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ALTERNATIVE SEA ROUTES FOR FREIGHT TRANSPORT BETWEEN SICILY AND NORTH-CENTRAL ITALY

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Abstract

Modal split of freights to and from Eastern Sicily is mainly performed by road carriers. Technological development of shipping opens new perspectives for Ro-Ro transport between ports in Sicily and Northern and Central Italy. To investigate the shippers' behaviour and the economic feasibility of Ro-Ro services, research has been carried out, articulated in four steps: analysis of freight traffic and performance of freight transport; analysis of goods transport operator behaviour and prevision of aptitude to divert travel mode to Ro-Ro; investigation of performance of modern vessels for very heavy traffic; design and economic analysis of Ro-Ro services between Sicily and the ports on the Central and Northern coasts of Italy.

INTRODUCTION

Studies on the modelling of user behaviour in terms of inter-regional mobility have received increasing attention in recent years. Despite the interest of this topic of investigation, not a great deal of research has been carried out on freight traffic and path choices in this field. This regards, in particular, the need to reduce the environmental impact on roads, caused by increasing traffic, developing alternative and preferably intermodal freight transport (such as the combined road-railway or road-sea modes). In fact, lorries, used for freight transport, constitute an important part of the total vehicular traffic on roads with the related problems of pollution and safety; measures that can switch lorry traffic from roads to alternative routes are therefore desirable.

A study carried out within the PFT2 (Finalized Transport Program) project, supported by the CNR (National Council for Research), has revealed different approaches that can be used to simulate path choices through random utility models in the field of freight transport, such as support for a stochastic demand assignment. The study concentrates on mono-modal networks following the traditional approach of a four-stage demand model.

This paper deals with the analysis of the behaviour of the freight transport operators with reference to different path alternatives along the Italian peninsula, considering the fact that some alternatives are really multi-modal. Some reference scenarios are then constructed and evaluated in order to establish both the feasibility of some combined alternatives (e.g. road-sea) for medium-long paths and the economic impact for the operators. In particular, the proposed scenarios are specialised for the relationships between the Northern-Central Italy and Sicily.

The study was carried out in four stages: a) analysis of freight traffic between Sicily and Italy and performance of freight transport; the Origin/Destination distribution of freight and the attributes of the present transportation system are investigated and a model is constructed, which constitutes a reference scenario in order to compare foreseen scenarios; a network model is designed and the cost parameters are also analysed; b) analysis of freight transport operator behaviour and forecast of aptitude to divert the transport mode to Roll on-Roll off (Ro-Ro) services: the analysis of freight transport operator behaviour and prevision of aptitude to divert travel mode to Ro-Ro is developed through a specific survey also based on the Stated Preference method; the survey and the statistical data analysis suggest interesting information about present day behaviour, especially about the preferred travel paths, and opinions on modal alternatives of product transfer; among the alternative paths, two are considered which utilise sea route through the ports of Leghorn and Naples; c) investigation of performances of modern vessels for heavy traffic, in the prevalent meteorological conditions of the Tyrrhenian Sea: modern shipping technologies are investigated because they offer new possibilities, especially in terms of speed and capacity; d) design and economic analysis of Ro-Ro services between Sicily and the ports of the Central and Northern coasts of Italy. The scenario analysis involves the individuation of multi-modal paths (i.e. road/sea transport, strategic ports, related costs), the technical and economic feasibility analysis (demand expectation, investment and management costs, profitability estimations) and the synthesis of resulting impact.

CHARACTERISTICS OF FREIGHT TRANSPORT BETWEEN SICILY AND CONTINENTAL ITALY

Sicily represents an important economical and social component of Italy. The island is approximately as wide as Belgium with a population of 5 million inhabitants.

Freight traffic between Sicily and the Continent is mainly by road and across the Messina Straits; sea routes are rarely exploited except in the case of oil transport.

Freight traffic globally generated from and attracted by Sicily in a reference period of one year for all transport modes is 33.6 million tons, for travel distances greater than 50 Km (Various Authors, 1990). Distribution is as follows: 24.4 million tons for freight exchange between Sicily and the Continent (Italy and foreign countries), 9.2 million tons of Sicily's domestic traffic.

With reference to the exchange traffic, about 65% of the total is with the Centre and the North of Italy; if we also consider the exchange with foreign countries, it can be seen that a large part of the exchange freight transport refers to travel distances greater than 1000 Km. This traffic is therefore particularly suitable for both rail and sea routes as competitive transport alternatives.

At present, road traffic is prevalent: in fact, 92% of Sicily's domestic traffic takes place by road, while this percentage drops to 58% for the exchange traffic with Italy. For long travel distances, however, other transport modes are preferred because road traffic with foreign countries has only a 4% share. In the latter case, sea routes and railways are preferred to roads respectively with a share of 78% and 17% respectively.

Sea routes are also preferred to rails even in exchanges between Sicily and continental Italy (respectively 30% and 12%), while for the Sicily's domestic traffic only 2% use rail.

This paper concentrates on analysing road traffic characteristics in order to verify the opportunity to insert combined alternatives (such as road/sea with Ro-Ro ships) in the reference transport scenario.

In terms of alternative transport paths, the geographical position of Sicily (South of Italy) and the national road network obviously affect choices; relationships with the Continental regions are consequently more difficult because Sicily is an island and because of the travel distances.

Freight transport mainly takes place along two national road corridors, the Tyrrhenian and the Ionian one, a railway network (not highly developed, however, in the South of Italy) and some important ports and airports equipped with suitable terminals for combined transport modes.

A debate regarding a stable link between Sicily and Calabria across the Straits of Messina has been going on for a decade or more in Italy; this does not yet seem economically feasible. However, sea routes have received considerable attention in recent years, thanks to some new technological developments in the ship building field.

STATISTICAL ANALYSIS OF DEMAND

The spatial distribution of road transport demand (expressed in equivalent lorries) with both from and Sicily in a given reference time period (average working day), that is the Origin/Destination, O/D, matrix reported in tab.1, has been constructed using some data collected both a specialized survey group (Sotecni, 1992) and from specific studies (Gattuso, 1992; 1994) and more recent investigation carried out in June 1996, on the Messina Straits (Gattuso and Postorino, 1996) with reference to a predefined zone subdivision.

Table 1 - Interregional freight traffic. O/D matrix (Lorries/day).

A - Sicily and other national regions.

O/D (*)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	*Total*
2	149	18	40	0	97	64	12	5	20	16	37	31	50	106	0	40	3	688
3	231	51	115	0	282	176	34	11	54	45	98	15	39	122	0	107	8	1388
Total	380	69	155	0	379	240	46	16	74	61	135	46	89	228	0	147	11	2076

B - Sicily and national macro-regions.

O/D (*)	6	*7,8,9,10*	*11,12,13,14*	*15,16*	*17,18,19*	*20,21,22*	*Total*
2	149	155	101	53	187	43	688
3	231	448	275	143	176	115	1388
Total	380	603	376	196	363	158	2076

(*) Ref. Fig.1

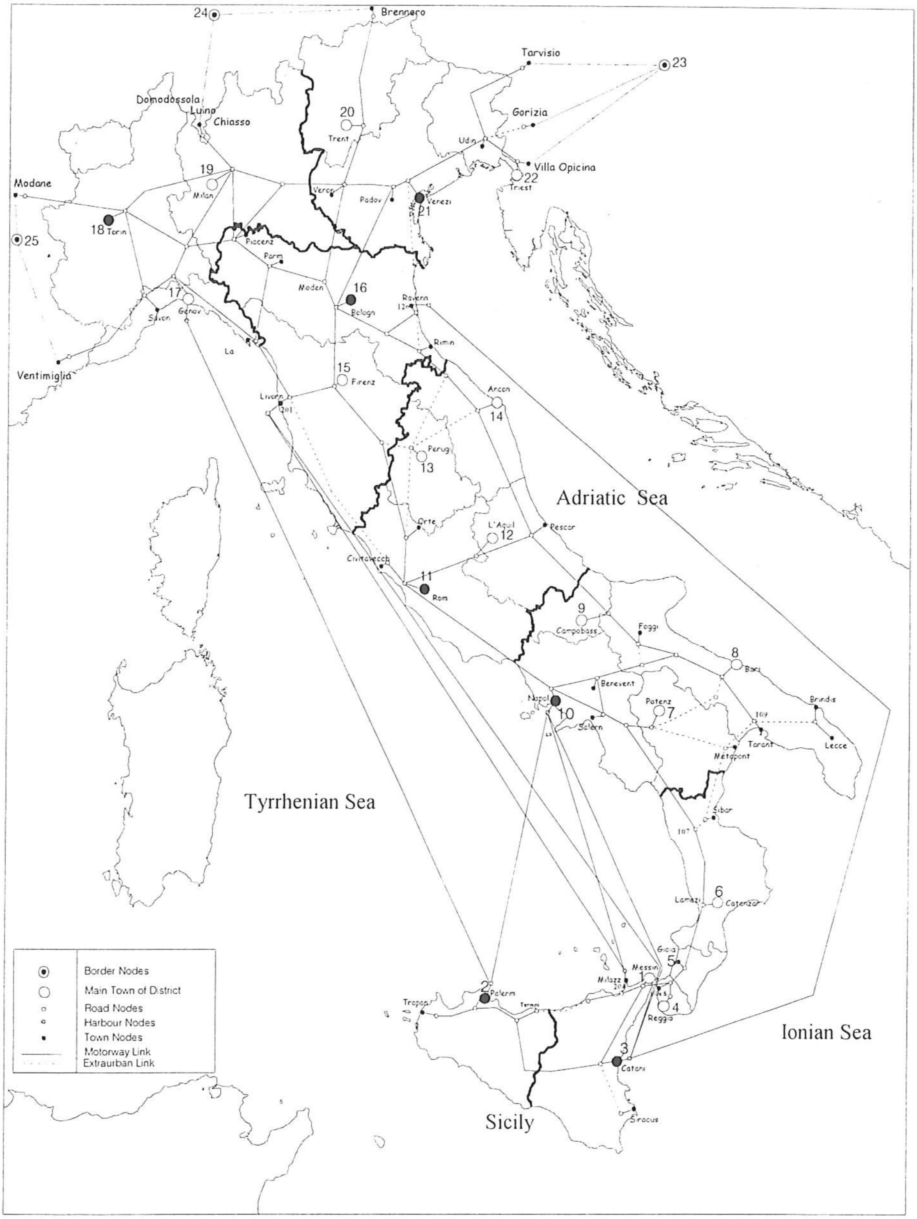


Fig.1 - Traffic zones (regions and macro-regions) and road-sea network.

The traffic zones considered in the analysis correspond to the Italian administrative regions, except in the case of Sicily, wich has been divided into two different zones: Western Sicily, with representative centroid Palermo and Eastern Sicily, with representative centroid Catania.

Two types of data were obtained through the interviews carried out in June 1996: Revealed Preferences (RP) and Stated Preferences (SP). In the latter case different scenarios were proposed to lorry-drivers in order to verify the attractiveness of certain combined road/sea route transport alternatives.

The questionnaire proposed to lorry-drivers is made up of three parts. In the first part some general data such as trip direction, origin and destination, departure time, presumable arrival time, schedule constraints, and so on, are required. The second part of the questionnaire is devoted to the collection data relative to the travel characteristics, such as the number of lorry-drivers, type of goods, trip frequency, trip costs, stops rest, and so on. Finally, the third part of the questionnaire refers to SP interviews: four different SP alternatives were proposed to the lorry-drivers, each referring to a combined road/sea route alternative. Four ports were identified: Leghorn and Naples for Northern and Central Italy respectively, Catania and Milazzo for Sicily (fig.1), to identify the propensity of lorry-drivers to combined transport alternatives for the direction Sicily-Continent and vice versa.

For the third part of the questionnaire certain elements should be pointed out. Firstly Northern and Central Italy as origin and destination of continental traffic have been defined according to a gravitation criterion as regards the ports of Leghorn and Naples, considered as reference nodes for freight transport from/to Sicily through the Tyrrhenian Sea (fig.1). Secondly four sea were considered because four ports have been identified as crucial exchange nodes for combined transport alternatives. The survey sample is made up of lorry-drivers in transit with a private shipping company operating on the Straits of Messina.

RP data analysis

A very interesting characteristic of the freight transport resulting from the collected data is the spatial distribution of the freight demand in terms of the origin/destination matrix. From the analysis of the relationships between Sicily and the continental areas it is evident that there is a fairly homogeneous distribution among the three geographical areas (Northern, Central and Southern Italy), even if the relationships with Northern Italy are slightly higher. However, if the analyses are made in a regional context, the majority of exchanges from/to Sicily occur with Calabria, the closest administrative region. Exchanges with central Italian administrative regions are also numerous.

Trips made by freight lorries are above all systematic (70%), that is they occur regularly and follow the same paths. Furthermore, many trips have no time constraints either in origin or in destination.

The occupation rate is about 1.3 drivers/lorry; in fact, in 32% of cases there was more than one person in a single lorry. Very large lorries make up the majority: in fact, 57% are road trains and articulated lorries, while simple lorries and vans make 35% and 7% respectively. As the collected data show, lorries generally belong to a forwarding agency and drivers are employees; but there is also a number of self-employed lorry-drivers (36%). In terms of the freight transport system, however, transport on behalf of third parties is the most frequent. Lorries almost always travel loaded, and this shows the organizational tendency to wards a greater productivity of the freight transport. In terms of goods, agro-industrial products (38%) and manufactured products (20%) are the most frequent freights. The distribution is practically the same in the two directions, Sicily-Continent and Continent-Sicily, although import of industrial product by Sicily is slightly greater than exports; while it exports +5% of agro-industrial products. The trip frequency distribution shows that weekly trips are the most common (39%); 28% make more than 2-5 weekly trips, while

29% only make one trip/week. Finally, 40% of the lorry-drivers make at least one rest stop between the origin and the destination: in 70% of cases this is a habitual stop.

SP data analysis

The well known SP method (Holden *et al.*, 1992; Jones *et al.*, 1983; Kroes and Sheldon, 1988) has been used to obtain statistical indicators referring to user preferences for the proposed scenarios. SP alternatives are then constructed with the aim of measuring the preferences of users with regard to variations in the transport system characteristics in the area of the Straits of Messina. The obtained SP data can be seen as indicators of the utility that each user associates to the different alternatives; this utility is a function of the aptitude and the travel attribute perception of users.

The performed SP experiment is of the choice type, that is the interviewed user has to choose the preferred alternative among a set of proposed alternatives; particularly, users have also been required to rank alternatives, in order to check the internal consistency of data (in fact, the chosen alternative must also be the first ranked alternative). In order to construct the experimental design (Pearmain, 1992; Postorino, 1993; Postorino and Pirrello, 1993), it was decided to consider the port of shipment, the port of discharge, the shipment time band and the travel time from the origin to the port of discharge (also divided into on-ground time between the origin and the shipment port and on-sea time between the shipment port and the discharge port) as the factors defining the SP alternatives. All other factors that might be perceived by users are considered constant among the various alternatives, and therefore not included in the SP questionnaire. In particular, during the survey the interviewed users were informed that the travel cost of the proposed alternatives is equal to that of the *status quo*, and therefore the possible advantages of the proposed travel alternatives are not cost reductions but greater travel comfort. In fact, travel time on the ships in the combined road/sea alternatives can be usefully employed by users for rest.

With regard to the above factors, different levels have been considered but only for the first three. Particularly, users can be considered belonging to four sets according to the trip origin and the travel direction (Sicily-Continent and Continent-Sicily); therefore, the following tables can be considered the starting point for constructing the SP experimental design:

Trip origin: Northern Italy (Sicily-Continent direction)	*Trip origin: Northern Italy* (Continent-Sicily direction)
Shipping port: Milazzo, Catania Discharge port: Naples, Leghorn Shipping time band: 7-9; 16-18; 20-22; 22-24	Shipping port: Naples, Leghorn Discharge port: Milazzo, Catania Shipping time band: 7-9; 10-12; 20-22
Trip origin: Central Italy (Sicily-Continent direction)	*Trip origin: Central Italy* (Continent-Sicily direction)
Shipping port: Milazzo, Catania Discharge port: Naples Shipping time band: 7-9; 20-22	Shipping port: Naples Discharge port: Milazzo, Catania Shipping time band: 8-10; 20-22

If the interviewed user begins or ends his trip in Central Italy or in Northern Italy (fig.1) the shipping/discharge ports considered are, respectively, Naples and both Naples and Leghorn. The shipping/discharge ports in Sicily have been defined without considering the reference continental zones (Northern or Central Italy), that is both Milazzo and Catania are always considered as alternative shipping/discharge ports. Finally, the shipping time bands have been identified by evaluating the opportunity to discharge in "useful" time bands in order to arrive at the final destination according to a predefined schedule.

The total travel time depends only on the origin/destination pairs; in this case there are no levels, but only one constant value, that is no investigations on the user preferences with regard to the class of ship have been made.

As widely known, the combination of factors and levels produces the full factorial design (Kroes and Sheldon. 1988). In this case the number of alternatives generated by the combination of factors and levels is greater than four. Studies already carried out in the field of Stated Preferences applications showed that when the number of alternatives to be evaluated at the same time

increases the answers provided by the interviewed users become more and more unreliable. In order to reduce the full factorial design and to maintain an orthogonal design the *fractional factorial design* technique can be used; in this way, the number of alternatives to be evaluated at the same time is suitably reduced, and the grouping of alternatives has been carried out in such a way as to guarantee the evaluation of the principal effects of each factor.
The first consideration that can be made in the light of the obtained results is that a large number of lorry-drivers (55%) is favourable to an inter-modal alternative with the largest part of the path undertaken on ship with respect to the status quo condition. Naturally, for users moving along the Sicily-Southern Italy direction the sea routes Naples-Sicily and Leghorn-Sicily are hardly worth taking into account; then, if these users are excluded from the sample, the percentage of users that might prefer the combined road/sea alternative increases.
In terms of preferred shipping/discharge ports, the following results are obtained:

- with regard to the Northern Italy-Sicily direction, even if all four alternative paths have a positive share, Leghorn is the most popular choice on the Continent, while Catania is the most attractive on Sicily;
- with regard to the Central Italy-Sicily direction, two alternative sea routes are considered (Naples-Catania and Naples-Milazzo). There is a slight preference for the Naples-Catania sea route over the Naples-Milazzo sea route;
- the need for a sea route between Southern Italy and Sicily is practically irrelevant.

As expected, the *status quo* alternative assumes increasing importance from the North of Italy to the South of Italy (from 27.5% to 86%); furthermore, in the North more than 70% of interviewed users are favourable to the combined road/sea alternative. This percentage drops to 60% in Central Italy. Overall, for shipping/discharge operations Catania has the highest percentage of preferences (32.6%); the other ports considered achieve the following results: Naples 27.4%, Leghorn 22.6% and Milazzo 17.4%. Regarding the shipping time band, whatever the sea route users prefer night-travel, and then the night shipping time bands are favoured. This tendency can be explained by the fact that users prefer to take advantage of night-travel for rest and in order to increase the trip safety.

THE SUPPLY REFERENCE MODEL

The mathematical relationships and the functions used to construct the reference transport model are explained below. The main network characteristics in terms of links and nodes are provided as well as the functions employed to evaluated the travel costs.
Because of the attention devoted to the road freight transport and the combined road/sea modality, the transport network is made up only of road links and sea route links.
A bi-modal network is then constructed also considering some exchange links from one mode to another; for each link, and particularly for the exchange links, suitable cost functions are defined.
With reference to the road links, highways and the main state roads are considered (*fig.1*), while the sea routes are considered without intermediate stops, that is one link directly connects the shipping port to the discharge port.

Road link cost functions

In terms of travel cost evaluation, different functions have been considered for each kind of link.
For road links the generalized cost function is formed by three quantities (Nuzzolo *et al.*, 1997):
$CT=\beta_1 *T_v + \beta_2 *C_v + \beta_3 *L_a$
where: T_v is the travel time measured in hours, C_v is the travel cost (measured in Italian Lire/1000), L_a is the length of the highway link measured in Km, $\beta_1=-4.525$, $\beta_2=-0.033$ and $\beta_3=0.013$ are parameters obtained through the already mentioned CNR/PFT2 research relative to the path choice

model for freight transport (Nuzzolo *et al.*, 1997). The travel time T_v is simply evaluated as T_v=L/v, L being the link length (Km) and v the average travel speed for lorries (it has been assumed equal to 90Km/h for highways and 50Km/h for state roads).

Strictly speaking, the total travel time would include an additional time for brief occasional stops and longer stops for rest. It is not easy to evaluate these quantities; furthermore, the length of the stop depends on the trip length and on the kind of goods carried. For these reasons, the additional cost induced by these stops is taken into account by evaluating it as a staff cost, because for long distance travel more than one lorry-driver is needed if no rest stops are allowed, and then the stop cost is considered an additional staff cost, particularly in terms of additional employed lorry-drivers.

The travel cost is expressed as the sum of three quantities: a lorry cost C_m, a staff cost C_p and the possible toll cost C_b: $C_v=C_m+C_p+C_b$..

The lorry cost C_m considers the fuel consumption cost, the lubricant consumption cost, the tyre consumption cost, the ordinary maintenance. All these quantities are considered proportional to the travel distance. The following function is then considered:

$C_m = \alpha_1$(lt/Km)*900(£/lt)*L+ α_2(gr/Km)*13(£/gr)*L+α_3(£/Km)*L+ α_4 (£/Km)*L.

The staff cost is expressed as:

$C_p = \alpha_5$(£/h)*Add*T_v

where Add is the number of lorry-drivers in each lorry. With this term, the additional cost due to possible intermediate rest stops can be taken into account by suitably increasing the number of lorry-drivers in each lorry. In fact, if the travel time length is shorter than 8 hours the number of lorry-drivers is equal to 1 (Add=1), while if the travel time length is greater than 8 hours then Add=2.

Finally, the possible toll cost C_b is considered proportional to the length of the road path, L, and to a shade variable x that is equal to 1 if the road link is tolled, otherwise 0:

$C_b = \alpha_6$(£/km)*L*x.

The parameters α_1, α_2, α_3, α_4, α_5 and α_6 represent the unit consumption and the unit cost; the values used for the performed application are (Russo, 1994): α_1 = 0,35 lt/Km; α_2 = 2,0 gr/Km; α_3 = 10 £/Km; α_4 = 60 £/Km; α_5 = 18.000 £/h; α_6 = 175 £/Km.

In particular, the value α_6 = 175 £/Km represents the toll cost for one Km of highway, as calculated from data provided by the AISCAT Society (1997); actually, different values could be calculated for each type of lorry, and then an "average lorry" has been considered in order to obtain the mean value of α_6 on the basis of the following unit values: lorry with two axles and height <1.3 m: 88 £/Km; lorry with two axles and height >1.3 m: 90 £/Km; lorry with three axles: 110 £/Km; lorry with four axles: 175 £/Km; lorry with five axles: 210 £/Km.

Sea route link cost functions

The generalized travel cost for one lorry, in the hypothesis of a Ro-Ro service, can be considered as the sum of four quantities:

$CT=\beta_1 * T_v + \beta_2 * C_v + \beta_4 * L_m Y + \beta_5/Q$

where T_v is the travel time (h), C_v the ship toll (£/1000), L_m the length of the sea route (Km), Q the daily frequency of the service and Y a shade variable that takes into account the preference for a sea path for long distance travel ($Y=L_m/L_{tot}$), L_{tot} being the total travel length; particularly, it has been considered equal to 1 if L_m is greater than 500 Km, and 0 otherwise.

The parameters β_4 and β_5 have been obtained through a calibration procedure, by using the data-base collected during the SP surveys (Gattuso and Postorino, 1996). The values obtained are:

β_4 = 0.035 £/Km; β_5= - 10.0 £*trip/day.

The travel time for sea links is assumed equal to T_v = D/v, where D is the distance between two ports, in Km, and v is the cruise speed (Km/h). The travel cost on the sea links is the sum of two quantities: the toll p (£) and the lorry-driver wage (by considering in this case Add=1):

$C_v = p + \alpha_5(£/h)*Add*T_v.$

For the existing sea routes the considered fare is that applied by the shipping Company, according to official data of the Italian Shipping Society (1997). The fare is proportional to the mean length of the lorries, and in the application a mean length of 10m has been considered.

For the proposed new sea routes, the fares have been calculated in a similar way.

Finally, some considerations have been made in order to compute the costs on the links that allow the change from one transport mode to another (in particular, from road to sea and vice versa). For links connecting road links to nodes representing ports, the cost functions have been assumed equal to those already used for road links, with a mean speed of 15 Km/h. Only an average time cost has been associated to access/egress links to/from ships, respectively equal to 1.5h and 0.5h, without considering the location of the port. This cost correspond to shipping/discharge operations, in the hypothesis of a Ro-Ro service and an "on time" ship service. Actually, the ship access time is a random variable that can be described beginning from a frequency distribution function of arrivals in the shape of an asymmetric bell. The far right edge corresponds to the limit time of acceptance for shipping in the hypothesis of no queue; the left-hand edge corresponds to the maximum probable before-time arrivals. The egress time takes into account the time associated to the egress operations from the ship to the unloading wharf.

The path choice model

The basic hypothesis on the way in which the demand uses the different allowable paths is that it follows a Logit distribution with α parameter. As widely known, the Logit model belongs to the class of random utility models (Ben Akiva and Lermann, 1985); particularly, the hypotheses of the model are that alternatives are independent of each other, that is the random error terms connected to the utilities that each user associates to each alternative are identically and independently distributed as a Gumble function. In the under study case, the hypothesis of independence of the random error term can be largely accepted, because the alternative (i.e. the different paths on the national transport system) can be considered really independent.

Sea resource model

The interest of the manager of a Ro-Ro transport service is strictly connected to operating costs and fare revenues. The operating costs depend on the ship technologies and the number of running ships while the fare revenue depends on the attracted traffic level and the adopted fares.

Table 2 - Constant and operative costs for a High-Speed Sea Service Ship

A - Constant costs		Italian £*10^9/year
Depreciation cost		13.55
Ship insurance		0.30
Harbour tax		0.20
Classification		0.04
Administrative costs		1.00
Crew		1.20
Bottom and engine maintenance		0.50
Total		16.79
B - Variable costs		
Speed (knots)	C_u (Kg/sea miles)	£/sea miles
18	180	81000
27	225	101250
36	300	135000

In order to evaluate each scenario, tab.2 summarizes the different kinds of costs for a fast ship (High-speed Sea Service, H.S.S., type) with loading capacity equal to 100 lorries (the mean length of lorries is assumed to be 10 m). Two types of cost can be considered: constant and variable costs.

The variable costs basically depend on the fuel and lubricant consumption:
$C=p_u*C_u*L_m$
where: p_u is the unit fuel consumption (450£/Kg) and C_u is the unit fuel consumption as function of speed (some values are reported in tab.2 for different speeds).

SCENARIO ANALYSES

The path choice model and the resource model have been used in order to analyze some different alternative transport hypotheses and then to deduce suitable indicators capable of expressing the advantages (or the disadvantages) of a given transport alternative. Three scenarios have been considered:

- Scenario 1: improvement of the existing supply (in terms of faster ships on the sea routes already used like Palermo-Genova and Palermo-Naples, with daily frequency), and definition of new sea routes (Catania-Leghorn, Catania-Naples, Milazzo-Leghorn and Milazzo-Naples) with fast ships;
- Scenario 2: maintenance of the existing supply (in terms of type of ships) and definition of the new sea routes (as explained in point a);
- Scenario 3: definition of only one port in Sicily for all the freight transport (Milazzo), and introduction of fast ships along the sea routes Milazzo-Leghorn and Milazzo-Naples.

With regard to the ship technologies, the use of fast ships has been considered (tab.3), whith cruise speeds of 27 and 36 knots, while at present speeds are on average equal to 18 knots. The speed of 27 knots is guaranteed for each meteorological sea condition. A speed of 36 knots is guaranteed only when the sea is calm. There are also ships that can exceed the speed of 40 knots (SES, tab.3) but their usage for freight transport is not yet possible. The scenarios considered refer to the use of fast ships (Stena Lynx III type, tab.3), in the hypothesis of exclusive lorry transport. Different freight distributions on the intermodal network (roads and sea routes) correspond to the three proposed scenarios. In the following, the variations relative to each proposed scenario are analysed with respect to the actual one, called Scenario Zero.

Table 3 - Characteristics of some ship typologies for Ro-Ro transport

		Traditional ferries	High-speed Sea Service	Super High-speed Sea Service
		Stena Jutlandica	Stena Lynx III	SES
Hull		monohull	catamaran	catamaran
Loa (m)		184	79	40-84
Beam (m)		28	23	14.5-23.2
Draught (m)		6	2.4	
Power (kW/hp)		25920/32300	22000/29900	4080/25300
	Pax	1500	670	350-600
Capacity	Car	550	550	
	Lorries	130	130	Vehic. 80-180
Cruise speed (knots)		21.5	36	42-53
Fuel cons. (kg/mile) (*)			300	
Shipbuilder		van der Giessen de Noord (NL)	Incat (AUS)	Fincantieri (I)

(*) Cruise speed for full load condition.

A comparative analysis of the different proposed scenarios has been made. For each origin-destination pair and for each set of the related alternative paths, the impedences and the percentage of attracted demand were been analised. Generally, sea routes take traffic from roads but with different percentages. The greatest effects of the Ro-Ro service appear in the Scenario 1, where the best supply conditions are foreseen. When only the sea routes coming from/arriving at the port of Milazzo are considered, the above effects are less relevant because of the lower supply compared with the Scenario Zero, and also because of the increase of the impedences related to the greater complexity of the paths.

CONVENIENCE ANALYSIS

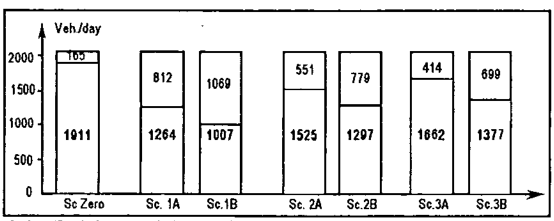
The indicators considered for the evaluation can be grouped into two classes:
User indicators

- Total travel time spent on the network and related variations;
- Total monetary cost paid by user to travel on the network and related variations;
- Freight traffic flows in lorry units that leave the road paths and prefer the sea paths, avoiding the crossing of the Straits of Messina.

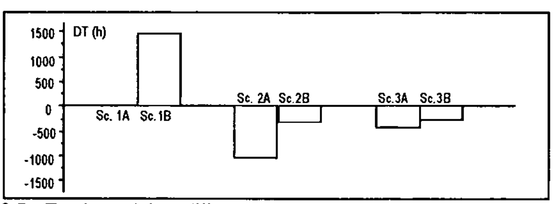
Ro-Ro transport service manager indicators

- Management costs with regard to the sea route and the number of working ships;
- Profitability coefficient, defined as the ratio between yearly revenues and costs.

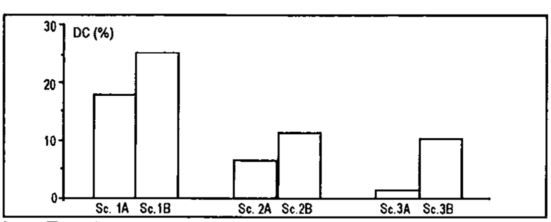
As shown in fig.2A, all the proposed scenarios produce a reduction in road traffic (in terms of lorries), and a greater usage of Ro-Ro services. The best effects are seen in scenario 1, where there are both a large number of sea route alternatives and the use of fast ships with speeds of 36 knots. In this case, the demand is distributed among a large number of sea routes.



2.A - Freight travel demand distribution between road path and combined road.sea path



2.B - Total travel time difference on the network (Project Scenario - Zero Scenario)



2.C - Travel cost percentage reduction for the users on the network

Fig.2 - Impacts of different scenarios (Ref.average day)

In all three proposed cases, the number of traffic units leaving roads for sea routes is very high (more than 400 traffic units). Furthermore, scenario 2 produces more variations than scenario 3; this can be explained in that scenario 2 offers a larger number of alternative sea routes, and users

prefer sea routes with discharge ports in "historical" cities such as Catania and Palermo. This result confirms the preferences expressed by users during the SP survey.
Other results can be seen in fig.2, where the variations of time and costs, in terms of user indicators, for each scenario are represented. Generally, there is an increase in the total time consumed, but a lower monetary cost.
The cost estimate for the manager of a shipping service has been calculated for each proposed sea route, by assuming 270 working days a year.
The following characteristics for the new introduced services have been defined: the frequency (Q) equal to 1 trip/day for long distance travel (relationships between Sicily and North of Italy) and 2 trips/day. for the medium distance travel (relationships between Sicily and Central Italy).
According to the navigation time and the time for the various port operations, the average round time (T_g) has been defined by adapting it to a multiple of 12 hours in order obtain an homogeneous interval among the trips. The number of ships forming the fleet has been then calculated as:
$N = Q * T_g$
The management costs also depend on this latter parameter (tab.4).
The daily transport capacity can be computed beginning from the frequency and the loading capacity of the single ship. In order to evaluate the revenues of management, the minimum value between the demand estimated through the model and the maximum accepted demand, that is the possible transport capacity, has been considered as paying demand. Because the service has been planned for 270 days/year and because in this period the traffic is equal to 85% of the total yearly traffic, the average daily traffic used has been increased by 15% with respect to the average yearly value. Then a coefficient of yearly profitability has been obtained (tab.4).

Tab.4 - Compared scenarios. Profitability coefficients

Sea link	Distance (miles)	Scenario	Ships	Costs (*) Fixed	Variable	Total	Revenue (*)	Ship occupancy	Revenue/ Cost
Milazzo Naples	162	1A	2	33.6	32.8	66.4	36.8	0.90	0.55
		1B	1	16.8	21.9	38.7	45.8	1.00	1.18
		2A	2	33.6	32.8	66.4	44.4	1.00	0.67
		2B	1	16.8	21.9	38.7	47.2	1.00	1.22
		3A	2	33.6	32.8	66.4	47.6	1.00	0.72
		3B	1	16.8	21.9	38.7	47.2	1.00	1.22
Milazzo Leghorn	405	1A	2	33.6	82.0	115.6	21.3	0.66	0.18
		1B	2	33.6	109.3	142.9	30.9	0.95	0.22
		2A	2	33.6	82.0	115.6	37.3	1.00	0.32
		2B	2	33.6	109.3	142.9	37.3	1.00	0.26
		3A	2	33.6	82.0	115.6	37.3	1.00	0.32
		3B	2	33.6	109.3	142.9	37.3	1.00	0.26
Catania Naples	216	1A	2	33.6	43.7	77.3	20.6	0.45	0.27
		1A	1	16.8	21.9	38.7	20.6	0.91	0.53
		1B	2	33.6	58.3	91.9	31.1	0.68	0.34
		1B	1	16.8	29.2	46.0	26.1	1.00	0.57
		2A	2	33.6	43.7	77.3	21.2	0.93	0.27
		2A	1	16.8	21.9	38.7	21.2	0.47	0.55
		2B	2	33.6	58.3	91.9	32.3	1.00	0.35
		2B	1	16.8	29.2	46.0	26.1	0.71	0.57
Catania Leghorn	470	1A	2	33.6	95.1	128.7	18.2	0.55	0.14
		1B	2	33.6	126.8	160.4	30.7	0.93	0.19
		2A	2	33.6	95.1	128.7	23.9	0.72	0.19
		2B	2	33.6	126.8	160.4	38.0	1.00	0.24

(*) Costs and revenues in Billions of Italian £

The management costs are naturally bigger for the Sicily-North of Italy relationship, due to the greater travel distances; they are relevant above all for the sea route Milazzo-Leghorn and Catania-Leghorn.

The revenues are greater with the ".B" scenarios with a ship speed of 36 knots; however a significant profitability coefficient has been obtained only on the relationship Sicily-Central Italy, and particularly on the sea route Milazzo-Naples. It must be pointed out that the analysis comes from the hypothesis that the sea service are realized *ex-novo*, operating only 270 days/year, and that the fare is the same as now. By taking into account these factors, the relationship Catania-Naples can also be considered interesting, even as an alternative to the sea route Milazzo-Naples. The sea routes coming from/arriving at Leghorn are not competitive. In fact the costs are higher, and furthermore there already exists a direct sea route Palermo-Genova that attracts a significant percentage of users with respect to a more complex and combined path such as Palermo-Milazzo-Leghorn-Genova.

CONCLUSIONS

The analysis carried out has allowed us to examine some very interesting aspects of combined road/sea freight transport alternatives. The results show the new Ro-Ro services have positive impacts on the users and, in some cases, also on the shipping manager. Generalized reduction of travel time and travel cost following the Scenario 1 hypothesis (better transport supply in terms of new sea routes, greater shipping speeds, more frequent services) causes a noticeable shifting from roads to sea (about an equal distribution between the two transport modalities). In the case of Scenarios 2 and 3, the gain in terms of monetary cost is less noticeable because the road distances to reach the ports are not negligible, and travel times are slightly than in the present situation. Then, the road-sea alternative results less attractive for lorry-drivers. From the point of view of users, the most interesting scenario is Scenario 1B; in this case, however, the only profitable path for managers is Milazzo-Naples sea route. From the point of view of the companies, the most attractive scenario is Scenario 3B, with a concentration of shipping services on the Milazzo-Naples sea route, but in this case the shifting of traffic from the road to the sea-road path is less evident compared with the other scenarios.

In this analysis the social community has not been taken into consideration; in fact, the reduction of road freight traffic flows is greatly desired, above all by the citizens in the area of the Straits of Messina, to reduce the level of environmental pollution. Furthermore, new sea routes could decrease the level of traffic flows on the highways: in fact, the setting up of activation of Milazzo-Naples and Catania-Naples sea routes, with reference to the Scenario 1B (ship speed 36 Knots), attracts about 300 lorries/day for the two considered traffic directions, corresponding to about 10% of the average daily freight traffic using the A3 (Naples-Reggio Calabria) highway. Naturally, the reduction of the freight vehicles on the roads means less energetic consumption (5 lts of Diesel oil allow carrying 1 ton of freight for 100 Kms of road, and 500 Kms on sea), less accident risk and better road service levels.

The potential attraction of the cabotage system can increase further if a suitable policy is adopted (e.g., subsidies for the public transport system, detaxation, and so on), and/or a penalty policy for the road transport (e.g. greater toll-roads, pollution tax); in this case, also the larger distance sea routes can be competitive, in particular the Milazzo-Livorno sea route.

The application highlights the existence of a threshold in terms of sea distance equal to about 200 sea miles; for greater distances, the management costs are too high and Ro-Ro services would not be convenient. Suitable organisation forms in the global transport chain can promote further the cabotage. For example, in terms of productivity of the transport companies unquestionable advantages can be obtained by embarking only the trailer, thus avoiding the shipment of the tractor. This operation requires a correspondence between the origin and destination ports, and an organisational capacity in order to balance the transport in both directions, by avoiding unloaded land trips. In the near future, the reorganisation of lorry transport in Italy could bring produce important developments in this direction.

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