The capability of Motorways of the Sea of being competitive against road transport. The case of the Italian mainland and Sicily

Marino Lupi[1,2*], Alessandro Farina[1,2], Denise Orsi[1,2], Antonio Pratelli[1,2]

[1] *Department of Civil and Industrial Engineering, University of Pisa. Pisa, Italy.*
[2] *University Centre of Logistic Systems, University of Pisa. Livorno, Italy.*

Abstract

The paper deals with a quantitative analysis on the competitiveness of intermodal transport, based on Motorways of the Sea (MoS), in comparison with all-road transport. This analysis is applied to MoS routes connecting the Italian mainland with Sicily. The study involves: a detailed intermodal network model which compares monetary costs and travel times from all relevant origins in the mainland to all relevant destinations in Sicily; and a survey carried out at some representative trucking firms operating to / from Sicily. The aim of the interviews has been: on one side to make a comparison between the theoretical and actual mode of transport and routes taken, and in case they are different, to understand the reasons of the discrepancy; on the other side to determine what are the main aspects taken into account by trucking companies in their modal choice, in order to understand how the competiveness of MoS against road transport can be improved. The results of the analysis show that the modal choice is affected by several elements: monetary costs and travel times; reliability of MoS routes; availability of MoS routes; MoS routes frequencies; but it resulted from the interviews that monetary costs and travel times are the most important factors considered by trucking companies in the modal and route choice. This study has also shown that an improvement of MoS routes on the Italian Adriatic side is necessary: actually, a strong reason for which in Italy MoS traffic is still a small percentage of road traffic is the low number of MoS routes currently in operation and their low frequency. This analysis could help decision makers, and maritime operators, to efficiently invest in the improvement of MoS routes. Moreover, this analysis, developed for an Italian case study, can be applied to other European and Mediterranean scenarios.

Keywords: Motorways of the Sea (MoS), competitiveness between intermodal transport and road transport, intermodal network, quantitative analysis.

[*] Corresponding author: Marino Lupi (marino.lupi@unipi.it)

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1. Introduction

The Motorways of the Sea (MoS) concept was suggested by the European Commission's White Paper (European Commission, 2001). MoS have thus become one of the priority projects of the program of the "Trans European Transport Network" (TEN-T) (European Parliament, 2004).

MoS are Short Sea Shipping (SSS) ro-ro services with particular characteristics; they must be: viable, regular, frequent, high-quality, reliable and integrated in door-to-door logistic chains. MoS are aimed at constituting a valid alternative to all-road transport and integrating inland transport especially when there are geographical constraints.

Italy is particularly advantaged thanks to its geographical conformation, as it is surrounded by the sea, therefore it has high potential for the growth of MoS routes. In Italy, not many MoS services are operational among ports in the Italian mainland; moreover they usually are part of, longer, international routes and often register a low frequency (because they are not planned for connecting ports in the mainland): therefore they cannot constitute, currently, an alternative to domestic road transport. Instead, there are several MoS routes connecting the Italian mainland with Sicily, which is actually divided from the mainland by only the strait of Messina: this alternative can be considered a "nearly all-road" mode of transport. It is also interesting to point out that the first MoS in Europe, established in 1992, was a MoS between the Italian mainland and Sicily: Genoa–Termini Imerese, by Viamare (Baindur and Viegas, 2011, Paixão Casaca, 2008).

In this paper we are going to analyse the competitiveness of MoS in comparison with all-road transport. This analysis will be applied to MoS routes connecting the Italian mainland with Sicily. The analysis involves: a model, which compares monetary costs and travel times, calculated in detail, and an investigation carried out by means of personal interviews to some representative trucking companies operating to/from Sicily.

The model determines, for each O/D pair, monetary costs, travel times and generalized costs for the three alternatives: accompanied intermodal, unaccompanied intermodal, and all-road. The purpose of the model is to determine: for which O/D pairs intermodal transport, based on MoS, is the most convenient mode; and in case of intermodal transport, the ports of boarding and unboarding, therefore the extent of the minimum generalized cost intermodal path, for the given O/D pair, which is covered by maritime transport.

The aim of the interviews has been: on one side to make a comparison between the theoretical (predicted by the model) and actual mode of transport and routes taken, and in case they are different, to understand the reasons of the discrepancy; on the other side to determine what are the main aspects taken into account by trucking companies in their modal choice, in order to try to understand how the competiveness of MoS against road transport can be improved. In particular, through the application of the model and from the results of the survey, we aim at understanding whether some new MoS routes are necessary and what are these new MoS routes.

The paper is organized as follows. In section 2, the current situation of MoS in Italy and Europe is discussed; after, some observations about the competitiveness of MoS with respect to road transport are made. In sections 3 and 4 the model is described, and in section 5 the results of the model application are shown. In section 6 the interviews to trucking companies are described and in section 7 the outcomes of interviews are compared with the model results. Conclusions follow.

2. Motorways of the Sea in Europe and Italy

2.1. The current situation of Motorways of the Sea in Europe and Italy

The development of MoS has been highly supported by the European Union policies (Paixão Casaca and Marlow, 2001). The European Commission's White Paper, "European Transport Policy for 2010: Time to Decide" (European Commission, 2001), considers intermodal transport based on MoS a viable, competitive, alternative to all-road transport. One of the main drawbacks of road transport, pointed out in the White Paper, is the saturation of traffic in some parts of the European Union. However the modal split is still in favor of road mode: in 2014, 49.0% of total freight transport in Europe, expressed in tonne-km, took place by road (European Commission, Directorate-General for Mobility and Transport, 2016, p. 36). Actually also the capacity of railways is limited and in several countries they have been optimized for passenger transport. Very expensive new infrastuctures are necessary to expand railway capacity; instead sea transport capacity may be increased, through the addition of more ships, or larger ships, or faster ships (Baird, 2007).

Statistical data show that much effort still has to be done to implement the MoS European policy. In EU-28, in 2015, ro-ro SSS accounts for only 2.2% of road freight traffic: the total ro-ro SSS traffic in Europe is equal to 252.6 million tons (143.0 accompanied and 109.6 unaccompanied), while the road freight traffic is equal to 11263.4 million tons (Eurostat, 2016). In Italy, in 2015, ro-ro SSS accounts for 5.6% of road freight traffic: the total traffic of ro-ro SSS is equal to 53.2 million tons (28.1 accompanied and 25.1 unaccompanied), while the road freight traffic is equal to 957.0 million tons (Eurostat, 2016). Italian data are better than the European average, but a relevant reduction of road traffic due to the development of MoS has not been achieved yet.

Italian MoS routes mainly integrate existing inland links, particularly motorway links, in order to connect places which can be accessed only by sea, or whose accessibility by sea is far more convenient than by road. In particular, the majority of Italian MoS routes connect: the Italian Tyrrhenian ports with ports of Sardinia, Sicily and western Mediterranean countries; the Italian Adriatic ports with the ports of Croatia, Montenegro, Albania and Greece. On the other hand only a few routes connect ports in the mainland, and these connections are almost always part of a longer international route and often register a low frequency. Furthermore cargo having both origin and destination in Italian mainland ports is accepted only on a few of these international routes. Instead there are several routes connecting the Tyrrhenian ports of the mainland, such as: Genoa, Livorno, Civitavecchia, Napoli and Salerno, with Sicily. Only a few connections exist between the Adriatic ports of the mainland and Sicily; in this regard it is interesting to note that Grimaldi has just recently developed a new route connecting Ravenna with Brindisi and Catania, where freight having origin in Ravenna and destination in Brindisi (both in the Italian mainland), o vice versa, is accepted. As to the importance of ro-ro traffic in Italy, in Lupi et al. (2014) the ranking of Italian ports is reported according to all freight typologies which are loaded and unloaded; in particular it is reported how ro-ro traffic influences the Italian port ranking.

2.2. Some observations about the competitiveness of MoS against road transport

In some studies the advantages and disadvantages of SSS transport have been highlighted (Paixão Casaca e Marlow, 2002, 2007). Some studies point out that a quota of freight traffic has been transferred from road to MoS in some freight transport corridors in Europe (Ferrari et al., 2011, tab. 1). Other studies have been carried out on whether intermodal transport, based on MoS, can realistically compete with all-road transport (Ng, 2009; Fusco et al., 2012); an overview of them is reported in Lupi and Farina (2014).

Despite the fuel emissions related to maritime transport, especially regarding SO2 (Martinez and Sanabra, 2009), Short Sea Shipping (SSS) incurs in lower external costs than road transport (see, for example: Perakis and Denisis, 2008; Medda and Trujillo, 2010). Actually there are also studies that question the best "environmental reputation" of SSS ro-ro services compared to road transport (Hejelle, 2010; Vanherle and Delhaye, 2010). In any case road transport registers a high accident rate. For all these reasons the modal shift, of at least some part of freight transport, to SSS is necessary. SSS has received attention, as a way to reduce traffic congestion and greenhouse gases, also in Canada and the USA (Brooks and Frost, 2004; Perakis and Denisis, 2008).

Anyway it must be emphasized that the possibility that SSS can move tons of freight from road transport cannot be overestimated (see, for example, paragraph 3.2 of Gouvernal et al., 2010). At European level it is often remarked that SSS is the only transport mode that, in the last twenty years, has kept pace with the growth of road transport. In 2014 the modal split in Europe, in terms of tonne-km, was: 49.0% road transport, versus 31.8% maritime transport (European Commission, Directorate-General for Mobility and Transport, 2016, p. 36). Regarding only inland modes (roads, railways and inland waterways), the modal split of road transport, in terms of tonnes, is 75.4% in 2014 (Eurostat, 2016).

However, in 2015 (Eurostat, 2016), of a total of 1844.9 million tons of SSS in Europe, 44.4% were liquid bulk; 20.8% were dry bulk; 14.4% were container cargo; 6.7% were conventional general cargo; 13.7% were ro-ro cargo (7.8% accompanied and 5.9% unaccompanied). In Italy, in 2015 (Eurostat, 2016), there was a total of 275.6 million tons of SSS: 45.7% were liquid bulk; 11.9% were dry bulk; 19.3% were container cargo; 3.7% were conventional general cargo; 19.3% were ro-ro cargo (10.2% accompanied, 9.1% unaccompanied). As a result, ro-ro cargo is only a minor part of SSS cargo in Europe and Italy. In addition, a study (Dubreuil, 2009, in Douet e Cappuccilli, 2011, tab.2) assert that: 90% of the ro-ro traffic in Europe (quantized in heavy vehicle number) is related to traffic with the islands or to overcome a strait; 4.9% is ro-ro traffic on a shorter route (called "shortest links" in the paper) and only the 4.8%, of ro-ro traffic in Europe, is relative to routes that are parallel to road routes.

Actually, in Italy, the competitiveness of all-road transport is usually higher than that of intermodal transport for trips having both origin and destination in the Italian mainland. Lupi et al. (2012) report that several authors consider intermodal transport more convenient than all-road transport for distances of at least 350 – 600 km. According to Van Klink and Van den Berg (1998), intermodal transport can be considered attractive over distances of at least 500 km. In particular, if we consider intermodal transport based on rail, Barthel and

Woxenius (2004) report that Kombiverkehr, one of the largest Multimodal Transport Operator (MTO) in Europe, had in 1998 a break-even distance of 350 km; Dalla Chiara and Pellicelli (2011) report that the minimum distance of convenience of a combined road-rail transport in Europe is, generally, between about 450 and 600 km.

Instead, if we consider intermodal transport based on MoS, Martinez-Lopez et al. (2015, p. 610) report higher values for the break-even distance. Martinez-Lopez et al. (2015) report that, for MoS through ports of the Atlantic Coast, a maritime inter-port distance between 834-1400 km can be convenient (EMMA Study, 1999; Olivella Puig et al., 2004). The EU (European Parliament, 1999) has reported a minimum land distance of 1385 km, which is very close to the value reported by Jiang et al. (1999), that is 1400 km. The West MoS project (2008) proposed a minimum land distance of 1000 km for the use of intermodal transport, based on MoS, in Spain.

In Italy the development of MoS finds some difficulties because the majority of freight traffic regards short distances. In 2015, 74.5% of tons of road freight transport, having both origin and destination in Italy, are carried for less than 150 km, while only 3.4% of tons of road freight transport, having both origin and destination in Italy, are carried for more than 500 km; but, in terms of tonne-km, 22.6% of road freight transport, having both origin and destination in Italy, are carried for more than 500 km. If we consider also the international transport, again in 2015, 4.43% of tons of road freight transport are carried for over 500 km, but in terms of tonne-km, 28.2% are carried for over 500 km (Eurostat, 2016). In any case, it must be pointed out that the geographical conformation of Italy is in favour of intermodality based on MoS: the distance, based on road, from Sicily to northern Italy is very high, for example the distance, based on road, between Milano and Palermo is around 1400 km.

3. The model

In order to quantify the competitiveness of intermodal transport based on MoS against all-road transport, the few routes connecting ports in the mainland cannot be significant. Therefore, we decided to consider the trips from the Italian mainland to Sicily, where MoS are alternative to a “nearly all-road” transport, which takes place by road despite the crossing of the Strait of Messina.

We took as origins almost all the representative cities in the Italian mainland: Trieste, Udine, Trento, Venezia, Padova, Verona, Milano, Brescia, Varese, Torino, Novara, Genova, La Spezia, Parma, Bologna, Ravenna, Firenze, Livorno, Ancona, Perugia, Pescara, L’Aquila, Civitavecchia, Roma, Napoli, Salerno, Potenza, Foggia, Bari, Taranto, Brindisi; and we took as destinations almost all the representative cities in Sicily: Palermo, Trapani, Agrigento, Gela, Ragusa, Catania, Messina, Milazzo. The choice of the origin and destination cities has been performed in order to cover all the parts of the Italian mainland and Sicily. Only one-way trips, from the Italian mainland to Sicily, have been considered: as return trips are exactly the same. The two cases of accompanied and unaccompanied intermodal transport have been taken into consideration. A 16 metre long articulated lorry (tractor plus semitrailer) has been considered in the first case, and a 12.5 metre long semitrailer in the second.

The road network and the intermodal network have been represented through a graph: cities, ports, motorway junctions and motorway entries and exits are represented through nodes; portions of motorways and highways and maritime routes are represented through links. Also paths between city centres and motorways/highways, and paths between ports and motorways/highways, or between ports and city centres, are represented through links. For the evaluation of minimum cost path we considered an articulated lorry, 16 metre long, driven by only one driver.

Several studies have been performed to determine what elements compose the generalized cost of a link. Button (2010, p. 143-144) expresses the generalized cost “as a single, usually monetary, measure combining, generally in linear form, most of the important but disparate costs, which form the overall opportunity costs of a trip”. Button reports also that “While in simple indices, generalized cost is formed as a linear combination of time and money (or distance) costs, in most applied analysis the time and money components are divided into a number of elements (for example, walking time, waiting time, on-vehicle time and so on)”. Consequently, in simple indices, the generalized cost function can be expressed as follows:

$$G = \sum_i M_i + \sum_j T_j \qquad (1)$$

Where M_i are the monetary cost components and T_j are the monetized travel times.

Other authors define the generalized cost function according to similar approaches. Lubis et al. (2003) define, specifically for modelling a multimodal freight transport network, the following generalized cost function:

$$C = \alpha\, T + c_{km}\, D \qquad (2)$$

where T is the travel time and D the distance (in km) related to each link; α is the value of time (VOT) and c_{km} is the monetary cost per unit of distance. It is interesting to notice that Lubis et al. proposed three different values of time, for: road links, rail links (they considered only the rail intermodal alternative) and transhipment links.

Hanssen et al. (2012) underline the importance of pre haulage and post haulage distances, i.e. respectively: "the provision of an empty container to the shipper and the subsequent transportation of the full container to the terminal" and "the distribution of a full container from the terminal to a receiver and return to the terminal of an empty container". The authors provide expressions in which they emphasize a linear dependence of the monetary cost per tonne and value of time from the distance for each mode of transport (rail, road, sea). In the monetary cost also external costs, for each mode of transport, are comprised.

Brummerstedt et al. (2015, p. 285) have modelized an intermodal network, for container transport, from the unboarding port to the final customers. They provided a detailed generalized cost function. In their approach they considered also costs and travel times related to the post–haulage leg of the logistic chain.

Finally, Moore (2013) studied the intermodal road-rail network in the Alabama and Georgia States of the U.S.A. Monetary costs (i.e. c_{km} reported in (2)) have been calculated in a detailed way in both road and rail links. As to road links, these main cost components have been analyzed: fuel, operation and maintenance, labor. In this research, the author made use of previous researches about methodologies to calculate the operating cost of trucks, for example the works of Barnes and Langworthy (2003) and Fender and Pierce (2012). The research of Fender and Pierce has been later updated by Torrey and Murray (2015).

Russo (2005) has proposed a link cost function which comprises, in a detailed way, the different components of monetary cost and transit time (see the following formulas: (3), (4) and (6)). This cost function has been determined for the Italian scenario and it is defined also for MoS links. We decided to choose the methodology proposed in Russo (2005) because the components of monetary cost (for example: fuel cost, "various costs") and of time (for example: time for boarding and unboarding, amount of working hours lost on board by the driver, hours of allowable driving) are considered in detail and concern the Italian scenario. Also the methodology of Moore provides generalized costs in detail, but it refers to the U.S. scenario (therefore costs are different) and it does not provide the cost function for MoS links. We added, to the transit time of MoS links a quantity, the waiting time, which takes into consideration the MoS route frequency (section 4.2).

Finally, from the interviews to trucking companies we try to understand whether further generalized cost components are actually taken into account by them in the modal choice. The interview outcomes have shown that, in this period of economic crisis in Italy, monetary costs and travel times, in particular monetary costs, are always the most important factors affecting modal choice, between intermodal transport based on MoS and all-road transport and, again because of the economic crisis, their importance is higher now than in the past. In addition, because we aim at a model that reflects the current real user behavior, the interview outcomes allowed us to neglect the external costs, considered in Hanssen et al. (2012), because they are neglected by trucking companies when they choose the mode of transport and the path in the network.

The chosen methodology for link cost calculation is described in detail in the following section (section 4), and the model results are described in section 5. The performed interviews are described in section 6, and the comparison of the interview outcomes with the model results is described in section 7.

4. Monetary costs and transit times of maritime and road links.

MoS routes, together with their weekly frequencies and voyage times, are reported in tab.1. Data have been collected from Rete Autostrade Mediterranee (2014) and shipping companies websites. Rete Autostrade Mediterranee (RAM) spa is the company, founded by the Italian Ministry of Economy and Finance, which promotes the development of MoS in Italy.

Table 1. Domestic ro-ro routes between the Italian mainland and Sicily. Data refer to January 2014 (Source: Rete Autostrade Mediterranee (2014) and shipping companies websites).

4.1. Monetary cost of maritime links

The monetary cost of a maritime link is made up of the ticket price and the driver cost.

The ticket price has been obtained: from the operators websites, or through the help of shipping agencies. The ticket price must be discounted of the Ecobonus contribution, where available. The Ecobonus is an initiative supported by the Italian government to promote a modal shift from road to MoS offering a 30% discount for the ticket, provided that the trucking company performs a minimum usage of MoS routes; however it is not available in all MoS routes. We considered that trucking companies can always benefit of the Ecobonus if it is applicable to the given route.

The cost of the driver comprises: the cost related to the working hours required for boarding and unboarding the vehicle, and, only in case of accompanied transport, the cost related to the working hours lost on board by the driver. The working hours lost on board by the driver, in the case of accompanied transport, are calculated taking into account the European Parliament law 561/2006 (European Parliament, 2006), concerning the maximum number of hours which can be worked by a driver each day. Actually, some hours spent by the driver on board can be considered as driver's rest hours and are not paid; but not all hours spent on board can be considered as rest hours. If the voyage lasts less than 24 hours, the driver can organize himself in order to make the hours spent on board coincide with rest hours. But if the voyage lasts more than 24 hours, an entire working day is lost: that is 9 hours. The driver cost (i.e. salary + taxes + pension contributions) has been considered, according to Il Sole 24 Ore (2011), equal to 26 €/h . The hourly cost of the driver on board (i.e. the cost of each working hour lost) is assumed equal to 17.60 €/h (Rossi and Rubino, 2009): a reduced value is taken, compared to the full hourly cost of 26 €/h, because during the voyage the driver is not working.

The generalized cost of a link, for accompanied transport, is calculated as follows:

$$C_{acc} = C_t + 26 \cdot 1.5 + 17.6(h_b + 0.5) + VOT \cdot t_t \tag{3}$$

Where:
C_t = ticket cost, greater in accompanied transport than in unaccompanied transport: because it refers to a 16 metre long tractor and semitrailer instead of a 12.5 metre long semitrailer;
1.5 = hours for boarding (1 hour) and unboarding (0.5 h) the truck and trailer in the case of accompanied transport;
h_b = total amount of hours lost on board. They are added with 0.5 hours, which is the amount of time the driver is supposed to be already on board, before the departure of the ship;
17.6 =driver cost for each hour lost on board;
VOT = value of time;
t_t = link transit time (hours).

The generalized cost of a link for unaccompanied transport is equal to:

$$C_{non.acc.} = C_t + 26 \cdot 1 + VOT \cdot t_t \tag{4}$$

Where:
C_t = ticket cost;
1 = one working hour of the driver: we consider 0.5 hours worked for boarding and 0.5 hours for unboarding the semitrailer;
VOT = value of time;
t_t = link transit time (hours).

4.2. Transit time and waiting time of maritime links

The transit time of each maritime link is equal to the sum of: the voyage time (i.e. the time interval from the departure time of the ship to the arrival time of the ship), the time required for boarding and unboarding the truck and trailer (or the semitrailer), and the waiting time. The waiting time is not a "physical" waiting time, but it takes into consideration that the maritime service is not always available at the time desired by the customer. The waiting time actually takes into account the frequency of the service on each route, because a route which registers one or more departures per day is highly preferable by the user to a route which registers only two departures per week. For the calculation of the waiting time, we took into consideration the approach adopted in the literature relative to air transport (Ghobrial and Kanafani, 1995). If we call: O_{pw} the weekly programming time of ship departures in a route, where O_{pw} = 168 (i.e. 7 operative days and 24 hours per day), and f_a the weekly frequency of the route, the time h between two successive departures is equal to:

$$h = \frac{O_{pw}}{f_a} \tag{5}$$

We assumed a waiting time equal to a fraction of h. In a first hypothesis we assumed, as Ghobrial and Kanafani proposed, a waiting time equal to 1/4 h; furthermore we assumed a maximum waiting time equal to 7 hours. However, this approach did not lead to the expected results, because the waiting time often resulted higher than the maximum. Because of this, in a heuristic way, we assumed a waiting time equal to 1/8 h. This choice has led to satisfactory results: actually only 2 routes would have had higher waiting times than 7 hours (while other 2 had exactly a waiting time of 7 hours). This is a first trial calculation of the waiting time: in a future extension of the research, the frequency of the route will be considered in the link cost function in a more rigorous way.

A synthesis of all costs and travel times for each MoS route is reported in tab. 2.

Table 2. Costs and travel times for each MoS route

4.3. Monetary cost of road links

For costs such as: tyres, brakes, amortized purchase cost of the vehicle, insurance, we made reference to an IVECO Stralis, having 5 axes and weighting 44 tons (Vado e Torno, 2012). The remaining costs of a road link have been calculated according to Russo (2005) and Regione Lazio (2009).

The generalized cost C_i, of the generic i^{th} road link, is given by:

$$C_i = C_{i,f} + C_{i,v} + C_{i,t} + C_{i,d} + VOT \cdot t_t \tag{6}$$

Where:

- $C_{i,f}$ = fuel cost;
- $C_{i,v}$ = "various costs", sum of costs non related to the link characteristics, i.e. amortized purchase cost, lubrification, tyres, maintenance, taxes, insurance;
- $C_{i,t}$ = motorway ticket cost;
- $C_{i,d}$ = driver cost;
- t_t = link transit time (hours).

$C_{i,f}$, fuel cost, is given by: $L_i \cdot C_g \cdot C_{gas}$, where:

- $L_i = i^{th}$ link length,
- C_g = cost of gasoil (in Italy: 1.334 €/l + VAT, on 19 May 2014, Ministero dello sviluppo economico, 2014);
- C_{gas} = gasoil consumption in l/km, calculated according to the following formula:

$$C_{gas} = \frac{(V_i - 70)^2}{5700} + m \tag{7}$$

Where:

- V_i is the ith link travel speed (km/h),
- 70 km/h is the travel speed associated to the minimum consumption,
- m is the fuel consumption in l/km at the speed of 70 km/h and depends on the typology of the vehicle; in our case (IVECO Stralis) $m = 0.393$.

$C_{i,v}$, "various costs", is given by: $L_i \cdot c_{i,v/km}$:

- $L_i = i^{th}$ link length;
- $c_{i,v/km}$, "various costs per km", for an IVECO Stralis, under the hypothesis of 130,000 km travelled by year, are the following:
    - Amortization: 22.24 € cent / km;
    - Taxes and insurance: 8.12 € cent / km;
    - Lubrificants: 15.93 € cent / km;
    - Tyres: 7.68 € cent / km;
    - Maintenance: 8.57 € cent / km.

    Which results in a total "various costs" per km of 62.54 € cent / km.

$C_{i,t}$, motorway ticket cost, has been taken from Autostrade per l'Italia (2014).
$C_{i,d}$, driver cost (26 €/h).

4.4. Transit time of road links.

For each road link, the length and the speed have been determined. Distances have been collected from road maps. The speed has been calculated according to the characteristics of the link (e.g. urban road, motorway, etc.) and to the typology of vehicle considered. For motorways and rural highways we considered the maximum allowed speed for a 5 axis truck and trailer, i.e. 80 km/h in motorways and multilane highways and 70 km/h in two-lane highways. We took into consideration lower speeds for motorways and highways characterised by high congestion or tortuous geometry. We calculated the speed of urban links according to the characteristics of each link: road typology, level of congestion, existence of traffic lights, existence of singularities which increase the transit time.

Actually the total travel time, for each O/D pair, regarding the road part, must be increased by the driver rest hours. The maximum possible working hours are calculated according to European law n°561/2006, in particular: after a 4 hours 30 minutes driving period, the driver must stop driving for at least 45 minutes; daily working period must consist of maximum 9 hours. Therefore:

- if the travel time is longer than 4.5 hours and less than 9, it is increased by 45 minutes,
- if the travel time is longer than 9 hours and less than 10, it is increased by 90 minutes,
- if the travel time is longer than 10 hours, it is increased by 10 hours: we take an average value between the regular and the reduced daily rest time.

4.5. Value of time

There is disagreement about the value of time for freight transport in the literature. According to Feo et al. (2011), we assumed a VOT of 6.82 €/h for each shipment, considering an average weight, for each shipment, equal to 15 tons. The value of 15 tons is reasonable as it agrees with the shipment weights mentioned by the interviewed trucking companies. As reported above, Lubis et al. (2003) took three different values of time for road links, rail links and transhipment links. We took a unique value of time for all typologies of links. Future work could be to estimate different VOT values, according to the typology of the link.

5. Analysis of the results of the model

The proposed methodology determines for each O/D pair whether all-road or intermodal transport based on MoS (accompanied or unaccompanied) is the most convenient mode (minimum monetary cost, minimum travel time, minimum generalized cost). For intermodal transport, the model determines the ports of boarding and unboarding and, consequently, the most convenient path in the intermodal road-sea network.

In tab. 3 the comparison between the different modes of transport (accompanied intermodal, unaccompanied intermodal, all-road), in terms of: travel time, monetary costs, generalized costs, for the considered O/D pairs, are reported. Because of the high amount of data, only the most relevant origins are shown. The shortest paths, in tab. 3, have been determined, for each mode, using generalized cost. For each O/D pair (row) the minimum quantity (for: travel time, monetary cost, generalized cost) is marked in bold and underlined.

Table 3. Comparison between the different modes of transport (accompanied intermodal, unaccompanied intermodal, all-road), in terms of: travel time, monetary cost, generalized cost, for the considered O/D pairs. Because of the amount of data, only the most relevant origins and destinations are shown.

Unaccompanied intermodal transport provides the lowest cost for the great majority of the O/D pairs, both considering generalized cost and monetary cost directly incurred, with a few O/D exceptions (tab.3). However it can be observed that intermodal transport based on MoS often registers higher travel times than all-road transport. Travel time is particularly important for just in time organized production and distribution (reduction of inventory costs). We try to take into account these aspects through the VOT, in order to assess the best path in terms of generalized costs. The problem is that there is much disagreement in literature about the VOT to assume. It depends on the type of freight shipped and on the type of logistic chain in which the transport is integrated. Actually, as the VOT increases, the all-road alternative may result more convenient in terms of generalized cost. In any case, it must be underlined that, with regard to intermodal transport, the transit time comprises another quantity, the waiting time, which, as previously specified in this paper, is not a real waiting time, but it has been considered in order to take account of the frequency of the route service.

If we compare the accompanied intermodal transport with the unaccompanied intermodal transport we can do the following observations.

As to the travel time, unaccompanied intermodal transport requires more time for the operations of boarding and unboarding. On the other hand, accompanied intermodal transport costs more than unaccompanied intermodal transport for three reasons:

1. the ticket price is determined by shipping companies according to the length of the vehicle: in the case of accompanied intermodal transport the vehicle is longer than in the case of unaccompanied intermodal transport. This affects the ticket price in a significant way;
2. in several shipping companies the ticket price is increased if also the driver (and not only the vehicle) is on board;
3. the driver labour cost is bigger, in case of accompanied intermodal transport, because the driver looses, generally, on board, working hours.

Consequently, the monetary cost, in unaccompanied intermodal transport, is lower than in accompanied intermodal transport, which, when considering generalized costs, it is only partially compensated by the minor time required for boarding and unboarding the vehicle in accompanied intermodal transport.

In tab. 4, the ports of boarding and unboarding of the minimum generalized cost path for each O/D pair are reported. For the each O/D pair for which all-road transport is the minimum generalized cost alternative, "Messina Strait" is reported.

Table 4. The minimum generalized cost path for each O/D pair in case of accompanied intermodal transport and unaccompanied intermodal transport. The table shows the ports of boarding and unboarding. For the O/D pairs for which all-road transport is the minimum generalized cost alternative "Messina Strait" is reported.

6. The performed interviews and data collection

Personal interviews have been performed, between December 2015 and January 2016, to several trucking companies operating in Italy. The purpose of the interviews has been: to verify whether the actual behaviour of trucking companies agrees with our model, and explain why in case the outcomes of the model disagrees ; and to ascertain what are the main aspects taken into account by trucking companies in their modal choice.

Among the trucking companies contacted: 33 of them usually carry out shipments to/from Sicily (26 of them have an office in Sicily). Among the 33 companies: 17 are very small and have only one office (10 in Sicily and 7 in the mainland); 12 trucking companies have between 2 and 5 offices (at least 1 of them is in Sicily); 4 trucking companies are large enterprises with offices located in nearly all Italian regions (and obviously also in Sicily). Among the 17 small companies, 3 companies are carriers who work on their own account and all of them have the office in Sicily. Questionnaires have been forwarded to the companies offices.

A unique questionnaire has been proposed. Companies had to provide the details regarding some of the last delivery trips to/from Sicily. In detail, the answers required concern the following aspects:

1. the dimension of the company and the localization of its offices;
2. the typology of goods shipped;
3. which were the origins and destinations of shipments;
4. for each O/D pair, if they chose all-road transport or intermodal transport (based on MoS), and the reasons of the choice;
5. for each O/D pair, if they chose intermodal transport, what were the port of boarding and the port of unboarding, and the reasons of the choice;
6. which factors have influenced their choice between all-road and intermodal based on MoS, and which factors have influenced the choice of the ports of boarding and unboarding;
7. to provide all the previous answers for both cases of accompanied and unaccompanied transport;
8. comments and suggestions.

Among the 33 companies interviewed:

- 20 provided the information of only one reference shipment;
- 12 provided the information of 2 to 5 shipments.
- 1 provided the information on 10 shipments.

The total number of shipments, for which we have obtained informations, is equal to 70.

We considered also routes having origin in Sicily and destination in the mainland. Actually, as reported in section 3, in the model only one-way trips, from the Italian mainland to Sicily, have been considered, because, in the model, return trips, from Sicily to the mainland, are exactly the same, in terms of monetary costs and travel times.

Companies have also provided comments on current MoS services and how they should be improved.

According to the interviews, intermodal transport appears the most convenient mode. Actually, 65.7% of shipments (i.e. 46 shipments) are performed through intermodal transport, while only 34.3% (i.e. 24 shipments) are performed through all-road mode. Only 7 shipments to northern Italy and central Italy are performed through all-road transport: all these shipments depart from Catania and are directed to: Milano and Roma (2 shipments each); Bologna, Rovigo and Terni (1 shipment each); moreover all these shipments are performed by the three carriers on their own account and they rarely perform shipments outside Sicily. The rest of shipments for which all-road mode results more convenient, that is 17 shipments, have all origin or destination located in southern Italy.

The interviewed companies carry all typologies of freight: fresh fruit and vegetables, cooled agricultural products, palletised cargo, clothes, groceries, industrial products, chemicals, new vehicles, high-tech products, products for building sites, and dangerous goods (ADR services; ADR means: Agreement for transport of Dangerous goods by Road). Companies offer, besides transport, also freight storage and handling.

Three companies mainly transport fruit and vegetables from Sicily to southern Italy; and other two companies mainly transport frozen products. These companies show the following behaviour regarding the mode choice: in their way to southern Italy they usually choose the intermodal transport, while in their way back to Sicily they visit several clients and carry any typology of freight to Sicily, in order to increase the load factor of return trips: as a result, they mainly choose all-road mode. In this case, we considered separately the two trips: the trip from Sicily to the mainland and the trip from the mainland to Sicily. The remaining companies are not specialised in an unique freight typology. Each of them is specialised in the transport of several typologies of freight: for example, the same company may offer the transport of dangerous goods, groceries, clothes and industrial products. The transport of dangerous goods is offered by 8 interviewed companies. The transport of new vehicles, through car transporters, is offered by 3 companies; the transport of oversized loads is offered by 2 companies, the transport of perishable groceries by 6 companies. The transport of high tech goods is offered by 3 companies, the transport of palletized cargoes is offered by 4 companies. Finally, 7 companies have reported that they carry any typology of freight without distinction.

The choice between all-road and intermodal transport usually does not depend on the typology of freight transported, but on the origin and the destination of the shipment; all-road transport is chosen, in large prevalence, from/to southern Italian origins/destinations.

Instead, the choice between accompanied and unaccompanied transport depends on the typology of freight carried. Trucking companies actually did not specify an exact percentage of shipments performed by accompanied and by unaccompanied transport; they all stated that around 90% of deliveries are performed by unaccompanied transport in long distances: for example, if the origin or the destination of the shipment is located in northern or central Italy. Accompanied transport is always chosen if the carried goods have a high monetary value or need a special care, that is: high value goods, high-tech products, dangerous goods. According to the results of the interviews, all the other typologies of goods, including perishable products, are transported through unaccompanied transport: they do not need any special care and the difference in costs, between accompanied and unaccompanied transport, is too high. Actually, trucking companies have reported that they choose more often accompanied transport for shipments between southern Italy (boarding port Napoli or Salerno) and Sicily: in this case the difference, in terms of monetary costs, between accompanied and unaccompanied transport is lower, because the voyage time is reduced , therefore the hours spent by the driver on board could coincide with the driver rest hours.

In table 5 the outcomes of the interviews are reported. For simplicity we have called "origin" the city in the mainland and "destination" the city in Sicily for all routes operated by the interviewed trucking companies, also for those routes which had origin in Sicily and destination in the mainland; because, as reported in section 3, in the model only one-way trips, from the Italian mainland to Sicily, have been considered. In this way it is clearer to understand the differences between the model and interview results discussed in the following section.

The routes chosen in case of accompanied and unaccompanied transport are the same.

Table 5. The outcomes of the interviews. The table shows: the origin and destination of the journey; the chosen mode of transport; the number of shipments; in case of intermodal transport, the boarding and the unboarding port.

7. Comparison of the results of the model with the results of interviews to trucking companies.

In most cases the results of the interviews agree with the results of the model. Unaccompanied intermodal transport turns out to be the most convenient mode, for the majority of O/D pairs, according to both the model and interviews.

However, from the interviews, we have noticed that the trucking companies did not have an accurate knowledge of monetary costs and travel times. Actually, they perceive that the ticket price per km of MoS routes is very expensive for short distances and much cheaper for longer distances, but this is only partially true. As a result, if the distance between the origin and the destination is not very high, they often choose all-road mode although it is more expensive. Furthermore MoS operators modify too often departure times, costs and voyage times: this creates confusion and it is seen as a high disadvantage by trucking companies. Additionally trucking companies do not always optimize monetary costs and travel times: if they decide for intermodal transport, they choose the route which minimizes the road part, although they incur in higher monetary costs and travel times. This is also due to the fact that hauliers based in northern Italy do not have a complete knowledge of the road network in Sicily and hauliers based in Sicily do not have a complete knowledge of the road network of numerous parts of northern Italy.

The interviewed firms have also reported that one of the main disadvantages of MoS routes is the low frequency: several MoS routes do not have a departure every day and this is a major problem in case of just in time deliveries. We tried to take into consideration this aspect in our model by introducing the waiting time, which, as reported in section 4.2, depends on the route frequency.

Trucking companies have also supported the importance of the introduction of discounts in ticket prices. In particular the ecobonus is not only seen as an incentive to intermodal transport, but also as a substantial monetary help to transport enterprises: which, obviously, has the consequence of a major usage of intermodal transport. As a result, the taxation of road transport, together with discounts on MoS ticket prices, could be a good solution to improve the shift to intermodal transport, if the revenues from the taxation of road transport are used for funding the discounts on MoS tickets.

Considering tab. 5, when we pass to the comparison between the theoretical (predicted by the model) and actual mode of transport and routes taken, we can carry out the following observations.

First of all, in tab. 5, Italian mainland origins of the shipments, performed by the interviewed companies, have been grouped in: north-western Italian mainland, north-eastern Italian mainland, central Italian mainland, Campania region, the rest of southern Italy. Destinations, in Sicily, have been grouped in: western Sicily (destinations Palermo and Trapani) and eastern Sicily (the remaining destinations).

As to the origin cities in north-western Italian mainland, the results of the interviews and of the model almost completely agree: the model suggests that intermodal transport is always more convenient, instead, basing on the interviews, 2 out of 14 shipments are performed by all-road. As to origin cities in north-eastern Italian mainland, again the results of the interviews and the model almost completely agree: the model suggests that intermodal transport is always more convenient, instead basing on the interviews 2 out of 10 shipments are performed by all-road transport. However, the shipments performed by all-road mode, from both north-western and north-eastern Italian mainland, are made by the three carriers, above mentioned, who operate on their own account, and they rarely perform shipments outside Sicily. As far as the boarding and unboarding port is concerned, as to the origin cities in north-eastern Italian mainland, if the destination is in eastern Sicily, the results of the interviews agree with the model, that is the Ravenna–Catania MoS route is the most convenient. If the destination is in western Sicily (for example Palermo), if the interviewee has the office based in Sicily, the MoS route chosen is the Ravenna – Catania (then the motorway from Catania to Palermo); if the interviewee has the office based in northern Italy, the MoS route chosen is the Livorno – Palermo (as for the model in the unaccompained case) and consequently a longer part of the route takes place in the mainland. Actually, hauliers aim at minimizing the road part in the area that the drivers do not know well, and concentrate the road part in the area the drivers know better. This is due to the lack of accurate knowledge of travel times and costs of the road network: drivers from Sicily consider motorways of northern Italy very congested; while drivers from northern Italy are worried about possible disruptions in the motorways in Sicily.

If we consider the central mainland origins in Italy, the model suggests that intermodal transport is always more convenient, instead basing on the interviews: 3 out of 17 shipments are by all-road. However, again the three shipments are performed by the above mentioned carriers who work on their own account and they rarely perform shipments outside Sicily. As far as the boarding ports are concerned, the model and the interviews generally agree, but for some origin cities there are a few differences between the results of the interviews and the model, again this is caused by the lack of knowledge of the hauliers of the exact cost of the links. If the origin city is in central Italy, Adriatic side, according to the interviews usually the boarding port is Napoli for all destinations in Sicily, while according to the model Napoli results more convenient for destinations in western Sicily, but for destinations in eastern Sicily also Ravenna, for some origins, results convenient. Also if the origin city is in Central Italy, Tyrrhenian side, the interviews and the model generally agree. There are a few differences between the model and the interviews when the origin cities are Firenze and Rome.

If we consider the Italian southern origins, according to the interviews all-road transport is mostly used by trucking companies. From Campania around 50% shipments are performed by intermodal transport, while according to the model intermodal transport is always more convenient. From the other Italian southern regions all-road transport is generally used by trucking firms, instead according to the model intermodal transport turns out to be more convenient than suggested by the interviews. Actually, according to the model, all-road transport is the most convenient mode only for Messina destination from all origins (apart from Napoli) and from Cosenza origin to all destinations in Sicily. If we consider the travel time, instead of the generalized cost, we notice a higher accordance between the model and the interviews. These discrepancies, between the model and the interview outcomes, regarding the Italian southern origins, are probably due to the reasons described above in this section: hauliers do not have a complete information of the cost of all alternatives, therefore they tend to overestimate the cost of maritime transport on short distances. Moreover, if along a route several customers have to be visited, clearly all-road mode is more convenient if distances are not too high.

8. Conclusions

The main reasons of the modal choice, in Italy, between intermodal transport based on MoS and all-road transport have been researched considering MoS routes connecting the Italian mainland with Sicily. The analysis has been carried out through the application of a detailed intermodal network model and the comparison of the model outcomes with the results of the interviews made to some trucking companies.

Actually, monetary costs and travel times are always the most important factors to determine whether, for a given O/D pair, intermodal transport, based on MoS, is competitive. However other aspects have emerged to be important. Firstly, a high frequency of MoS routes is essential to improve the competitiveness of intermodal transport. According to both our model and the interviews, the low frequency on a route highly increases intermodal times and costs and leads a high number of users to choose all-road mode. At least one departure per day, in each MoS route, is essential in order to provide enough flexibility to trucking companies. The reliability of MoS routes is another essential factor: instead, in Italy, MoS operators change very often route timetables; as a result, hauliers choose all-road transport for short distances, although it is less convenient, in terms of generalized cost (and monetary cost), than intermodal transport.

From the interviews, it emerged that the hauliers did not have an accurate knowledge of monetary costs and travel times, therefore they tend to overestimate the cost of maritime transport on short distances. This limits the use of intermodal transport based on MoS on short distances. Furthermore the limited knowledge of road infrastructures, far from the places where the driver usually lives and works, limits the road part of the intermodal path. According to the interview outcomes, drivers do not have a good knowledge of travel times and monetary costs of the parts of the road network that they know less, and perceive them as bigger than they really are. For example, truck drivers from Sicily consider motorways in northern Italy more expensive and especially more congested than they really are, while drivers from north-eastern Italy consider motorways in Sicily slower than they really are.

In any case it resulted from the interviews, that the monetary cost and the travel time are the most important factors considered by trucking companies in the modal and route choice; in this period of economic crisis in Italy, in particular the monetary cost is an important factor affecting modal choice. While it is not worth to reduce relevantly voyage times of MoS routes, especially because of the high amount of time required for boarding and unboarding operations, and the high fuel consumption, the introduction of discounts on ticket prices is always seen as a measure to improve the competitiveness of MoS as it clearly emerges by trucking companies interviews.

A peculiarity of Italy is its geographical conformation, therefore there is a difference, in the competitiveness of MoS services, between north-eastern and north-western origin cities. Hauliers from North-western Italian origin cities can use without difficulty (that is with a short road path) the Italian Tyrrhenian ports which are well connected to Sicily. Instead hauliers from north-eastern Italian origin cities are in disadvantage: because the distance between the Adriatic ports and Sicily is high, especially the distance with the port of Palermo, and also because the supply of MoS routes is low. Actually the only Adriatic port connected to Sicily is Ravenna; moreover, it is connected only to Catania (eastern part of Sicily). As a result, given the current supply of MoS services, from north-eastern Italian origin cities, the optimal choice would be an intermodal path with a long road part which is necessary to reach a Tyrrhenian port: this choice is in any case better, considering the monetary cost and the travel time, compared to the all-road alternative, but trucking companies appear not to consider an intermodal choice based on MoS with a long road part as a valid alternative in any case. Anyway trucking companies claimed that a major development of MoS routes to/from the northern Adriatic ports to western Sicily is necessary. As a result, we can conclude that a strong reason why in Italy MoS traffic is still a small percentage of road traffic is the low number of MoS routes currently in operation and their low frequency.

The proposed model can be a useful tool to evaluate, through a "what if" analysis, the convenience of political measures, aimed at improving the modal shift from all-road to intermodal transport, such as the development of new MoS services, or some modifications in existing MoS services: for example changes in the route frequency or in the ticket price, or the establishment of an intermediate call (as for example Brindisi in the route Ravenna – Catania). The suggested model shows also, in a given scenario, what are the most important MoS routes, and therefore what are the most effective investments.

Moreover, this analysis, developed for an Italian case study, can be applied to other European and Mediterranean scenarios. Actually, Europe, like Italy, has high potentiality for the development of MoS services: the length of the coastline in countries like Spain, Greece, Denmark and the presence of navigable rivers and channels in central European countries clearly provide suitable conditions for the development of MoS services. The model, proposed in this paper, is applicable to any type of scenarios: the difference among different scenarios depends on link costs, but the methodology for their calculation is the same in all possible cases of study. The same factors, which affect the competitiveness of MoS in Italy, are valid in other European countries: the legislation and the economic situation are quite similar (for example, the maximum working hours of a driver are exactly the same). Furthermore, some of the interviewed trucking companies operate also abroad, and the reasons why they choose intermodal transport or all-road transport are always the same, no matter what country they operate in. A situation which often occurs, in the European scenario, is when the road path, from the origin to the destination of the journey, crosses several countries. This reduces the competitiveness of all-road transport, because, according to trucking company interviews, the difference, from a country to another, in traffic rules and language, increases the stress related to driving. This situation is especially relevant when countries which do not belong to the Schengen area are crossed, because further documentation may be needed (e.g. visas), or the freight is subject to custom taxes. An example of this case is the crossing of Balkan countries: all-road transport from northern Italy to Greece, through former Jugoslavia, is much less convenient than intermodal transport based on MoS.

However, as future research, according to the interview outcomes, other elements should be taken into account in the calculation of link costs: the stress of driving; the level of information that the driver has on the transit time of a link; the disutility, perceived by truck drivers, related to changes in the schedules of MoS routes; and the disutility related to boarding and unboarding operations. Furthermore, although the frequency of MoS routes is already taken into account in our model, the calculation of its contribution to the generalized cost of links could be improved.

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Table 1

Table 1. Domestic ro-ro routes between the Italian mainland and Sicily. Data refer to January 2014 (Source: Rete Autostrade Mediterranee (2014) and shipping companies websites).

Route	Operator	Weekly frequency	Voyage time
Ravenna – Brindisi – Catania	Grimaldi	3	39h
Ravenna – Catania (*)	Tirrenia	4	36h30'
Genova – Catania	Grimaldi	4	28h
Livorno – Catania	Grimaldi	3	25h
Napoli – Catania	TTT Lines	7	11h30'
Salerno – Catania	Grimaldi	6	14h
Genova – Palermo	Grimaldi	4	29h
Genova – Palermo	Grandi Navi Veloci	6	20h
Livorno – Palermo	Grimaldi	4	19h
Salerno – Palermo	Grimaldi	2	9h
Civitavecchia – Termini Imerese	Grandi Navi Veloci + SNAV	2	13h
Napoli – Palermo	Tirrenia	7	10h45'
Napoli – Palermo	Grandi Navi Veloci + SNAV	6	10h30'
Civitavecchia – Palermo	SNAV	1	15h
Salerno – Messina	Caronte & Tourist	12	9h

(*) Currently also the route Ravenna – Catania offered by Tirrenia has intermediate stop in Brindisi (August 2015 data)

Table 2

Table 2. Costs and travel times for each MoS route

Origin	Destination	Weekly frequency	Cost of the ticket		Voyage time + boarding time		Waiting time	Generalized cost accompanied	Generalized cost unaccompanied
			Accompanied	Unaccompanied	Accompanied	Unaccompanied			
Brindisi	Catania	3	1009.87	791.77	18.33	19.33	7.00	1380.04	997.36
Civitavecchia	Palermo	3	929.64	746.03	15.00	16.00	7.00	1277.08	928.89
Genova	Palermo	10	1694.58	1340.78	25.30	26.30	2.10	2078.85	1560.47
Genova	Catania	4	1368.32	1100.32	37.00	38.00	5.25	2012.27	1421.28
Livorno	Catania	3	1694.58	1340.78	18.33	19.33	7.00	2064.75	1546.37
Livorno	Palermo	4	1324.50	1055.50	30.00	31.00	5.25	1832.71	1328.72
Napoli	Palermo	14	712.48	555.37	12.38	13.38	1.50	1004.51	682.82
Napoli	Catania	7	754.67	582.34	13.50	14.50	3.00	1064.60	727.69
Ravenna	Catania	6	1092.56	872.57	39.42	40.42	3.50	1741.05	1198.08
Salerno	Catania	6	682.00	559.70	15.00	16.00	3.50	1005.57	718.69
Salerno	Messina	11	1092.56	872.57	11.00	12.00	1.91	1378.00	993.43
Salerno	Palermo	2	1092.56	872.57	12.00	13.00	7.00	1419.54	1034.97

Table 3

Table 3. Comparison between the different modes of transport (accompanied intermodal, unaccompanied intermodal, all-road), in terms of: travel time, monetary cost, generalized cost, for the considered O/D pairs. Because of the amount of data, only the most relevant origins and destinations are shown.

Origin	Destination	Intermodal								All-road			
		Accompanied				Unaccompanied							
		Travel time		Monetary cost (€)	Generalized cost (€)	Travel time		Monetary cost (€)	Generalized cost (€)	Travel time		Monetary cost (€)	Generalized cost (€)
		h	m			h	m			h	m		
Trieste	Palermo	**31**	**41**	2573	2789	42	36	**2065**	**2356**	45	14	3400	3708
	Trapani	**33**	**8**	2779	3005	44	3	**2272**	**2572**	46	29	3593	3910
	Gela	50	39	2546	2892	51	39	**1997**	**2349**	**46**	**8**	3451	3766
	Catania	48	10	2248	2577	49	10	**1698**	**2034**	**43**	**39**	3153	3451
	Messina	49	32	2455	2793	50	32	**1905**	**2250**	**33**	**17**	2946	3173
Venezia	Palermo	**29**	**58**	2290	2494	40	53	**1783**	**2061**	43	31	3117	3414
	Trapani	**31**	**25**	2497	2711	42	20	**1989**	**2278**	44	46	3310	3615
	Gela	48	56	2264	2597	49	56	**1714**	**2054**	**44**	**25**	3168	3471
	Catania	46	27	1965	2282	47	27	**1416**	**1739**	**32**	**56**	2870	3095
	Messina	47	49	2172	2498	48	49	**1622**	**1955**	**30**	**34**	2664	2872
Milano	Palermo	**29**	**44**	2223	2425	30	44	**1697**	**1907**	44	8	3206	3507
	Trapani	**31**	**11**	2429	2642	32	11	**1904**	**2124**	45	23	3399	3708
	Gela	47	5	2355	2676	48	5	**1757**	**2085**	**45**	**2**	3257	3564
	Catania	44	37	2057	2361	45	37	**1459**	**1770**	**33**	**34**	2959	3188
	Messina	45	59	2264	2577	46	59	**1666**	**1986**	**32**	**11**	2752	2972
Torino	Palermo	**30**	**9**	2287	2493	31	9	**1762**	**1974**	45	30	3395	3706
	Trapani	**31**	**36**	2494	2709	32	36	**1969**	**2191**	46	45	3589	3907
	Gela	47	31	2420	2744	48	31	**1822**	**2153**	**46**	**24**	3447	3763
	Catania	45	2	2122	2429	46	2	**1524**	**1838**	**43**	**55**	3149	3448
	Messina	46	24	2328	2645	47	24	**1730**	**2054**	**33**	**33**	2942	3171
Bologna	Palermo	**28**	**3**	1973	2165	38	58	**1466**	**1732**	32	35	2801	3023
	Trapani	**29**	**30**	2180	2381	40	25	**1673**	**1948**	33	50	2994	3224
	Gela	47	8	1966	2287	48	8	**1416**	**1744**	**33**	**29**	2852	3080
	Catania	44	40	1668	1972	45	40	**1118**	**1429**	**30**	**1**	2554	2758
	Messina	46	2	1874	2188	47	2	**1325**	**1645**	**28**	**38**	2347	2542
Genova	Palermo	**27**	**43**	1918	2107	28	43	**1393**	**1589**	43	23	3039	3335
	Trapani	**29**	**10**	2125	2324	30	10	**1600**	**1806**	44	38	3232	3537
	Gela	45	4	2051	2358	46	4	**1453**	**1767**	**44**	**17**	3091	3393
	Catania	42	35	1753	2043	43	35	**1155**	**1452**	**32**	**49**	2792	3016
	Messina	43	58	1960	2259	44	58	**1362**	**1668**	**30**	**26**	2586	2793
Firenze	Palermo	**26**	**50**	1787	1970	37	45	**1280**	**1537**	30	17	2589	2796
	Trapani	**28**	**17**	1994	2187	39	12	**1486**	**1754**	32	32	2782	3004
	Gela	48	36	2098	2430	49	36	**1630**	**1969**	**32**	**11**	2641	2860
	Catania	46	7	1800	2115	47	7	**1332**	**1654**	**38**	**43**	2274	2538
	Messina	47	29	1910	2234	48	29	**1539**	**1870**	**27**	**20**	2136	2322
Livorno	Palermo	**25**	**41**	1619	1794	36	40	**1124**	**1375**	32	11	2658	2877
	Trapani	**27**	**8**	1826	2011	38	7	**1331**	**1591**	33	26	2851	3079
	Gela	**29**	**32**	2116	2318	40	31	**1622**	**1898**	33	5	2709	2935
	Catania	**25**	**47**	1937	2113	26	47	**1412**	**1595**	29	36	2411	2613
	Messina	28	38	2073	2268	29	38	**1619**	**1811**	**28**	**14**	2204	2397
Ancona	Palermo	**20**	**44**	1936	2077	21	44	**1607**	**1756**	29	56	2524	2728
	Trapani	**22**	**11**	2143	2294	23	11	**1814**	**1972**	32	11	2717	2937
	Gela	48	12	2124	2453	49	12	**1575**	**1910**	**30**	**50**	2576	2786
	Catania	45	43	1826	2138	46	43	**1276**	**1595**	**28**	**22**	2277	2471
	Messina	47	5	1845	2166	48	5	**1483**	**1811**	**26**	**59**	2071	2255
Civitavecchia	Palermo	**22**	**14**	1148	1299	23	14	**793**	**951**	28	6	2225	2417
	Trapani	**23**	**41**	1354	1516	24	41	**999**	**1168**	29	21	2418	2618
	Gela	**26**	**5**	1645	1823	27	5	**1290**	**1474**	29	0	2276	2474
	Catania	**25**	**8**	1563	1734	26	8	**1208**	**1386**	26	31	1978	2159
	Messina	25	11	1601	1773	26	11	**1246**	**1425**	**24**	**9**	1771	1936
Roma	Palermo	**17**	**6**	1382	1498	24	45	**995**	**1164**	27	9	2057	2242
	Trapani	**18**	**33**	1588	1715	26	12	**1202**	**1381**	28	24	2250	2443
	Gela	**22**	**14**	1724	1876	23	14	**1380**	**1539**	28	3	2108	2299
	Catania	**19**	**45**	1426	1561	20	45	**1082**	**1224**	24	34	1810	1977
	Messina	**21**	**7**	1536	1680	22	7	**1289**	**1440**	23	12	1603	1761
Foggia	Palermo	**17**	**4**	1415	1532	18	4	**1087**	**1210**	24	31	1826	1993
	Trapani	**18**	**31**	1622	1748	19	31	**1293**	**1426**	26	46	2019	2202
	Gela	**22**	**11**	1758	1909	23	11	**1414**	**1572**	25	25	1878	2051
	Catania	**19**	**43**	1460	1594	20	43	**1116**	**1257**	22	56	1579	1736
	Messina	21	5	1589	1733	22	5	1323	1473	**11**	**34**	**1373**	**1452**
Napoli	Palermo	**14**	**4**	925	1021	15	4	**596**	**699**	23	16	1619	1778
	Trapani	**15**	**31**	1132	1237	16	31	**803**	**916**	24	31	1812	1980
	Gela	**19**	**11**	1268	1398	20	11	**924**	**1062**	24	10	1671	1835

	Catania	**16**	**43**	969	1083	17	43	**626**	**746**	11	41	1372	1452
	Messina	**18**	**5**	1099	1223	19	5	**832**	**962**	10	19	1166	1236
Bari	Palermo	**17**	**26**	1467	1586	18	26	**1139**	**1264**	23	8	1593	1750
	Trapani	**18**	**53**	1674	1803	19	53	**1345**	**1481**	24	23	1786	1952
	Gela	29	43	1644	1726	30	43	**1370**	**1579**	**24**	**2**	1644	1808
	Catania	27	14	1346	1411	28	14	**1072**	**1264**	**11**	**33**	1346	1425
	Messina	31	10	1169	1384	32	10	1282	1504	**10**	**11**	**1139**	**1209**
Brindisi	Palermo	**10**	**55**	1556	1630	29	31	**1258**	**1460**	22	55	1556	1712
	Trapani	**12**	**10**	1749	1832	30	46	**1451**	**1661**	24	10	1749	1914
	Gela	28	7	1496	1688	29	7	**1141**	**1340**	**23**	**49**	1607	1770
	Catania	25	38	1198	1373	26	38	**843**	**1025**	**11**	**20**	1309	1387
	Messina	29	58	1409	1613	30	58	1054	1265	**8**	**58**	**1103**	**1164**
Potenza	Palermo	**16**	**13**	1230	1341	17	13	**902**	**1019**	22	35	1518	1672
	Trapani	**17**	**40**	1437	1557	18	40	**1108**	**1235**	23	50	1712	1874
	Gela	**22**	**47**	1406	1562	23	47	**1113**	**1275**	23	29	1570	1730
	Catania	20	18	1108	1247	21	18	**814**	**960**	**11**	**0**	1272	1347
	Messina	26	37	1319	1500	27	37	1025	1213	**8**	**38**	**1065**	**1124**
Cosenza	Palermo	22	10	1913	2066	23	10	1585	1744	**8**	**4**	**1041**	**1096**
	Trapani	23	35	2140	2299	24	35	1811	1978	**10**	**19**	**1234**	**1304**
	Gela	25	20	2620	2793	26	20	2276	2457	**8**	**58**	**1092**	**1153**
	Catania	27	41	2530	2717	28	41	2187	2380	**6**	**29**	**794**	**838**
	Messina	29	2	2660	2856	30	2	2393	2596	**5**	**7**	**587**	**622**

Table 4

Table 4. The minimum generalized cost path for each O/D pair in case of accompanied intermodal transport and unaccompanied intermodal transport. The table shows the ports of boarding and unboarding. For the O/D pairs for which all-road transport is the minimum generalized cost alternative "Messina Strait" is reported.

Origin	Destination	Accompanied		Unaccompanied	
		Boarding	Unboarding	Boarding	Unboarding
Trieste	Palermo	Civitavecchia	Palermo	Livorno	Palermo
	Trapani	Civitavecchia	Palermo	Livorno	Palermo
	Gela	Ravenna	Catania	Ravenna	Catania
	Catania	Ravenna	Catania	Ravenna	Catania
	Messina	Ravenna	Catania	Ravenna	Catania
Venezia	Palermo	Civitavecchia	Palermo	Livorno	Palermo
	Trapani	Civitavecchia	Palermo	Livorno	Palermo
	Gela	Ravenna	Catania	Ravenna	Catania
	Catania	Ravenna	Catania	Ravenna	Catania
	Messina	Ravenna	Catania	Ravenna	Catania
Milano	Palermo	Genova	Palermo	Genova	Palermo
	Trapani	Genova	Palermo	Genova	Palermo
	Gela	Genova	Catania	Genova	Catania
	Catania	Genova	Catania	Genova	Catania
	Messina	Genova	Catania	Genova	Catania
Torino	Palermo	Genova	Palermo	Genova	Palermo
	Trapani	Genova	Palermo	Genova	Palermo
	Gela	Genova	Catania	Genova	Catania
	Catania	Genova	Catania	Genova	Catania
	Messina	Genova	Catania	Genova	Catania
Bologna	Palermo	Civitavecchia	Palermo	Livorno	Palermo
	Trapani	Civitavecchia	Palermo	Livorno	Palermo
	Gela	Ravenna	Catania	Ravenna	Catania
	Catania	Ravenna	Catania	Ravenna	Catania
	Messina	Ravenna	Catania	Ravenna	Catania
Genova	Palermo	Genova	Palermo	Genova	Palermo
	Trapani	Genova	Palermo	Genova	Palermo
	Gela	Genova	Catania	Genova	Catania
	Catania	Genova	Catania	Genova	Catania
	Messina	Genova	Catania	Genova	Catania
Firenze	Palermo	Civitavecchia	Palermo	Livorno	Palermo
	Trapani	Civitavecchia	Palermo	Livorno	Palermo
	Gela	Napoli	Catania	Ravenna	Catania
	Catania	Napoli	Catania	Ravenna	Catania
	Messina	Napoli	Catania	Ravenna	Catania
Livorno	Palermo	Civitavecchia	Palermo	Livorno	Palermo
	Trapani	Civitavecchia	Palermo	Livorno	Palermo
	Gela	Civitavecchia	Palermo	Livorno	Palermo
	Catania	Livorno	Catania	Livorno	Catania
	Messina	Civitavecchia	Palermo	Livorno	Catania
Ancona	Palermo	Napoli	Palermo	Napoli	Palermo
	Trapani	Napoli	Palermo	Napoli	Palermo
	Gela	Ravenna	Catania	Ravenna	Catania
	Catania	Ravenna	Catania	Ravenna	Catania
	Messina	Ravenna	Catania	Ravenna	Catania
Civitavecchia	Palermo	Civitavecchia	Palermo	Civitavecchia	Palermo
	Trapani	Civitavecchia	Palermo	Civitavecchia	Palermo
	Gela	Civitavecchia	Palermo	Civitavecchia	Palermo
	Catania	Civitavecchia	Palermo	Civitavecchia	Palermo
	Messina	Civitavecchia	Palermo	Civitavecchia	Palermo

Roma	Palermo	Napoli	Palermo	Civitavecchia	Palermo
	Trapani	Napoli	Palermo	Civitavecchia	Palermo
	Gela	Napoli	Catania	Napoli	Catania
	Catania	Napoli	Catania	Napoli	Catania
	Messina	Napoli	Catania	Napoli	Catania
Foggia	Palermo	Napoli	Palermo	Napoli	Palermo
	Trapani	Napoli	Palermo	Napoli	Palermo
	Gela	Napoli	Catania	Napoli	Catania
	Catania	Napoli	Catania	Napoli	Catania
	Messina	Messina Strait	Messina Strait	Messina Strait	Messina Strait
Napoli	Palermo	Napoli	Palermo	Napoli	Palermo
	Trapani	Napoli	Palermo	Napoli	Palermo
	Gela	Napoli	Catania	Napoli	Catania
	Catania	Napoli	Catania	Napoli	Catania
	Messina	Napoli	Catania	Napoli	Catania
Bari	Palermo	Napoli	Palermo	Napoli	Palermo
	Trapani	Napoli	Palermo	Napoli	Palermo
	Gela	Brindisi	Catania	Brindisi	Catania
	Catania	Brindisi	Catania	Brindisi	Catania
	Messina	Messina Strait	Messina Strait	Messina Strait	Messina Strait
Brindisi	Palermo	Brindisi	Catania	Brindisi	Catania
	Trapani	Brindisi	Catania	Brindisi	Catania
	Gela	Brindisi	Catania	Brindisi	Catania
	Catania	Brindisi	Catania	Brindisi	Catania
	Messina	Messina Strait	Messina Strait	Messina Strait	Messina Strait
Potenza	Palermo	Napoli	Palermo	Napoli	Palermo
	Trapani	Napoli	Palermo	Napoli	Palermo
	Gela	Salerno	Catania	Salerno	Catania
	Catania	Salerno	Catania	Salerno	Catania
	Messina	Messina Strait	Messina Strait	Messina Strait	Messina Strait
Cosenza	Palermo	Messina Strait	Messina Strait	Messina Strait	Messina Strait
	Trapani	Messina Strait	Messina Strait	Messina Strait	Messina Strait
	Gela	Messina Strait	Messina Strait	Messina Strait	Messina Strait
	Catania	Messina Strait	Messina Strait	Messina Strait	Messina Strait
	Messina	Messina Strait	Messina Strait	Messina Strait	Messina Strait

Table 5

Table 5. The outcomes of the interviews. The table shows: the origin and destination of the journey; the chosen mode of transport ; the number of shipments; in case of intermodal transport, the boarding and the unboarding port .

Origin	Destination	Intermodal / all-road	Boarding port	Unboarding port	n° shipments
North-western mainland	Western Sicily	Intermodal	Genova	Palermo	5
North-western mainland	Eastern Sicily	Intermodal	Genova	Catania	7
North-eastern mainand	Eastern Sicily	Intermodal	Ravenna	Catania	5
North-eastern mainand	Western Sicily	Intermodal	Ravenna	Catania	3 (the office interviewed was in Sicily)
North-eastern mainand	Western Sicily	Intermodal	Livorno	Palermo	2 (the office inter-viewed was in northern Italy)
Central Italy, north Tuscany	Western Sicily	Intermodal	Livorno	Palermo	1
Central Italy, north Tuscany	Eastern Sicily	Intermodal	Livorno	Catania	2
Central Italy, south Tuscany and Lazio	Western Sicily	Intermodal	Civitavecchia, Napoli	Palermo	2 (Civitavecchia is chosen by only its surroundings; rest of Lazio region chooses Napoli)
Central Italy, south Tuscany and Lazio	Eastern Sicily	Intermodal	Napoli	Catania	5
Central Italy, Adriatic part	Western Sicily	Intermodal	Napoli	Palermo	2
Central Italy, Adriatic part	Eastern Sicily	Intermodal	Napoli	Catania	2
South Italy: Campania and northern Puglia	Western Sicily	Intermodal	Napoli, Salerno	Palermo	6
South Italy: Campania and northern Puglia	Eastern Sicily	Intermodal	Napoli, Salerno	Catania, Messina	4
North-western mainland	Eastern Sicily	All-road	-	-	2
North-eastern mainand	Eastern Sicily	All-road	-	-	2
Central Italy, south Tuscany and Lazio	Eastern Sicily	All-road	-	-	3
South Italy: Campania and northern Puglia	Western Sicily	All-road	-	-	2
South Italy: Campania and northern Puglia	Eastern Sicily	All-road	-	-	10
South Italy: southern Puglia, Basilicata and Calabria	Western Sicily	All-road	-	-	3
South Italy: all Puglia, Basilicata and Calabria	Eastern Sicily	All-road	-	-	2