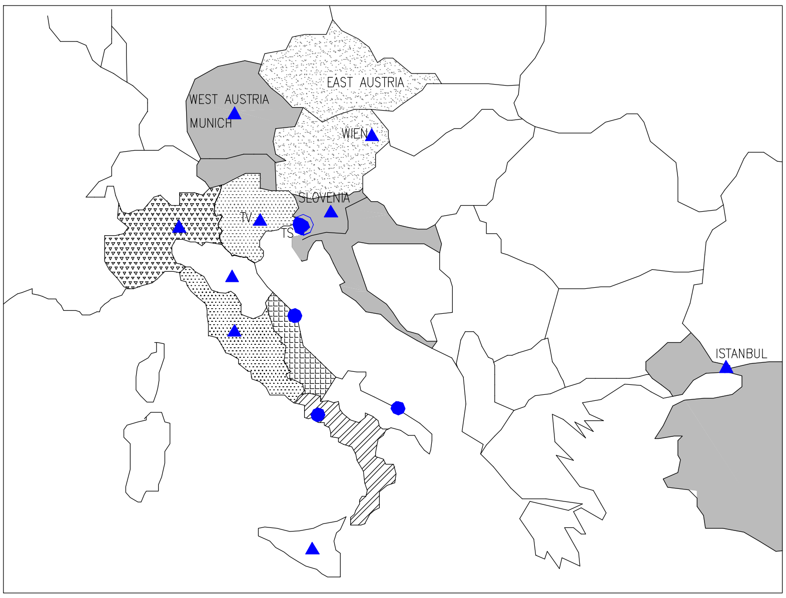

Figure 1 – Zoning and regions involved

Twelve zones have been used: eight zones for Italy, a single one for Turkey and the last three zones include respectively the Western part of Austria and the South of Germany (Bayer), the Eastern part of Austria and Czech Republic, Slovenia and Croatia.
Only links where an inter-modal alternative with Ro-Ro ships is possible and interesting have been finally considered within the model.

2.1 Turkey-Europe

Exportations from Turkey to Europe in the two alternative transport modes (road and sea-road combined transport) have been studied according to the data included in International Transporters Association (1999).
In 1998, the total number of journeys from Turkey to the reference area of the Adriatic port had been about 27000 and 35000 for road and combined transport respectively; at the same time, the journeys directed to the other Countries of West and Central Europe have been about 18000 and 13000 in the same order.

2.2 Italy demand

In this case, the collection of useful data is not so easy: in fact freight demand data are sometimes confidential and they depend on the different sources because each collection of data is strictly connected to the objective of the research. For these reasons, more than one sources have been considered in order to obtain a complete O/D matrix for Italian national freight traffic. ISTAT (Italian State Statistical Bureau), and C.N.T. (National Transport Council) were the principal sources of data.
In Italy measures that can switch lorry traffic from roads to alternative routes are not applied from the Government, and so the social benefits guaranteed by the development of combined road-sea or rail-road modes are not take in account by national policy; that's why recent improvements in short sea shipping supply system have not reduce road transport dominance. Despite of these difficulties, combined road-sea transport represents an efficient alternative route to pass some critical nodes or links caused by high traffic flows; for example Ro-Ro lines in the Adriatic Sea are Venezia-Bari-Catania and Catania-Ravenna, and in the Tyrrhenian Sea are Napoli-Palermo, Livorno-Palermo, Livorno-Catania and Genova-Palermo.
As an example of the possibility of Ro-Ro routes to divert lorry traffic from the road to alternative routes, freight flows (tons) between North-West Italy and Sicily were in 1998 about 994000 t. and 408000 t. for road and road-sea combined transport respectively. In the other origin/destination couples, traffic flows are much more unbalanced between the two transportation modes; moreover it seems important to note that also a small (in percentage) modal split from road to alternative combined transports could signify a relevant improvement in road traffic flows conditions, levels of service and safety.

2.3 Exports from Italy to Europe

The reference market of Trieste port has been considered. Towards this reference area, exportations from Central and South Italy to the foreign areas called "East Austria", "West Austria" and Slovenia are considered potential sources for some Ro-Ro lines across the Trieste port and along the Adriatic Sea.
Export flows data were reached from more than one documents and data sources, in order to reduce the errors typical of every data collection.

3. SUPPLY MODELS

Together with the demand system, the supply system is the second factor that influences modal split of freight. The European Commission is trying to improve the image of combined road-sea transport, showing that it could be considered a door-to-door freight transportation mode because of its particular characteristics of regularity and safety; at the same time the Commission recommends to unify the administrative and Customs procedures.
An existing example of a maritime liner Ro-Ro service that follows these recommendations is the new link between Trieste and some Turkish ports. This link represents an efficient non-communitarian example of short sea shipping route: the liner service has started in 1987 and now is charged by about the 45% of all the freight flows that move from Turkey to Europe by road transport.
The singular and innovative elements that make this route unique in the Mediterranean Area are:

- the existence of road capital in managing a collective service of combined transport;
- the utilisation of fast and big ships only for freight flows;
- spreading of non-accompanied transport and improvement in the services provided to the road-haulers such as the charter flights between the airports of Istanbul and Ljubljana;
- regularity of service and reduction of waiting times during the charge and discharge operations (rapid Customs operations);
- co-ordination between all the operators and use of E.D.I. (Electronic Data Interchange).

The study of this Ro-Ro service has been very useful to understand the preferences of users (lorry haulers) with regard to variations in the transport system characteristics, and so to make easier the calibration process.
The functions used to construct the supply transport model are explained below. A bimodal network has been constructed throughout a lot of attributes, both elementary and composed ones: some mathematical relationships were used to express the level of service of each mode of transport through a coefficient and so to simulate modal choices. Every function is defined by a process of specification of the attributes and by a process of calibration of the respective coefficients.
The values of each considered attribute have been determined according to some hypotheses which are explained below.
In this paper are reported only the most important results of a particular combination of demand-supply sources: this combination of data seems to give the most adherent simulation of the actual modal split of freights between the two modes of transport considered.

3.1 Road link cost functions

With reference to road links, highways and main state roads are considered; concerning the travel cost evaluation, different functions have been used for each kind of link. The lorry cost is expressed as the sum of three quantities, a lorry cost (fuel, lubricant and tyres consumption cost and the ordinary maintenance), a staff cost and a possible toll cost, as reported in the following functions and values where C_{hr} is the highway travel cost and C_{sr} is the Road travel cost (Italian lire/Km):

$$C_{hr}=C_{fuel}+C_{lubricant}+C_{tyres}+C_{maintenance}+C_{staff}$$

$$C_{sr}=(C_{fuel}+C_{lubricant}+C_{tyres}+C_{maintenance})*1,1+ C_{staff}$$

where

$C_{fuel}=(((V-46)^2)/5700+0,18*(1+0,58*p))*1500$, £/km

V = average speed, assuming 80 Km/h in C_{hr} and 50 Km/h in C_{sr}

p = longitudinal slope;

$C_{lubricant}=100$ £/km;

$C_{tyres}=27$ £/km;

$C_{maintenance}=55$ £/km;

$C_{staff}=24000$ £/km;

$C_{toll}=173,5$ £/km;

Travel time is simply evaluated as T=L/V, L being the link length and V the average travel speed for lorries. The total travel time includes also an additional time for rest; the length of these stops, according to the Italian law, is equal to eight hours every 24 hours. The average road fare is considered equal to 2300£/km.

3.2 Sea route link cost functions

The same hypothesis are considered for the land component of each sea-road combined transport; as concern the sea component, the actual characteristics of national and international (Turkey-Trieste) Ro-Ro lines were introduced to measure the level of service of each maritime link.
The travel time for sea links is assumed equal to T=D/V, D being the distance between the two ports and V the average travel speed of the ships. The cruise speed, the frequency of the service, the loading capacity, the fares applied from the shipping Company and the port costs depend on each route. The fare is proportional to the mean length of the lorries, and also this variable depends on the link and on its direction. Charge and discharge operations times are considered equal to four and two hours (respectively) for each kind of link and ports involved. Only non-accompanied combined transport has been considered and so the travel cost doesn't comprehend lorry-driver wages.

4. MODAL CHOICE MODELS

The mathematical relationships used to realise the reference transport model are explained below. A bimodal Logit model has been introduced to get the probability to choose the different allowable transport modes; basic hypotheses of the model are:

- every operator aims to maximise her utility;
- alternatives are really independent each other;
- the probability to choose each alternative can be expressed by a mathematical explicit expression (that derives from the Gumble distribution of the random error terms connected to the utilities of each alternatives).

The utility functions are defined by some attributes and the relative coefficients; each coefficient has to be calibrated with a linear regression by a statistical program: some regression tests measure the quality of the results.
In the specification phase, a lot of attributes have been introduced trying to express all the factors that influence modal choice between road and road-sea transport. At the end of the specification and calibration procedures an utility function has been found.
As said before, during the specification process, different attributes were introduced: at the beginning some elementary ones such as the costs, the frequency of the service and so on, and then some composed variables. They have been chosen also according to the variables which are usually considered in the technical and scientific literature for similar studies. Moreover some innovative elements have been included in the utility functions, such as a comparison of all the documentation requested by the short sea shipping and the road transport, and an evaluation of how unbalanced flows can modify the modal choice.
It seems important to point out that some of the factors, identified as relevant in transport modal choice, could not be measured and compared in an objective manner; so, first of all, it is important to give a correct range to all these factors, and then to distil the factors that are really specific to the two modes of transport considered in the study.
Table 1 reports the main results of the calibration process data; the table also shows the growth of the statistical indicator value (ρ^2). The simulation process has obtained good results introducing new variables and also separating the national Ro-Ro traffic data from the international (Trieste-Turkey) ones.
The meaning of the variables is explained below, where "s" and "r" indicate sea and road respectively:

- T_s, T_r are the travel times (h), while f_s is the frequency (1/h) of the service (for road transport it is considered infinite);
- L_s and $L_{s,road}$ (Km) are the distances of the sea route and of the two terminal road links from the shipping and the discharge ports to the central node of each zone; L_r is the distance of each link in road transport;
- C (10^6 Italian £) are the trip costs taking in account the unbalanced flows;
- "Documentation" represents the administrative process connected to the transport; its value is linked to the possibility of simplifying the organisational aspects.

Variables	**Coefficients calibrated by a statistical program for each regression operation**										
	1	**2**	**3**	**4**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
$(T_s-T_r)+1/f_s$	-0,032	-0,030	-0,024	-0,032	-0,033	-0,025	-0,026		-0,027	-0,022	-0,023
$L_s/(L_s+L_r)$											-4,793
Document	0,736	2,516	4,604	2,928	3,305	5,835	19,163	16,508	14,769	46,335	
Fares	-1,2	-1,37	-1,95								
$(L_s+L_r)/(L_r)$			-2,658			-3,294			-0,896		
L_s/L_r		-4,752		-5,15	-7,005					-6,271	
$(1/f_s)-(1/f_r)$								-0,03			
C				-1,1	-1,2	-1,6	-1,5	-2,5	-1,2	-1,4	-1,6
L_r/L_s	-1,895										
$?^2_{correct}$	**0,632**	**0,672**	**0,708**	**0,723**	**0,763**	**0,796**	**0,837**	**0,910**	**0,928**	**0,944**	**0,952**

Table 1 – Calibration process: main results

Some considerations could be useful to understand the meaning of some attributes. For example, the first one in the table represents a temporal variable that takes into account the travel time and the period between two consecutive departures of a ship (this time period is not considered in road transport because its frequency is infinite); this formulation is equivalent to consider, as representative of all lorry-drivers that use Ro-Ro ships, the driver that arrives when the previous ship has just sailed. Another variable that plays, more or less the same role, is the frequency of the service. The importance of these two expressions underlines that, above all and in particular for medium distances, the frequency of a maritime service is probably the most important variable. That's why high frequency and regularity of a maritime service better than high-speed ships could switch lorry traffic from roads to Ro-Ro routes.

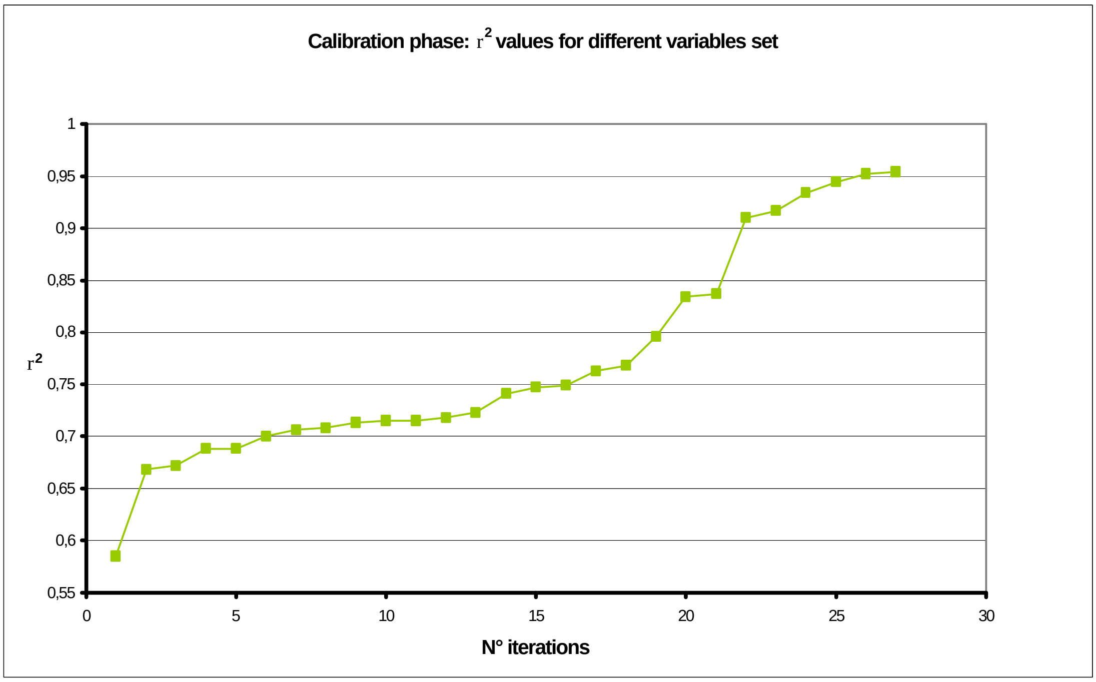

Figure 2 – Calibration process: r^2 values

Some other variables were introduced to explain how different lengths from origin to destination in the two transportation modes could influence the modal choice; also the fares applied to lorries and the operating costs of haulage companies were introduced. An attempt to insert into the simulation model the importance of empty returns on modal choices had given good results: operating costs were modified by a coefficient that depends on freight flows unbalance for each origin/destination couple.

Regression tests give very good results, and, as a proof, also the differences between the measured national sea flows and the predicted ones by the model are in the complex very low. The figure below illustrates the growth of the statistical indicator (ρ^2) varying the variables introduced into the utility functions and testing their possible combinations through a lot of iterations.

After the calibration procedures, we can summarize that:

- all the statistical indicators take interesting values;
- some new attributes introduced in the utility functions play an important role;
- the frequency is probably the most important parameter for a maritime service.

During the regression operation each coefficient was verified in its physical and economic meaning: particular attention was paid into the signs that the statistical program assigns to each coefficient. In example, the definition of a positive value for the “documentation” variable in the case of rapid and well-arranged administrative process connected to the transport, request a positive value also to the relative coefficient: in fact, in this case, a greater value of the variable could increase also the utility that each operator assigns to the modal choice that allows short times for documentation flows.

5. CONCLUSIONS

The research study has examined some very interesting features of combined road-sea freight transport alternatives; in particular the construction of a modal split model together with the introduction of new attributes in the utility functions has obtained good results in the calibration procedure.
Simulation of modal choices through random utility models can measure the opportunity to insert combined alternatives (such as Ro-Ro routes) in the reference transport scenario. Some hypotheses are then constructed with the aim of measuring the preference of users to variations in the transport system characteristics and to understand which measures can switch lorry traffic from roads to alternative routes.
The attempt to improve the level of understanding of ferry choice in the maritime context has been in part achieved considering some new and composed factors in the mathematical formulations of the model; surely the development of more sophisticated mathematical models is possible, but this research has also underlined that at the beginning an important effort has to be focused in particular into the understanding of how shippers and other operators behave (demand needs and strategies). In fact transport choice changes over time, depends on different markets, involves different operators, new logistic strategies and company interactions. Moreover, the objective of this research has been to predict the decision outcome, at least in an aggregated sense, and that’s why only a preliminary study of demand structure has been introduced.
In this analysis the social community has not been taken into consideration; the reduction of freight vehicles on the roads means less accident risk and better road service level. The potential attraction of the short sea shipping system can increase if a suitable policy is adopted. Also some suitable organisation forms in the global transport chain can promote the short sea shipping in particular through a reorganisation of lorry transport (particularly in Italy): for example a lot of advantages for the productivity of haulage companies can be obtained by embarking only the trailer, just avoiding the shipment of the tractor (non-accompanied transport).

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