TRANSPORT PROBLEMS 2017 Volume 12 Issue: Special Edition
PROBLEMY TRANSPORTU DOI: 10.20858/tp.2017.12.se.11

Keywords: Motorways of the Sea (MoS); italian MoS network; MoS routes; ro-pax services; ro-ro services; competitiveness against all-road transport

Marino LUPI*, Alessandro FARINA, Antonio PRATELLI, Letizia BELLUCCI
University of Pisa, Department of Civil and Industrial Engineering
Lungarno Pacinotti 43, 56126 Pisa, Italy
**Corresponding author*. E-mail: marino.lupi@unipi.it

AN ANALYSIS OF THE ITALIAN RO-RO AND RO-PAX NETWORK IN THE YEARS 2008-2015

Summary. In this paper, the development of Motorways of the Sea (MoS) services offered at Italian ports from 2008 to 2015 is analyzed. In particular, a detailed research on MoS routes calling at Italian ports in the year 2015 is carried out; within MoS routes: ro-pax and only cargo ro-ro services are identified. MoS routes in the year 2015 are compared with those in the years 2008, 2010 and 2012. The study highlights two main aspects. First, the great majority of MoS routes in Italy are ro-pax ones: ro-ro routes are only 31% of the total, but ro-pax service frequencies are highly variable during the year, from high to low season. Second, due to the economic crisis, carriers are trying to operate services with high load factors and trying to find new markets: in fact, from 2008 to 2015, route frequencies have decreased, whereas the number of port calls in each route has increased. Finally, the capability of ro-ro and ro-pax routes of being competitive versus all-road transport has been analyzed. The analysis has shown that both ro-ro and ro-pax routes show relevant problems in terms of their competitiveness against all-road transport. Ro-pax routes are not reliable and ro-ro routes are not fast and frequent; thus, they both do not fulfill essential requirements for MoS services.

1. INTRODUCTION

Motorways of the Sea (MoS) have been proposed in the 2001 White Paper [1] on the European transport policy and have therefore become one of the priority projects of the "Trans European Transport Network" (TEN-T) programme [2]. Motorways of the Sea are ro-ro and ro-pax Short Sea Shipping (SSS) services, with particular characteristics; they have to be scheduled, reliable, high speed, economically feasible and integrated into door-to-door logistic chains. In particular, the integration of Motorways of the Sea with road transport must be optimized [3]. The Article 12a of the TEN-T Guidelines [2] has stated the main objectives of MoS: "The trans-European network of motorways of the sea is intended to concentrate flows of freight on sea-based logistical routes in such a way as to improve existing maritime links or to establish new viable, regular and frequent maritime links for the transport of goods between Member States so as to reduce road congestion and/or improve access to peripheral and island regions and States. Motorways of the sea should not exclude the combined transport of persons and goods, provided that freight is predominant."

The development of Motorways of the Sea in Europe has focused on the following areas: the Baltic Sea, the Western Europe Atlantic coast, the West Mediterranean and the East Mediterranean. Italy has been considered by the European Commission as a "border" between the West and the East Mediterranean zones.

The development of Motorways of the Sea is supported by the EU policies [1, 4]. According to the 2011 White Paper [5], road transport is no longer sustainable: high CO2 emissions are registered and the increase in road congestion requires the construction of new roads. In a study (by Grimaldi for the

European Climate Change Programme), cited in the 2001 White Paper [1], it is shown that intermodal transport, based on SSS, produces, on any given link, 2.5 times less pollution, in terms of CO2, than the all-road alternative. In Craig et al. [6], the savings of CO2 emissions, resulting from the shift to intermodal transport, based on rail, have been calculated on a USA scenario: the average carbon intensity of intermodal transport has been estimated to be 67 g CO2/ton-mile, 46% lower than the road mode.

In Denisis [7] it has been calculated that, in the USA, the external cost of MoS is, on average, 0.0319 $/ton-mi, whereas the external cost of all-road transport is, on average, 0.0647 $/ton-mi. External costs are calculated from air pollution, climate change, noise, congestion and accidents.

On the other hand, in Lopez-Navarro [8], it has been shown that external costs of MoS increase as the speed increases. Actually, although generally, MoS external costs are significantly lower than those of road transport, if the velocity of ships is very high, in particular greater than 23 km, the external costs of MoS are greater than those of all-road transport. Moreover, if the geography is in favor of maritime transport, for example between Spain and Italy, savings of external costs could be very high. For example, for the O-D pair Barcelona–Florence, the environmental cost (i.e. external costs excluded congestion and accidents) of all-road transport is nearly two times the environmental cost of intermodal transport based on MoS ([8], p. 1560).

In addition, as reported in the 2011 White Paper [1], road transport has a high accident rate: in the year 2015, 25,075 deaths have occurred on European roads (25,974 in 2014) (Source: Eurostat [9]).

For all these reasons, the modal shift, of at least some part of freight transport, to intermodal transport based on Rail or Mos is necessary. Several policies could be adopted to achieve this target: the 2011 White Paper states that it is necessary to improve the accessibility to ports, the dimension of the MoS network and the completion of the TEN-T rail network. Furthermore, the White Paper also suggests policies aimed at internalizing the external costs of road transport: external costs are not perceived by shippers and trucking companies when choosing among the possible transport modes.

Some studies have been carried out on the competitiveness of Mos against all-road transport; see for example: Ng [10], Lupi et al. [11]; MoS are yet to overcome several shortcomings: to carry out an integrated door-to-door service, MoS require the “collaboration” of road, or rail, mode for collection and delivery, and a network of well-located inland terminals. Nowadays, the efficiency of ports, sea side port services and land side port services, that is, port-hinterland connections, is still too low: as shown in Fusco et al. [12], this can adversely affect the competitiveness of intermodal transport based on MoS with respect to all-road transport. The most critical aspect is related to the complexity of administrative procedures in ports, which leads to high transit times and, therefore, to a marked decrease in the efficiency of MoS services. Considerable effort still has to be made, both in Italy and Europe, to achieve a considerable modal shift from road to MoS. Actually, in Italy, in 2014, MoS accounted for 5.5% of road freight traffic, whereas in the EU-28, the situation was even worse: MoS accounted for only 1.7% of road freight traffic [9]. On the other hand, the EU would have a wide potentiality for the development of MoS because it has a coastline of 67,000 km and between 60% and 70% of its industrial and production centers are located within 150-200 km of the coast.

In this paper, first (section 2), the main characteristics of Motorways of the Sea (MoS) services, to and from Italian ports, in 2015 are presented. A distinction is made between only cargo ro-ro (called simply ro-ro in the following) and ro-pax services. In section 3, a comparison between the characteristics of ro-ro and ro-pax services is performed, and their competitiveness versus all-road transport is analyzed. In section 4, the evolution of MoS services in the years 2008, 2010, 2012 and 2015 is described. In section 5, the degree of connectivity of the MoS network is evaluated. Finally, the conclusions are presented.

2. ITALIAN MOTORWAYS OF THE SEA ROUTES IN THE YEAR 2015

In this paper, an analysis has been carried out on Motorways of the Sea routes to/from Italian ports. In this study, for the first time, in the quantitative analysis of Italian MoS, differences have been identified between ro-pax services (i.e. routes that serve not only freight vehicles but also passenger

vehicles) and only cargo ro-ro services (which carry only freight vehicles). In the following, we will refer to "only cargo ro-ro" services as simply "ro-ro" services.

Data have been recorded from July to October 2015 due to the high variability of ro-pax services during the year: several routes reduce their frequencies, or register no departures at all, during low season periods. The months of July and August are high seasons, the month of September can be considered a transition period, whereas the month of October is low season. As a result, the most significant data are those from July and August (high season) and October (low season).

There are 12 domestic ro-ro routes (i.e. routes that connect exclusively Italian ports); these are managed by 3 shipping companies, with 31 departures per week. These routes connect 10 Italian ports. Departures per week are always the same in the period considered because there is no variability in ro-ro departures from high season to low season periods. Domestic ro-ro routes are reported in detail in appendix A tab.1. There are 18 international ro-ro routes; these are managed by 6 shipping companies and register 38 departures per week. These routes connect 12 Italian ports and 10 non Italian ports. Departures per week remain the same in all the periods under study because, just like in the domestic case, there is no variability in ro-ro departures from high season to low season periods. Portions of some ro-ro international routes connect together Italian ports. International ro-ro routes are reported in detail in appendix A tab.3. The total number of ro-ro routes (national + international) is 30; these routes are managed by 7 shipping companies, with 69 departures per week, and connect 14 Italian ports and 10 non Italian ports. The number of departures per week is always the same in the period of study, as underlined above.

Domestic ro-pax routes are 21 in high season and 17 in low season; these are managed by 9 shipping companies, with 133 departures per week in high season and 78 departures per week in low season. These routes connect 15 Italian ports in high season and 14 in low season. Domestic ro-pax routes are shown in detail in appendix A tab. 2. There are 40 international ro-pax routes in high season and 30 in low season; these are managed by 19 shipping companies, with 206 departures per week in high season and 122 departures per week in low season. These routes connect 12 Italian ports and 19 non Italian ports. Portions of some ro-pax international routes connect together Italian ports. International ro-pax routes are reported in detail in appendix 4. The total number of ro-pax routes (domestic + international) is 62 in high season and 47 in low season; these are managed by 23 shipping companies. The total departures by week are equal to 339 departures per week in high season and 200 departures per week in low season. They connect 41 ports in high season and 40 in low season: 22 (high season) and 21 (low season) Italian and 19 non Italian ports.

A synthesis of the characteristics of ro-ro and ro-pax routes in the year 2015 is reported in table 1.

Table 1

Synthesis of characteristics of ro-ro and ro-pax routes to/from Italian ports in 2015. Data refer to July – October 2015.

Source: ramspa website [13] and MoS operators' websites

	n° routes	n° departures per week	n° ports connected	
			Italian	non Italian
Domestic ro-ro routes	12	31	10	0
International ro-ro routes	18	38	12	10
Total ro-ro routes	30	69	14	10
Domestic ro-pax routes, high season	21	133	15	0
Domestic ro-pax routes, low season	17	78	14	0
International ro-pax routes, high season	40	206	12	19
International ro-pax routes, low season	30	122	12	19
Total ro-pax routes, high season	62	339	22	19
Total ro-pax routes, low season	47	200	21	19

The most frequent ro-ro domestic route is Catania – Salerno, offered by Grimaldi Lines, which registers 6 departures per week (during the entire period under study), whereas the most frequent ro-pax domestic routes are Livorno – Golfo Aranci and Livorno – Olbia, offered, respectively, by Sardinia/Corsica Ferries and by Moby Lines, which register both 14 departures per week in high season and, respectively, 8 and 7 departures per week in low season. The most frequent international ro-ro route is Trieste – Pendik, offered by U.N. ro-ro, with 6 departures per week. The most frequent international ro-pax routes are Livorno – Bastia, offered by Sardinia/Corsica Ferries, with 14 departures per week in high season and 10 in low season, and Pozzallo – Malta, offered by Virtu Ferries, with always 20 departures per week. The longest domestic routes are Catania-Brindisi-Ravenna: 1165 km; Genova-Livorno-Catania: 1028 km; Savona-Genova-Catania: 1026 km; they are all ro-ro routes. The longest international routes are: Savona-Genova-Catania-Bar-Catania-Savona: 3439 km; and Savona-Genova-Catania-Patrasso-Savona: 3138 km. Again, all these routes are ro-ro ones.

The port connected with the highest number of destinations (national + international) is Genoa, with 13 destinations, whereas Livorno is connected to 12 destinations. The port that registers the highest number of departures per week is Livorno, with 75 departures per week in July and August (high season), 68 in September and 48 in October (low season).

The collected data show that the majority of MoS routes are ro-pax. Actually, in high season (July and August), only 33% of routes are ro-ro versus 67% of ro-pax. In low season (October), the percentage of ro-pax routes is slightly less: 39% of routes are ro-ro versus 61% of ro-pax routes. Moreover, ro-ro departures per week are 17% of the total departures per week in high season (July and August) and 27.7% in October (low season). Ro-pax departures, however, are 83% of the total in high season and 72.3% in low season. In table 2, a comparison is provided of the characteristics of ro-ro and ro-pax routes (in high and low season) in terms of the number of calls at ports.

Table 2

Number of routes which call at a given number of ports in 2015. Values are different: among domestic, international and total (domestic + international) routes, and among ro-ro and ro-pax (high and low season) routes. h.s. and l.s. stand for high season and low season. Source: ramspa website [13] and MoS operators websites

Route typology	Domestic			International			Total		
	ro-ro	ro-pax h.s.	ro-pax l.s.	ro-ro	ro-pax h.s.	ro-pax l.s.	ro-ro	ro-pax h.s.	ro-pax l.s.
point-to-point	6	19	16	5	26	17	11	45	33
connect 3 ports	5	2	1	8	12	11	13	14	12
connect more than 3 ports	1	0	0	5	2	2	6	2	2
Total	12	21	17	18	40	30	30	61	47

Actually, although only 50% of domestic ro-ro routes and 28% of international ro-ro routes are point-to-point, the quota of ro-pax point-to-point routes is much higher: only 1 (in low season) or 2 (in high season) domestic ro-pax routes call at more than 2 ports, whereas the 65% (in high season) and the 56% (in low seasons) of international routes are point-to-point. The shape of ro-ro and ro-pax routes is generally different: a ro-ro route may take a long path, for example it connects Savona and Genoa with Catania and Bar to achieve a higher load factor of the ship and a ro-pax route usually stops at intermediate ports only if their geographical position is along the route. For example, in the ro-pax route Venezia–Ancona–Igoumenitsa–Patrasso, the route calls at the ports of Ancona and Igoumenitsa because they are along the route between Venezia and Patrasso.

As pointed out before, the length of ro-ro routes is longer than that of ro-pax ones: the average length of domestic ro-ro routes is around 810 km versus 390 km for ro-pax ones; the average length of international ro-ro routes is around 1600 km versus 600 km for ro-pax ones. This probably occurs because, in this period of economic crisis, for freight transport, travel time is considered less important

than the cost. However, this is not the case for passenger transport, and consequently for ro-pax routes, where travel time remains important.

Finally, operators choose to maximize frequencies in the routes where there is always a high demand. These routes usually are those that connect the Italian main-land with the islands or the two sides of the Adriatic Sea. A high frequency is therefore registered by the routes Livorno–Olbia and Livorno–Golfo Aranci, which connect the Italian mainland with Sardinia. Similarly, the route Napoli–Palermo, which connects the Italian mainland with Sicily, registers a high frequency. Another important route is Pozzallo–Malta, which is the shortest route to reach Malta from Italy. However, the routes that show the highest frequencies are those that perform local connections to ensure territorial continuity. It must be underlined that some of these routes are offered by small ships, and are so short that they cannot be considered real MoS, for example, routes between Piombino and Elba Island, those connecting Villa San Giovanni with Messina and the route connecting the north coast of Sardinia with the south coast of Corsican, i.e. Santa Teresa Gallura–Bonifacio.

All these aspects adversely affect the competitiveness of intermodal transport based on MoS with respect to all-road transport. Actually, MoS routes, to be competitive, must be scheduled, frequent, reliable, fast and integrated into the door-to-door logistic chain. On the one hand, the high number of port calls and the low frequency maximize the load factor of the ship and on the other, they reduce the competitiveness of intermodal transport respect to all-road transport. In addition, domestic MoS routes usually connect the mainland with the islands; usually, these routes are ro-pax ones. Instead, not many routes connect together ports in the mainland; they are usually part of longer (and often international) routes. However, as reported in Lupi and Farina [14], routes connecting the Italian mainland and Sicily can constitute a valid alternative to the "nearly all-road" transport, where the only maritime part is the crossing of the Strait of Messina.

3. RO-RO AND RO-PAX SERVICES AND THE COMPETITION OF INTERMODAL TRANSPORT AGAINST ALL-ROAD TRANSPORT

To understand whether ro-ro or ro-pax routes can be competitive against all-road transport, the results of the research reported in Lupi et al. [11] have to be taken into account. In this research, trucking companies, operating between the Italian mainland and Sicily, were interviewed on the main factors that influence their choice between intermodal transport, based on MoS, and all-road transport. The interviewed firms reported that monetary costs (in particular ticket costs), travel times and route frequencies are always the most important characteristics of a competitive MoS route. But trucking firms reported that the reliability of MoS routes is another important factor: a change in routes schedules or unavailability of some services because if the ship is full is perceived very badly.

Ro-pax routes register higher frequencies and lower travel times (because they call at a lower number of ports) than ro-ro ones. On the other hand, ro-pax routes lack reliability. First, they show high seasonality effects: ro-pax route frequencies are much higher in high season periods; consequently, the day of departure and the departure time may change too often. Second, although in low season ro-pax ships have a low load factor, in high season, they are almost full. As a result, it often happens that freight vehicles are not able to make the reservation for the desired ship departure because it is already full, and have to postpone their departure, for example to the day after. This occurs quite often because usually passengers (and their cars) are able to make their reservation a long time in advance (therefore they usually find an available space on the ship), whereas it is not the same for freight vehicles. This results in a lack of reliability, which is not acceptable for MoS services in competition with all-road services. Therefore, allowing passengers and cargo on the same ship is not a good solution to increase the competition of intermodal transport. On the other hand, it is clear that this choice is made by MoS operators to maximize their revenues.

However, ro-ro routes usually have a lower ticket price. Comparing two point-to-point connections offered by the same operator, i.e. Livorno–Cagliari (ro-ro) and Napoli–Cagliari (ro-pax), it could be observed that although the ro-ro connection (Livorno – Cagliari) is much longer than the ro-pax one (Napoli–Cagliari), the ticket price of the ro-ro connection is lower. Actually, Tirrenia reports the ticket

price per linear meter in each route offered. The ro-ro route Livorno–Cagliari (the airline distance between Livorno and Cagliari is over 570 km) has a ticket price of about 35 € per linear meter, which results in 577 € for a 16.5 m long truck and trailer. Instead, the ro-pax route Napoli–Cagliari (the airline distance between Napoli and Cagliari is around 500 km, and therefore it is slightly shorter than the previous one) has a ticket price of 38 € per linear meter, which results in 627 € for a 16.5 m long truck and trailer.

In sum, both ro-ro and ro-pax services are inadequate to offer a real alternative to all-road transport. Ro-pax routes have good performance in terms of frequencies and travel times, but have poor performance in terms of the reliability. On the other hand, ro-ro services have good performance in terms of the reliability of the service and ticket prices, but they have poor performance in terms of travel times and frequencies. We have to keep in mind that MoS routes must be reliable, fast, frequent and integrated in the door-to-door logistic chain.

Therefore, ro-pax routes are not reliable and ro-ro routes are not fast and frequent; thus, they both do not fulfill essential requirements for MoS services.

4. THE DEVELOPMENT OF MOTORWAYS OF THE SEA IN 2008, 2010, 2012 and 2015

A comparison has been carried out of Italian MoS routes operated in the year 2015 with those in the years 2008, 2010 and 2012. The collected data refer to February 2008, March 2010 and November 2012. These routes have been reported in detail in Danesi et al. [15,16] and Lupi and Farina [17].

These data have been collected in low season periods. Actually, the analysis of the years 2008 – 2012 did not aim to distinguish between ro-ro and ro-pax routes, and in analyzing their differences, therefore, the seasonality of ro-pax routes was not the main focus. In addition, whereas ro-ro routes follow the same frequencies during the year, in high season, ro-pax routes are not reliable because some departures are unavailable for booking because the ship is full. This was the reason why the survey in the previous years was conducted only in low season periods.

In addition, ro-ro and ro-pax routes are considered together in the comparison because ro-ro and ro-pax routes were also not distinguished in the previous years.

The results of the comparison are shown in Tables 3, 4 and 5. All these data show an evolution, from 2008 to 2015, toward longer routes, calling at a greater number of ports. As a result, the route length increases, but the travel times increase and speeds also decrease. Therefore, the competitiveness with all-road transport decreases. This is particularly evident when the low season of 2015 is considered.

In Table 3, the number of routes and the route frequencies, in the years under analysis, are reported. The numbers of routes and route frequencies have been distinguished in domestic, international and total (i.e. domestic + international) sectors.

Table 3

Synthesis of the comparison among 2008, 2010, 2012 and 2015 (low and high season) data: n°departures per week, n° routes. l.s and h.s stand for low season and high season

	n° departures by week					n° routes				
	2008	2010	2012	2015 l.s.	2015 h.s.	2008	2010	2012	2015 l.s.	2015 h.s.
Domestic	169	174	166	109	164	28	32	35	29	33
International	245	250	241	156	244	50	45	46	48	58
Total	414	424	407	265	408	77	77	91	77	91

Table 4
Number of routes that call at a given number of ports in the years 2008, 2010, 2012 and 2015 (low and high season): l.s and h.s stand for low season and high season. Data refer to both domestic and international routes

Route typology	n° routes					percentage of routes				
	2008	2010	2012	2015 l.s.	2015 h.s.	2008	2010	2012	2015 l.s.	2015 h.s.
Point-to-point	73	67	63	43	55	94.8	86.8	69.2	55.8	60.4
connecting 3 ports	4	10	19	26	28	5.2	13.2	20.9	33.8	30.7
connecting more than 3 ports	0	0	9	8	8	0	0	9.9	10.4	8.8
Total	77	77	91	77	91	100	100	100	100	100

From the comparison, a marked decrease in the departures per week can be observed from 2012 to 2015, although this trend already existed from 2010 to 2012. Actually, departures per week in the high season of 2015 are almost the same as in the low season of 2012 (408 and 407, respectively), whereas in the low season of 2015, they are much less (i.e. 265). In addition, the variability of weekly frequencies between high and low season in 2015 is relevant: 408 in high season and 265 in low season. In terms of the number of routes, an initial increase from 2008 to 2012 could be observed: from 77 routes in 2008 and 2010 to 91 in 2012. However, the number of routes also showed a marked decrease from 2012 to 2015: in the high season of 2015 it is still equal to 91, but in the low season of 2015, only 77 routes are in operation.

An explanation for this phenomenon could be that operators try to maximize the revenues and put in operation only routes with a high load factor of ships: therefore, in low season, when the transport demand is lower, some routes are not operated and the route frequencies are highly reduced. In addition, it can be observed that some routes, from 2012 to 2015, have been combined: for example, the routes Genoa – Palermo and Livorno – Palermo have been combined with the route Genoa – Livorno – Palermo – Genoa. This choice was made by MoS operators to serve more markets, through a single route, because, in this way, the load factor of ships could be further increased.

Furthermore, as shown in Table 4, from 2008 to 2015, MoS routes became longer and called at a higher number of ports. In 2008, around 95% of routes were point-to-point; in 2015, only 61% of routes were point-to-point in the high season period, whereas in the low season period they were only 55.3%. In addition, the longest route in 2015 is the Savona–Genoa–Catania–Bar, over 3400 km long; in 2012, the longest route was Trieste–Mersin (2546 km): all the other routes were less than 2500 km in length.

Table 5 shows the trend of the average routes length, the average travel time and the average speed. The average route length and the average travel time have generally increased from 2008 to 2015, in particular, from 2010 to 2015. In addition, both the route length and the average travel times are greater in the low season of 2015 than in the high season of 2015: in the period of low demand, the operators prefer to invest in the routes that call at a greater number of ports, and therefore, serve more markets, to increase the load factor of ships.

The average speed has decreased from 2008 to 2015. The general decrease in the average speed is due to the greater number of port calls per route: the average speed is calculated by also taking into account the time spent by the ship at the port for the loading and unloading operations.

Finally, in the year 2012, it could be observed that the most important operator was Grimaldi Lines in terms of both departures per week and number of routes. Actually, Grimaldi Lines operated 37 routes, considering both domestic and international ones, and offered more than 80 departures per week. The second operator was Tirrenia, with 13 routes and 48 departures per week. In 2015, Grimaldi operated 29 routes in high season and 26 in low season, whereas Tirrenia operated 12 routes in both high and low seasons. Moreover, again in 2015, Grimaldi offered 71 departures per week in high season and 66 in low season, whereas Tirrenia offered 44 departures per week in high season and 39 in low season. As a result, in 2015, Grimaldi was still the most important MoS operator, but it has reduced the service supplied.

Table 5
Average route length, average travel times and average speeds for domestic, international and total (domestic + international) routes in the years 2008, 2010, 2012 and 2015 (low and high season): l.s and h.s stand for low season and high season; D. stands for domestic routes; I. stands for international routes; T. stands for total (domestic + international) routes

	Average route length (km)			Average travel time (h)			Average speed (km/h)		
	D.	I.	T.	D.	I.	T.	D.	I.	T.
2008	489	706	618	16.5	25.2	22.12	31.15	36.0	34.3
2010	478	795	646	15.5	22.8	19.8	31.9	35.5	34.0
2012	518	967	794	15.7	29.1	24.0	32.9	33.2	33.1
2015 h.s.	539	970.5	810	18.5	29.6	26.6	29.2	32.8	31.2
2015 l.s.	571	1028	856	21.0	32.7	28.3	27.2	31.5	30.3

5. MEASURES OF CONNECTIVITY

To evaluate the change in the connectivity of the domestic MoS network in the years under consideration and to compare the connectivity of ro-ro and ro-pax routes, two measures have been used: the beta index and the gamma index [18,19]. The Beta index measures the average number of links per node, and it is the ratio between the number of links in the network and the number of nodes. On the other hand, the gamma index summarizes how relatively connected a network is by considering the ratio between the number of actual links and the maximum number of potential links. Considering L the number of links and n the number of nodes, it holds that

$$\beta = L/n \tag{1}$$

and

$$\gamma = L/[n(n-1)] \tag{2}$$

The analysis has been carried out for the following:

- the domestic network;
- the portion of international routes calling at Italian ports: for coherence with the previous years, and because it is considered the possibility that cargo having both origin and destination in Italy is accepted.

Nodes represent Italian ports and links represent direct connections between couples of Italian ports: for example, the route Ravenna – Brindisi – Catania is composed of 2 links: Ravenna – Brindisi and Brindisi – Catania; instead, in the route Venezia – Ancona – Igoumenitsa – Patrasso, only the link Venezia – Ancona is taken into account. Each link is considered bidirectional.

Connectivity measures are reported in tab. 6 and 7. As shown in table 6, the connectivity values have increased from 2008 to 2012, but have decreased from 2012 to 2015.

Comparing, instead, the connectivity measures of ro-ro and ro-pax routes (tab. 7), it turns out that ro-ro ones have much higher connectivity values: the beta index of ro-ro routes is 2.6, whereas the beta index of ro-pax ones is between 1.15 and 1.30; the gamma index of ro-ro routes is 0.19, whereas the gamma index of ro-pax is 0.06. This is an expected result because the number of Italian ports crossed by ro-ro routes (i.e. 14 ports) is much lower than the number of ports crossed by ro-pax ones (22 ports in high season and 21 in low season as shown in table 1. Therefore, although ro-ro routes are less than ro-pax ones, connectivity measures remain higher because the number of ports involved is much lower.

In addition, connectivity indexes of ro-ro routes are quite similar to the indexes of the whole MoS network (see Table 6, year 2015, high and low season). Actually, although the number of ro-ro routes

is much lower than the total number of all the MoS routes, the number of ports crossed by ro-ro routes is much lower than the total number of Italian MoS ports. Instead, connectivity indexes of ro-pax routes (table 7) are much lower than the connectivity indexes of the entire MoS network (Table 6, year 2015, high and low season): the number of ro-pax routes is less than the total number of MoS routes, whereas all Italian MoS ports are crossed by ro-pax routes.

Table 6

Values of connection measures, the beta and the gamma index, in the domestic MoS network, in 2008, 2010, 2012 and 2015 (low and high season): l.s and h.s stand for low season and high season

	2008	2010	2012	2015 h.s.	2015 l.s.
n, number of nodes (ports)	18	19	20	22	21
L, number of links (connections)	56	64	72	64	60
$\beta = L / n$	3.11	3.37	3.6	2.9	2.86
$\gamma = L / [n (n - 1)]$	0.16	0.19	0.20	0.14	0.14

Table 7

Values of connection measures, the beta and the gamma index, in the domestic MoS network, distinguishing between ro-ro and ro-pax routes. Data refer to the year 2015 (low and high season): l.s and h.s stand for low season and high season

	ro-ro routes	ro-pax routes (h.s.)	ro-pax routes (l.s.)
n, number of nodes (ports)	14	22	21
L, number of links (connections)	36	28	24
$\beta = L / n$	2.6	1.27	1.15
$\gamma = L / [n (n - 1)]$	0.19	0.06	0.06

6. CONCLUSIONS

In this paper, an analysis of Italian MoS routes in the year 2015 has been carried out. It has been distinguished between ro-pax routes, carrying both passengers and freight, and ro-ro routes, carrying only freight, which have been called simply "ro-ro" in the paper. Then, these routes have been compared with those registered in the years 2008, 2010 and 2012.

The analysis of 2015 data has shown that ro-ro and ro-pax routes have different characteristics. First, the great majority of Italian MoS routes are ro-pax ones so ro-ro services defect in frequency clear. Ro-ro routes have been developed to maximize the operators' revenues by calling at several ports, therefore serving several markets, although this results in a worse quality of the service because of higher travel times and a worse capacity of being competitive against all-road transport. Ro-ro routes are usually much longer, and call at a higher number of ports, than ro-pax ones. Actually, ro-pax routes may also stop at some intermediate ports, but this occurs only when they are close to the direct route. Furthermore, although ro-ro routes maintain almost the same frequencies during the year, ro-pax routes highly reduce their frequencies from high season to low season periods.

The high travel times and low frequencies registered by ro-ro routes decrease their competitiveness against all-road transport; on the other hand, the low reliability, shown by ro-pax routes, due to their seasonality, adversely affects the ro-pax routes' competitiveness against all-road transport. As a result, both ro-ro and ro-pax routes show relevant problems in terms of their competitiveness against all-road transport. The ro-pax routes are not reliable and ro-ro routes are not fast and frequent: consequently, they both do not fulfil the essential requirements for MoS services.

However, MoS operators are not really interested in offering competitive services against all-road transport. MoS operators prefer to invest in a niche demand, to/from islands, which is rigid and is not in competition with all-road transport. In addition, they aim to maximize their revenues by calling at a

higher number of ports and increasing the load factors. This results in low frequencies and high travel times for ro-ro routes, and in the lack of reliability of ro-pax routes.

On the other hand, the comments made earlier (in the previous paragraph) are mainly related to domestic MoS routes. Actually, international routes are generally more competitive. For example, the routes between Italy and Spain are alternatives to a long and congested road path; therefore, they are attractive with respect to the all-road alternative. The international routes connecting the two sides of the Adriatic Sea are even more competitive: the all-road alternative, through Balkan countries, requires crossing several borders, in addition to a long road path that only partially involves motorways. This has been clearly understood by MoS operators, who invest massively in this market, by offering several MoS routes, often with high frequency. Finally, international MoS routes connecting Italy with North Africa could also be very important: in this case, for geographical reasons, they are not in competition with a parallel "all-road" path.

Data of 2015 have been compared with those registered in 2008, 2010 and 2012. However, in these years, separate data for ro-ro and ro-pax services were not available.

The results of the comparison clearly show a decrease in the number of routes and, in particular, in the number of departures per week. Moreover, the number of port calls per route has peaked from 2012 to 2015: in 2015, point-to-point routes were only around 50% of the total. These results are all a result of the economic crisis: the operators prefer to maximize the load factor of the ships to increase the revenues and reduce costs. However, this results in an increase in travel times and in a decrease in the average speed of the routes, which, together with the decrease in frequencies, adversely affects the competitiveness of MoS with respect to all-road transport.

To improve the competitiveness of Italian MoS routes, several policies could be adopted. Actually, the Italian peninsula is characterized by two "natural" MoS corridors, i.e. the Tyrrhenian and the Adriatic ones, which could allow some part of freight transport to shift from road to MoS. The efficiency of ports, which reduces the time for boarding and unboarding ro-ro and ro-pax ships, and the accessibility of port terminals are important factors for the competitiveness of Motorways of the Sea against all-road transport [20]. The improvement in MoS connections between ports of the Italian peninsula is necessary. In particular, there is a lack of MoS routes to/from ports in north-east Italy, e.g. Trieste and Venice. An essential factor of MoS is the reliability; furthermore, the interviews with trucking firms, reported in Lupi et al. [11], show that a relevant modal split increase could be achieved by a reduction of MoS ticket prices.

In conclusion, considerable effort still has to be made, both at the Italian and at the European level, to achieve a considerable modal shift from road to MoS: MoS traffic is still a minor percentage of intra-EU freight traffic. In addition, as shown in Medda and Trujillo [21], European MoS routes are characterized by low frequency and low reliability. Our study of Italian ro-ro routes (low frequency and low speed) and ro-pax routes (low reliability) confirms these general European results. Furthermore, integration into door-to-door logistic chains is not always easy and port connections need to be improved. In addition, as shown in the studies by Dubreuil [22] (in Douet and Cappuccilli [23]) and Gouvernal [24] (par. 3.2), currently, in the EU, MoS mainly act on "captive markets"; therefore, currently, only a few of them are in competition with a parallel all-road path. For example, as shown in Kapros [25], a large proportion of MoS connections in the East Mediterranean involve MoS routes between islands (Cyprus, Crete) and the continent (e.g. Greece, Slovenia) or among islands: again, our study confirms these results.

On the other hand, the geography of the EU is in favor of SSS: the EU has a long coastline and some enclosed sea, such as the Mediterranean, the Adriatic and the Baltic Seas; the MoS alternative in several cases would be more favorable than all-road transport.

References

1. European Commission. *European Transport Policy for 2010: Time to Decide*. White Paper. 12 September 2001. Brussels.

2. European Parliament. Decision No 884/2004/EC of the European Parliament and of the Council of 29 April 2004 amending Decision No 1692/96/EC on Community guidelines for the development of the trans-European transport network. *Official Journal of European Union*. 2004. No. L 167. P. 1-38.
3. Baird, A.J. The economics of Motorways of the Sea. *Maritime Policy & Management*. 2007. Vol. 34. P. 287-310.
4. Aperte, X.G. & Baird, A.J. Motorways of the sea policy in Europe. *Maritime Policy & Management*. 2013. Vol. 40. No. 1. P. 10-26.
5. European Commission. *Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system*. White Paper. 28 March 2011. Brussels.
6. Craig, A.J. & Blanco, E.E. & Sheffi, Y. Estimating the CO_2 intensity of intermodal freight transportation. *Transportation Research Part D*. 2013. Vol. 22. P. 49-53
7. Denisis, A. *An Economic Feasibility Study of Short Sea Shipping Including the Estimation of Externalities with Fuzzy Logic*. PhD Thesis. University of Michigan. 2009.
8. Lopez-Navarro, M.A. Environmental Factors and Intermodal Freight Transportation: Analysis of the Decision Bases in the Case of Spanish Motorways of the Sea. *Sustainability*. 2014. Vol. 6. P. 1544-1566.
9. *Eurostat*. *Transport statistic database*. Available at: http://ec.europa.eu/eurostat/web/transport/data/main-tables
10. Ng, A.K.Y. Competitiveness of short sea shipping and the role of port: the case of North Europe. *Maritime Policy & Management*. 2009. Vol. 36. No. 4. P. 337-352.
11. Lupi, M. & Farina, A. & Orsi, D. & Pratelli, A. The capability of Motorways of the Sea of being competitive against road transport. The case of the Italian mainland and Sicily. *Journal of Transport Geography*. 2017. Vol. 58. P. 9-21.
12. Fusco, P.M. & Saurì, S. & Lago, A. Potential freight distribution improvements using motorways of the sea. *Journal of Transport Geography*. 2012. Vol. 24. P. 1-11.
13. *Ramspa website*. Available at: http://www.ramspa.it/
14. Lupi, M. & Farina, A. Motorways of the Sea as an alternative to all-road transport: an application to an Italian case study / Le autostrade del mare come alternative al "tutto strada": una applicazione ad un caso italiano. *Ingegneria Ferroviaria*. 2016. Vol. 2. P. 121-150.
15. Danesi, A. & Lepori, C. & Lupi, M. The Italian Motorways of the Sea system: current situation, policies and prospects. In: *Proceedings of 11th International Conference of Transport Science*, *ICTS 2008*, Portoroz, 2008.
16. Danesi, A. & Farina, A. & Lupi, M. A comparative Analysis of Lo-Lo and Ro-Ro short sea shipping networks in Italy. In: *Proceedings from the 13th International Conference of Transport Science, ICTS 2010.* Portoroz, 2010.
17. Lupi, M. & Farina, A. The development of the Italian Motorways of the Sea network in the years 2008-2012. In: Losa, M. & Papagiannakis, T. *Sustainability, Eco-Efficiency and Conservation in Transportation Infrastructure Asset Management*. CRC Press - Taylor and Francis Group. 2014. P. 765-775.
18. Xie, F. & Levinson, D. Topological evolution of surface transportation networks. *Computers, Environment and Urban Systems*. 2009. Vol. 33. P. 211-223.
19. Han, D.D. & Qian, J. H. & Liu, G. Network topology and correlation features affiliated with European airline companies. *Physica A: Statistical Mechanics and its Applications*. 2009. Vol. 388. P. 71-81.
20. Bergantino, A.S. & Bolis, S. An Analysis of Maritime Ro-Ro Freight Transport Service Attributes through Adaptive Stated Preference: an Application to a Sample of Freight Forwarders. *European Transport \ Trasporti Europei*. 2003. Vol. 25-26. P. 33-51.
21. Medda, F. & Trujillo, L. Short-sea shipping: an analysis of its determinants. *Maritime Policy & Management*. 2010. Vol. 37. No. 3. P. 285-303.
22. Dubreuil, D. *La compétitivité par les interfaces: l'exemple du transport maritime comme alternative à la route*. PhD Thesis. University of East-Paris. 2009.

23. Douet, M. & Cappuccilli, J.F. A review of Short Sea Shipping policy in the European Union. *Journal of Transport Geography*. 2011. Vol. 19. P. 968-976
24. Gouvernal, E. & Slack, B. & Franc, P. Short sea and deep sea shipping markets in France. *Journal of Transport Geography*. 2010. Vol. 18, P. 97-103.
25. Kapros, S. *European transport policy instruments and actors' attitudes in specific markets: The case of motorways of the sea in the East Mediterranean*. Association for European Transport and contributors. 2010. P. 1-19.
26. *MoS operators websites*. Available at:
http://www.anekitalia.com/
http://www.carontetourist.it/v2.6_it/
http://www2.gnv.it/
http://www.grimaldi-lines.com/
http://www.jadrolinija.hr/
http://www.messinaline.it/
http://www.minoan.it/index.shtml
http://www.moby.it/
http://montenegrolines.com/
http://www.corsica-ferries.it/
http://www.snav.it/
http://www.tirrenia.it/

APPENDIX A. RO-RO AND RO-PAX ROUTES REPORTED IN DETAIL

Table 8

Domestic ro-ro routes to/from Italian ports. Data refer to July – October 2015
Source: Italian MoS website and MoS operators' websites

Route	Operator	Weekly freq.	Travel time (h)	Distance (km)
Cagliari – Livorno	Tirrenia	3	18,5	572.6
Cagliari - Palermo - Salerno	Grimaldi Lines	2	59	644.5
Cagliari – Salerno	Grimaldi Lines	1	13	328.5
Cagliari – Savona	Gruppo Grendi	3	31	686
Catania – Genova	Grimaldi Lines	2	27	997.4
Catania – Livorno	Grimaldi Lines	1	23	882.2
Catania – Genova – Livorno	Grimaldi Lines	2	40	1028.5
Catania – Genova – Savona	Grimaldi Lines	1	49	1026.0
Catania – Salerno	Grimaldi Lines	6	12	393.2
Genova – Livorno – Palermo	Grimaldi Lines	4	38	796
Ravenna - Brindisi – Catania	Grimaldi Lines	3	53	1165.2
Ravenna - Brindisi – Catania	Tirrenia	3	44	1165.2

Table 9

Domestic ro-pax routes to/from Italian ports. Data refer to July – October 2015
Source: Italian MoS website and MoS operators' websites

Route	Operator	Weekly frequency			Travel time (h)	Distance (km)
		July, August	Sept.	October		
Arbatax - Olbia - Genova	Tirrenia	2	0	0	17	516
Cagliari - Arbatax - Civitavecchia	Tirrenia	2	2	2	14,5	446
Cagliari - Napoli	Tirrenia	2	2	2	13,5	503
Cagliari - Palermo	Tirrenia	2	1	1	12	416
Catania - Napoli	TTT Lines	7	7	7	12	440

Civitavecchia - Olbia	Moby Lines	9	3	0	7,5	223
Civitavecchia - Olbia	Tirrenia	9	7	7	5,8	223
Civitavecchia - Palermo	GNV - SNAV	3	3	1	14	472
Civitavecchia - T. Imerese	GNV	0	2	2	15	487
Civitavecchia-Porto Torres	Grimaldi Lines	5	4	0	6	318
Genova - Olbia	Moby Lines	11	9	0	11	419
Genova - Olbia	Tirrenia	3	4	3	11	419
Genova - Palermo	GNV	7	6	6	21	796
Genova - Porto Torres	Tirrenia	7	7	7	11	399
Livorno - Olbia	Moby Lines	14	14	7	8,5	313
Livorno - Olbia/Golfo Aranci	Sardinia Ferris	14	14	8	8	392
Messina - Salerno	Caronte & Tourist	7	7	7	9	297
Milazzo - Napoli	Siremar	2	2	2	18	325
Napoli - Palermo	GNV - SNAV	10	7	7	10,5	320
Napoli - Palermo	Tirrenia	7	7	7	10	320
Olbia - Piombino	Moby Lines	8	2	0	5	245
Palermo - Salerno	Grimaldi Lines	2	2	2	8	316

Table 10

International ro-ro routes to/from Italian ports. Data refer to July – October 2015
Source: Italian MoS website and MoS operators' websites

Route	Operator	Weekly freq.	Travel time (h)	Distance (km)
Civitavecchia - Barcellona	Grimaldi Lines	1	18	826.9
Genova - Catania - Malta	Grimaldi Lines	1	44	1124.2
Genova - Livorno - Catania - Malta	Grimaldi Lines	2	49	1124.2
Genova - Livorno - Salerno - Palermo – Tunisi	Grimaldi Lines	2	40	867.3
Genova - Salerno – Tripoli	Ignazio Messina	1	88	1244.9
Livorno - Savona - Barcellona - Valencia	Grimaldi Lines	3	38	1107.7
Livorno - Savona - Valencia	Grimaldi Lines	3	31	990
Livorno - Tunisi	Tirrenia Navigazione/CTN	2	30	760
Salerno - Cagliari - Valencia	Grimaldi Lines	4	67.5	1589.6
Salerno - Catania - Malta	Grimaldi Lines	1	26.5	630.8
Salerno - Genova - Tunisi	Ignazio Messina	1	94	1576.9
Savona - Genova - Catania - Bar	Grimaldi Lines	1	76	3438.6
Savona - Genova - Catania - Patrasso	Grimaldi Lines	1	82.8	3137.8
Trieste - Ancona - Pendik	U.N. Ro-Ro	1	62	2422.5
Trieste - Cesme	Ulusoy Gemi Isletmeleri	3	56	1931.1
Trieste - Mersin	U.N. Ro-Ro	2	60	2545.9
Trieste - Pendik	U.N. Ro-Ro	6	60	2214.9
Venezia - Bari - Patrasso	Grimaldi Lines	3	50	1216.9

Table 11

International ro-pax routes to/from Italian ports. Data refer to July – October 2015
Source: Italian MoS website and MoS operators' websites

Route	Operator	Weekly frequency			Travel time (h)	Distance (km)
		July, August	September	October		
Ancona - Corfù - Igoumenitsa - Patrasso	Superfast Ferries, Anek Lines	2	0	0	22.5	982.9
Ancona - Durazzo	Adria Ferries	2	1,5	2	20	575
Ancona - Hvar - Spalato	Blue Line	1	0	0	11	292.3
Ancona - Igoumenitsa - Patrasso	Minoan Lines	6.5	6	6	22.5	953

Ancona - Igoumenitsa - Patrasso	Superfast Ferries, Anek Lines	10	6	6	22	953
Ancona - Spalato	Blue Line	6	7	7	11	260
Ancona - Spalato	Jadrolinija	5	3	3	11	260
Ancona - Zadar	Jadrolinija	9	2	0	9	180.9
Bari - Bar	Montenegro Lines	6	3	2	9	215
Bari - Cephalonia	Ventouris Ferries	1	0	0	18	494
Bari - Corfù	Ventouris Ferries	4	0	0	13	329
Bari - Corfù - Igoumenitsa - Patrasso	Superfast Ferries, Anek Lines	3	1	0	17.5	574
Bari - Dubrovnik	Jadrolinija	6	4	2	10	201
Bari - Durazzo	Adria Ferries	12	7	7	9	221.8
Bari - Durazzo	Europeanseaways/Ventouris Ferries	13	11	0	9	221.8
Bari - Igoumenitsa	Ventouris Ferries	3.5	0	0	15	357.5
Bari - Igoumenitsa - Patrasso	Superfast Ferries, Anek Lines	5	6	7	17	576.6
Bari - Zante	Ventouris Ferries	1	0	0	22	554
Brindisi - Igoumenitsa	Grimaldi Lines	2	2	2	9,5	245
Brindisi - Igoumenitsa - Patrasso	Grimaldi Lines	6	6	6	17	470
Brindisi - Valona	Europeanseaways	3.5	3.5	3.5	7.5	133.8
Brindisi - Valona	Red Star Ferries, European Ferries	7	7	7	7	133.8
Civitavecchia - Palermo - Tunisi	GNV	1	1	1	25	803.6
Civitavecchia - Porto Torres - Barcellona	Grimaldi Lines	5	5	5	20	827
Civitavecchia - Tunisi	Grimaldi Lines	1	1	1	23	602.7
Genova - Barcellona - Tangeri	GNV	2	2	2	47	1687.8
Genova - Bastia	Moby Lines	7	3	0	8,5	226.8
Genova - Tunisi	GNV	3	3	2	24	867.3
Genova - Tunisi	Tirrenia Navigazione/CTN	2	2	2	21	867.3
Livorno - Barcellona –Tangeri	Grimaldi Lines	1	1	1	56	2399.2
Livorno - Bastia	Corsica Ferris	14	14	10	4	113.6
Livorno - Bastia	Moby Lines	7	3	0	4	113.6
Livorno - Isola Rossa	Corsica Ferris	3	0	0	10	175.4
Porto Torres – Marsiglia	La Meridionale	1	2	2	17	407.3
Pozzallo - Malta	Virtu Ferris	20	20	20	1,5	95.7
Salerno - Palermo – Tunisi	Grimaldi Lines	2	2	2	23	581.5
Savona – Barcellona	Grimaldi Lines	3	3	3	17	632.2
Savona - Bastia	Corsica Ferris	16	9	4	10	200.6
Trieste - Ancona – Durazzo	Adria Ferries	1	1	1	36	798.2
Trieste - Ancona - Igoumenitsa - Patrasso	Minoan Lines (Grimaldi Group)	0	2	2	32.5	2192.6
Venezia - Ancona - Igoumenitsa - Patrasso	Superfast Ferries, Anek Lines	0	1	1	33	1150.5
Venezia - Igoumenitsa - Patrasso	Superfast Ferries, Anek Lines	2	2	2	33	1150.5

Received 02.03.2017; accepted in revised form 24.11.2017