The Open Transportation Journal
DOI: 10.2174/0126671212285520240105073430, 2024, 18, e26671212285520

ISSN: 1874-4478

RESEARCH ARTICLE

OPEN ACCESS

Rail Transport across the Strait of Messina: Some Policies to Improve the Service

Massimo Di Gangi[1], Orlando Marco Belcore[1] and Antonio Polimeni[1,*]

[1]*Dipartimento di Ingegneria, Università degli Studi di Messina, Messina, Italy*

Abstract:

Background: The railway system represents a more sustainable alternative to road and air transport. In some cases, barriers negatively impact travel by train, thus affecting users' choices. Some of such barriers (*e.g.*, rivers, and maritime straits) divide urbanized areas (especially if a stable connection between the two areas is unavailable). In these cases, methods, policies, and planning procedures must be adopted to improve the service. The Strait of Messina (South Italy), considered in the paper as a case study, represents a particular barrier so long as the trains must be decomposed before embarking on a ferry, thus increasing dwelling time.

Objectives: This paper moves from analyzing the current crossing condition in the Strait of Messina and offers an analysis of the most pointless activities at the maritime barrier. In it, some policies (with short or middle time horizons) aimed at reducing long embarkation and disembarkation times due to the decomposing operation of the convoys, as well as the subsequent recompositing and verification operations of the rolling stock, are proposed.

Methods: The proposed solutions are based on time schedules and direct observation. The proposals are not to be considered mutually exclusive, and they could represent a progressive improvement whose results are beneficial in reducing the crossing time. For each one, setup time and costs are considered to evaluate which is more appropriate.

Results: The report assesses the benefits of introducing some interventions, and the solutions have been organized sequentially to reduce infrastructure costs. Consequently, some of the proposed solutions can be implemented immediately, thus improving the quality of the service without requiring high financial and time costs.

Conclusion: Planning a succession of actions could lead to a progressive improvement in the quality of the services offered, letting public administration focus on priorities, thus offering the opportunity to monitor and evaluate the efficiency of each measure.

Keywords: **:** Transportation planning, transport policy, sustainable transportation, railway node, maritime hub, policies assessment.

*Address correspondence to this author at the Dipartimento di Ingegneria, Università degli Studi di Messina, Messina, Italy; E-mail: antonio.polimeni1@unime.it

Cite as: Di Gangi M, Belcore O, Polimeni A. Rail Transport across the Strait of Messina: Some Policies to Improve the Service. Open Transplant J, 2024; 18: e26671212285520. http://dx.doi.org/10.2174/0126671212285520240105073430

Received: October 04, 2023
Revised: November 22, 2023
Accepted: December 11, 2023
Published: January 15, 2024

1. INTRODUCTION

In 1996 the EU, with Directive 96/48/EC of the Council, laid the foundations for the development of the high-speed railway (HSR) network in Europe. In this definition are included the *railway infrastructures constructed or upgraded to be travelled on at high speeds, and rolling stock designed fortravelling on those infrastructures* [1]. In this way, the countries started or accelerated the plans for developing the HSR (*e.g.*, in Italy, from 1998 to 2008, 32 billion euros have been invested [1]. In Italy, one of the first high-speed lines was the Milan-Bologna line, inaugurated in 2008, followed by a progressive upgrading of the entire national network. In the first ten years of life, the Italian high-speed railway doubled the number of trains per kilometer with an increase in passengers from 6.5 million to 40 million [1]. The reduction in travel times has triggered a modal shift toward the train and increased commuting between cities connected by high-speed trains. There are also effects on the real estate market and on tourism. Parallel with infrastructures, services must be developed to avoid the formation of bottlenecks that could negatively affect the system as a whole. Bottlenecks can be linked with the interaction between demand and supply, so actions are requested to optimize the system. For example, Armstrong and Preston [2, 3] analyze the capacity of the railway system at stations; similarly, Li *et al.* [4] proposed a method to optimize the capacity and train timetable simultaneously. Jovanović [5] developed an optimization model to design a railway station to maximize capacity. However, there are still other critical points that represent a barrier to the railway service. A typical example is represented by the maritime crossing and the necessary operations on the rolling stocks. In Europe, some of the main relevant examples are represented by the rail service between Sassnitz and Trelleborg and between Rødby and Puttgarden. For these connections, the train is no longer provided, on the contrary, in Italy, the connection between Sicily Island and the Italian peninsula is still active (Fig. **1**). This represents a critical issue that affects the performance of passenger and freight flows.

Based on a real case, this paper deals with the temporal and spatial barrier represented by a discontinuity that exists at a hub of passengers. The situation analyzed is the railway connection between Sicily Island and Italy, supplied by a passenger train ferry service (performed by ro-ro vessels that embark/disembark the trains). The Strait of Messina marks the border between the Sicily region and the Calabria region (Fig. **1**), two southern areas of Italy: they are among the most distant community territories from the demographic and economic center of gravity of the European Union. The geographical distance is amplified by the quality of the connections, which involves higher travel costs and times for the same distance traveled than those faced in central-northern Italy.

The crossing service on the Strait of Messina has allowed citizens and visitors to reach the Italian peninsula from Sicily and vice versa. Each year, more than 60,000 couches cross the Strait area, and approximately 2,600,000 passengers (about 7,100 per day) choose to cross the corridor by train [6]. In line with the increasing interest in more sustainable transport solutions [7] passenger rail transport represents the most valuable environmentally sustainable alternative [8, 9]. Therefore, an in-depth study of the services provided, and possible improvement strategies is of specific interest to the area. Infrastructure investments also positively affect regional GDP growth along the corridor, facilitating trade [10-12]. Furthermore, from the European point of view, interventions focus on removing barriers for passengers and freight on the continent [13-15]. Therefore, the interest in solving bottlenecks became a crucial task in European countries where, in recent years, significant financial and technological strengths were underpinned to improve rail infrastructure in favor of a more competitive development [16-18]. Consequently, several researchers investigated the potential benefits and infrastructural limits in transport corridors [19-21].

The Strait of Messina has always been a strategic node in the Italian transport system, and several researchers have focused on the needs and limitations of this area, approaching the critical reduction of supply by integrating both planning solutions and digitalization of the infrastructures [22-24]. Furthermore, Di Gangi and Russo [25] assessed the benefits of introducing a high-speed rail system for both Sicily and the Calabrian region; the study pointed out how travel times from Sicily to Rome by train can be drastically reduced by improving rail services; from this study also emerged how ferry services reduce the global performance of the system. Similarly, Musolino [26] focused on the integration between the two shores, highlighting how improving transport systems will contribute to the economies of the area.

This paper proposes some policy measures to reduce the effects of territorial discontinuity. Specifically, the paper contributes by defining some policies and measures to reduce crossing time for ferry passenger trains. It represents a step towards analyzing the train services for passengers. The proposed solutions concern short- and medium-term horizons; their introduction may require only new scheduling and a low budget, as well as new rolling materials and vessels, thus implying higher infrastructural costs. The proposed policies are specified considering the setup time.

All the information presented in the paper refers to public data, that can be consulted directly online, provided by the company that manages the studied railway service. Furthermore, data on vessel supply operating in the area also come from public archives and can be consulted online.

In summary, the purpose of the paper consists of evaluating the current situation of the transportation service to highlight strengths and weaknesses. Some possible policies are suggested, and middle-term policies are assessed, evaluating preliminary costs and set-up time. Such policies concern operations on rolling stock, land-side and sea-side changes.

The paper is structured as follows. Section 2 reports a brief literature review. Section 3 reports a summary of train-ferries services in Europe and the description of the Italian case. Section 4 reports the proposed measures (tactical and middle-term measures). Finally, the discussion on the obtained results and the conclusion.

2. LITERATURE REVIEW

Rail services, and in particular those provided by high-speed rail (HSR), affect user mode choices both for long-distance travel [27] and for adduction to other transport modes [28]. On long-distance travel, time uncertainties have more severe impacts on people from lower accessibility areas, increasing the inequity between groups of travelers, thus affecting the area's economic development of the area [29].

Albalate *et al.* [28] evaluated the impact of HSR services on the supply of air services in terms of seats and frequencies. Jiménez and Betancor [30] evaluated how the introduction of HSR services affects frequency, passenger rate, and airline market share. Bergantino *et al.* [31] analyzed HSR services considering two aspects: the competition between two different companies offering the service (the observed effect is an increase in supply) and the influence on the price of air services (the observed effect is a reduction in the price of the air ticket). Jiang and Zhang [32] considered the long-term impacts of HSR on airline alternatives showing that the presence of HSR services can lead 123 the airline to increase the market coverage and the social welfare. Takebayashi [33] studied the collaboration between airlines and analyzed whether this collaboration can reduce 125 airport congestion.

Lin *et al.* [34] explored the impacts of HSR on economic and urban development; the objective is to provide a set of policies to improve HSR services and contribute to economic growth. Fan *et al.* [35] analyzed how HSR contributed to increasing accessibility (also causes economic growth). Other works on this topic [36, 37] explored the role of HSR in regional economic disparity. The introduction of better services reduces the existing mismatch between regional areas and helps economies to develop, thus closing the discrepancy with the wealthiest area of the country [36, 38]. For such a reason, it also represents a way to help the general economic growth of the area and reactivate the productive system [39]. Therefore, the value of time and the reliability of the transportation system are essential factors.

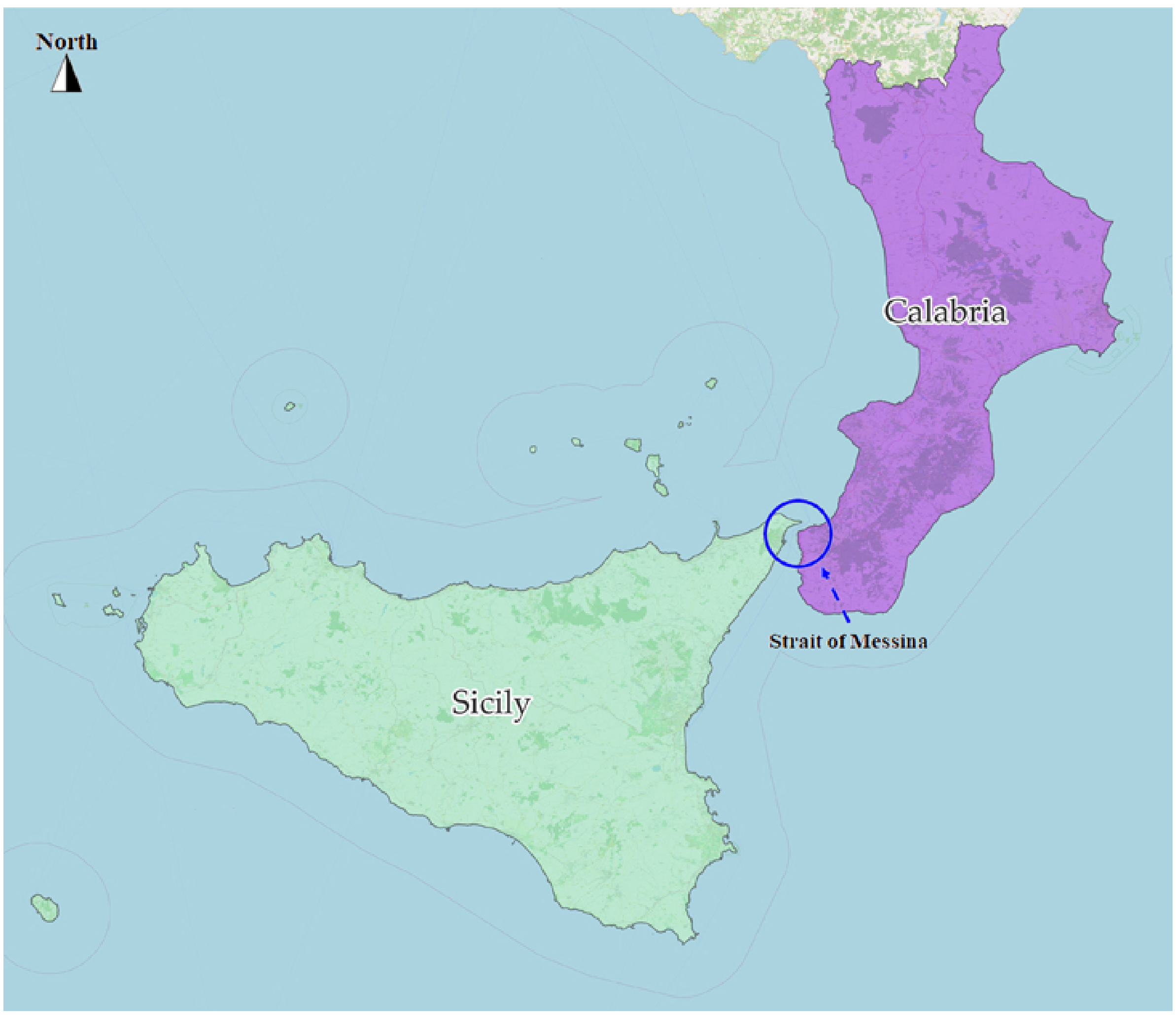

Fig. (1). The Strait of Messina (background map: OpenStreetMap [22]).

Regarding environmental impacts, the authors report both positive and negative outcomes. As an example, Liu *et al.* [40] analyzed the variation in air quality in some cities after the introduction of HSR; the conclusion is that such a service can reduce emissions and improve air quality in urban areas. On the other hand, there are studies showing how the construction of HSR has a negative impact on the environment [41, 42].

Investigating attributes that affect the modes of rail-air transport, some authors [43-45] showed that elements such as travel time (or distance), price, and service frequency are the ones that influence the user's choice. A similar analysis for the choice between HSR and road passenger transport [46] highlighted choices are influenced by attributes such as fares, comfort, speed, and safety. Bergantino *et al.* [47] investigated the effect of distance and travel time on modal choice. The results indicated that the relevant attributes to choosing HSR are income, travel purpose, and age. Chiambaretto *et al.* [48] evaluated the willingness to pay users using, if available, the combined rail-air transport: the results are that users were considered as the main criterion, followed by luggage handling and the priority in the case of delay.

Another critical factor affecting the choices for rail services and the efficiency of the rail corridor is the dwelling time for operations [49, 50]. Sanudo *et al.* [51], through combined quantitative and qualitative analysis methods, stated how rail service users consider the fare system, travel time, and intramodality as the most important attributes to increase the quality of rail transport. Furthermore, similar studies highlighted how improving railway service always led users to be more sustainable in their choices, thus mitigating the effects produced by transportation [52, 53]. Erhardt *et al.* [54] focused on understanding the importance of frequency of service and travel experience as factors driving travelers' choices on long-distance trips.

Furthermore, Mackie *et al.* [55] and Flugel [56] indicated that willingness to pay and time savings must be considered in relation to the nature of the trip. Karmarkar *et al.* [57] evaluated the willingness to pay passengers who reduce travel time using the HSR service: the aim is to understand the perception of saved travel time and contribute to the definition of policies for ticket prices and management strategies. To the knowledge of the authors, there are no works that consider the case of trains embarked on ferries. Therefore, this paper tries to fill this gap by describing an existing train-ferry system and proposing some policies to improve the performance of the system.

3. MATERIALS AND METHODS

There are only a few cases of passenger train ferries in Europe, and only one in Italy is currently active. The cited services are one between mainland Italy and Sicily, one from Sassnitz in Germany to Trelleborg in Sweden, and one from Rødby in Denmark to Puttgarden in Germany. It is important to note that the current crossing service of the Strait of Messina represents the only service available for an urban area (more than 800,000 inhabitants [58].

The data used in the following analyses are collected online by consulting the official websites of the companies that offer (or offered) the crossing service. The data for the service between Sassnitz and Trelleborg come from [59] while those for Rødby and Puttgarden are from [60]. Data related to the Strait of Messina crossing service are from a few studies [6, 61, 62].

Referring to the Italian case, the data are analyzed to know the status of the system and formulate and assess some possible policies to update the service, in terms of operational time reduction. The method takes into consideration both rolling stocks and the vessels.

3.1. Passengers' Trains on Ferries Experience from other Countries

On the Berlin-Malmoe route, between Sassnitz and Trelleborg, the Snallalltaget company guaranteed the Berlin Night express service, the only periodic service allowed to travel between Germany and Sweden without crossing Denmark; this was for a long time the only intermodal connection on the Baltic Sea. The shipping service was active mainly in summer, from June to August, only on weekends and public holidays. The rolling stock was loaded through a wheeled tractor, the ferry is a one-way vessel, and the train is embarked on the lower deck with other vehicle types; the crossing time is 3 hours and 45 minutes. Since 2020, the company has decided to permanently suspend the service.

The Fehmarnbelt, between Rødby and Puttgarden, has been closed since 15 December 2019, and it is under construction of a stable link. Currently, trains take the longest route through Flensburg and Odense will use this route during all phases of the reconstruction of the direct line *via* Puttgarden, the duration of which is expected to be eight and a half years. The proposed link through the Fehmarnbelt will be an 18-kilometer submerged floating tunnel, equipped with a four-lane motorway and double-track railway. At its completion, it will be the longest tunnel ever built. The crossing times will be, respectively, 7 minutes for trains and 10 minutes for road vehicles, compared to 45 minutes for crossing by ferry for both modes of transport. Rolling stock was an ICE TD, whose characteristics are indicated in Table **1**. The convoy consisted of four carriages with 154 standard-class seats and 41 first-class, for an overall train length equal to 107.74 m (the carriage head is 27.45 m, the intermediate ones 25.9 m long). The diesel-electric drive unit can reach a top speed of 200 km/h. On the Danish side, it was operated with IC3 material, made up of 3 carriages, and could reach a maximum speed of 180 km/h.

Table 1. ICE TD characteristics (elaboration from [59]).

Key	Value
In service	2001 — today
Manufacturer	Bombardier/Siemens
Number built	20 trainsets
Number in service	19 trainsets
Formation	4 cars per trainset
Capacity	154 standard class, 41 first class
Articulated sections	Flexible diaphragm (within unit only)
Maximum speed	125 mph (200 km/h)
Weight	232 tonnes (228 long tons; 256 short tons)
Traction system	DEMU
Prime mover(s)	Cummins QSK19 of 560 kilowatts (750 hp) at 1800 rpm each (four engines)
Power output	3,000 hp (2,200 kW)
Transmission	Diesel-electric transmission
UIC classification	2'Bo'+Bo'2'+2'Bo'+Bo'2'
Braking system(s)	Rheostatic
Safety system(s)	Sifa, PZB90, LZB, Eurobalise
Coupling system	Dellner
Track gauge	1,435 mm (4 ft 8 1⁄2 in) standard gauge

Table 2. Schleswig-Holstein characteristics [60].

Key	Value
Route	Rødbyhavn - Puttgarden
IMO	9151539
Building year	1997 / 2004
Building yard	Van der Giessen, Netherlands
Owner	GEFA Leasing GmbH
Operator	Scandlines GmbH
Length	143,0 m
Breadth	24,8 m
Draft	5,3 m
GT	15.187
Machinery	2 * MaK 6M32 + 3 * MaK 8M32
Speed	18,5 kn.
Number of passengers	900
Number of beds	0
Number of cars	292 / 355
Lane metres	625
Number of railway tracks	1
Length of railway tracks	118 m

Two-way ferries Schleswig–Holstein and Deutschland were used for the crossing managed by Scandlines, whose characteristics are indicated in Table 2. This type of ferry allows the convoy to embark on the lower deck together with the road vehicles; the length of the rail is 118 meters. The loading ramp dedicated to the train is parallel to the one used for boarding road vehicles. During loading and unloading maneuvers, there is no interference between the two methods, but the train is still loaded once the unloading is complete. The operating times have been inferred through video recordings: on average, the train is embarked in 2 minutes and 6 seconds, while 2 minutes and 10 seconds are required for disembarkment.

3.2. Strait of Messina Context

Sicily is the fifth most populous region in Italy. It accounts for approximately five million inhabitants during the summer season, and the presences on the island tend to double. For this reason, an efficient and flexible railway system makes it possible to move vehicles and people more sustainably than much more harmful transport by car or by plane. Taking into account the passenger trains that cross the strait (Fig. 2), the Sicilian railway networks are served by two different convoy configurations following, respectively, the Tyrrhenian director East-West towards Palermo and the North-South Ionian direction towards Catania. Generally, an intercity train (IC) coming from Catania (IC727) and another one from Palermo (IC728) proceed simultaneously to Messina where they are embarked to go to Villa S. Giovanni, where they are composed as a single train. Vice versa, the train coming from Villa S. Giovanni, in the Messina station, breaks down and comes to form two trains.

Concerning IC 728, the composition of the section coming from Palermo consists of a locomotive E.464 (a class of Italian railway electric locomotives) and four UIC-Z1[1] derivative carriages (three-second class and one first-class). The train coming from Catania consists of an E.464 locomotive, a second-class semi-driver carriage of UIC-Z1 derivation and three UIC-Z1 derivation carriages (two of second class and one of first class). The material is embarked on the ferry by placing the semi-driver carriage at the head to form a reversible composition at the Calabrian side with traction ensured by a pushing E.402/b locomotive.

The characteristics of the vessel supply are reported in Table 3. The reported lane length refers to the longest and the shortest available one, these values can be used as a benchmark for the direct embarkation of a blocked composition trainset. The values for the entire capacity are then reported also assessing the convoy capacity. The same also states how the vessel fleet has homogeneous cargo and geometrical characteristics.

The evaluation of service performance derives from the Trenitalia timetable (Table 4), considering the intercity pair 728 (from Palermo) and 727 (from Catania). The crossing time of IC 728 from Messina Centrale to the Villa S. Giovanni station is, according to the timetable (Table 4), even at 70 minutes, and, overall, from the arrival in Messina Centrale at the departure from Villa S. Giovanni, it takes 115 minutes. For Intercity 727, the time to cross the strait remains, according to the timetable, at 70 minutes. Overall, the arrival at Villa S. Giovanni to the departure from Messina Centrale requires 125 minutes. The details of the operations, reported in Table 5, can be used in both directions.

Table 3. Vessel supply, ferries characteristics [61].

Vessel (Name)	Capacity (Units)*	Total Length (m)	Lanes (Number)	Lane Lengths (m)
Scilla	16	440.30	4	92.80 - 136.30
Villa	16	440.30	4	92.80 - 136.30
Logoduro	12	440.30	4	92.80 - 136.30
Messina	16	449.54	4	94.53 - 133.31
Iginia	16	449.54	4	94.53 - 133.31

Note: * Mean capacity convoy considers a length equals to 26.40 meters

Fig. (2). A portion of the interest rail network (background map: OpenStreetMap [22]).

Table 4. Timetable trenitalia [62].

Intercity 728	Palermo	Roma Termini	-	Intercity 727	Roma Termini	Catania
Arrival	***Departure***	***Station***		***Arrival***	***Departure***	***Station***
---	07:00	Palermo Centrale	-	---	11:26	Roma Terini
09:35	09:37	Milazzo	-	16:52	16:55	Lamezia Terme
10:00	10:15	Messina C.le	-	**18:00**	18:20	Villa S. Giovanni
11:25	**11:55**	Villa S. Giovanni	-	19:30	**20:05**	Messina Centrale
18:34	---	Roma Termini	-	21:26	---	Catania

Table 5. Operational time.

Operation	Duration (min)
Disassembly in Messina Centrale	*15*
Move to embarkment	5
Embarking Operations	10
Ferry Service	35
Unloading to Villa S. Giovanni	15
Positioning in Villa S. Giovanni	5
Verify Continuity	30
Total Time	***115***

These times are defined as safe for considering any uncertainties (for example, bad weather). Taking into account a crossing time equal to 35 minutes, the remaining amount is attributable to the decomposition times for boarding the ferry. Once the convoy is reconstituted, before being cleared for circulation into the network, it is also necessary to consider the time associated with verifying the continuity of the braking system.

4. POLICIES PROPOSAL

In the following proposed scenarios, the train breakdown will no longer be taken into account and the convoys from Palermo and Catania will be considered staggered. Short-term solutions are introduced, explaining the benefit of reducing the total crossing time. Solutions with a longer time horizon are introduced; these also concern infrastructure costs, new vessels, or the supply of new train sets, and similarly to the previous case, time reduction and preliminary direct costs are evaluated for each proposal.

4.1. Short Term Policies

The first policy (Solution A) concerns some operations on rolling stocks. Traction would be ensured by an E.402B locomotive used above all for IC services in combination with Z1 carriages. The same is prepared for the TCN (Train Communication Network) remote control and can, therefore, also travel in a blocked composition with semi-driver carriages type Z1, with a train length equal to 194.20 meters. The length is equal to 265.50 meters, and a Z1a semi-pilot could be used as a driving car designed for reversible IC train solutions. Alternatively, consider a composition of a semi-driver, three third-series carriages, and a locomotive whose overall length would slightly exceed 125 meters (to be exact, it would have an overall length of 125.62 meters). The same could be transported on one of the central platforms of the ferry used for ferrying passenger trains.

The breakdown of the train and the consequent operations to verify the continuity of the braking pipeline can therefore be avoided by using a coupler to hook up to the E.402B locomotive or by positioning the locomotive in a pushing position for departing from Sicilian stations, thus avoiding the need to equip the driving with a coupler. This solution will reduce the operational and verification time; moreover, as stated, the operator will avoid the decomposition and composition of the convoys and the relative security check. The time will be reduced from 115 minutes to 65 minutes (Table 6).

The amount of savings would also be similar, considering the ferry operations in the reverse direction. Referring to the timetable shown as the current situation, the time saved would cause the train to leave the station again of Villa S. Giovanni would take place only 50 minutes after the departure from Messina station.

Considering that all rolling stocks are already available and in service, no additional financial costs are required; therefore, implementing this service only requires technical and operational time to plan and introduce it by the terminal operator.

Table 6. Maneuvering, loading and unloading times concerning the proposed solution.

Operation	Duration (min)
Train stops at Messina	5
Path to Messina	5
Embarking Operation	5
Transit	35
Positioning in Villa S. Giovanni	5
Train stops at Villa S. Giovanni	5
Total	**65**

Table 7. Comparing middle term policies.

Solution	Description	Operational Time (min)	Operational Time Saving (*)
B	Self-Propelled trainset	55	- 52.17%
C	ETR400	65	- 43.48%
D	New vessels	50	- 56.52%

Note: * with respect to current scenario.

4.2. Middle Term Policies

In this section, three middle-term policies are proposed, the first two are related to land-side changes, the latter to sea-side changes:

- Self-Propelled fixed formation trainsets (Solution B),
- ETR400 train (Solution C),
- New vessels (Solution D).

Table **7** reports a summary of the middle-term policies in terms of saved operational time with respect to the current scenario (Table **5**). Such policies would allow for a reduction in operating times of between 44 and 56%. Each policy is explored in detail in the next subsections.

4.2.1. Self-propelled Fixed Formation Trainsets

First, the introduction of an autonomous engine to reduce the time of embarking and disembarking operations, as an example, the example is the British Rail 800 super express train, whose characteristics are shown in Table **8**.

These units are native to high-speed infrastructure. Such powertrains are bi-mode electro-diesel, capable of being powered by electrified overhead lines, where available, and use autonomous diesel generators off the grid electrified. The ability to change the mode during for trip also allows the eventual use in the absence or fall of the overhead power line. Furthermore, such a train can reach 220 km/h, which would also reduce travel times.

Considering the composition of five carriages, the convoy would measure 130 meters to be accepted in a single solution on existing ships, and the operations of embarkation and disembarkation could take place independently without the need for maneuvering means. Compared to the time analyzed up to now, this configuration would allow a further saving of about 15 minutes. Furthermore, not having to resort to hooking a locomotive for embarkation and disembarkation maneuvers, the stops at stations could be reduced by a total of 5 minutes, to which the potentials should then be added benefits introduced by landing and disembarkation operations, which, as highlighted above, would lead to a further saving of 10 minutes.

As regards the determination of costs, the reference is an order placed by the British railways concerning the production of 210 trains; the total contract value was 6.65 billion euros (including the production and delivery of trains, new maintenance depots and infrastructure upgrades). The contract also includes maintenance and fleet assistance for 27.5 years [63, 64]. From these data, the net cost per train is approximately €31.70 million. The timing for the supply of a convoy was arranged according to what was previously indicated (poly-tension) and is estimated to be approximately three years.

4.2.2. Employing ETR400

Concerning the ETR400, known as Frecciarossa 1000, the trainsets of the V300 Zefiro platform can be configured in 4, 8, 12 or 16 carriages, with a driving position at each end. Table **9** reports the frame footprint of the train [65].

The standard composition of the ETR400 train has eight couches and a total length of 202 m. In 2013, the composition of four coaches was already tested to travel on the traditional line; thus, the resulting train will be 102.4 meters long. Taking into account the availability of the length of the vessel, it could also be possible to use a solution with five couches. However, this solution has not yet been tested by the Italian railway company, so we will not consider this as a further solution. Since the ETR 400 is equipped with a coupler, assuming a quick opening/closing system, the reader refers to Table **6** regarding operative time.

As regards the determination of costs, considering the 4-carriage composition, it is possible to quantify a prudential estimate of around 20 million Euros for such a convoy and the time required for assembly would be around six months.

Table 8. HITACHI A-TRAIN characteristics [63].

Characteristic	Description
In service	2015 (testing) 2017 (passenger service)
Manufacturer	Hitachi
Number under construction	34 x 9-car sets – 46 x 5-car sets
Car body construction	Aluminum
Car length	26 meters (85 ft 4 in)
Width	2.7 meters (8 ft 10 in)
Capacity	154 standard class, 41 first class
Maximum speed	125 mph (200 km/h) (140 mph, with minor modifications) (100 mph, 160 km/h with diesel-power only)
Prime mover(s)	MTU 12V 1600 R80L
Power output	560 kW (750 hp) per engine (The engines are fully rated at 700 kW (940 hp), but have been de-rated on these units)
Electric system	25 kV 50 Hz AC overhead lines
Current Collection method	Pantograph
Safety system(s)	AWS, TPWS, ETCS, ATP
Track gauge	1,435 mm (4 ft 8 1⁄2 in) standard gauge

Table 9. ETR400 characteristics [66].

Parameter	Values
Train Length	202.000 meters
Length end-car (over coupler)	26.300 meters
Length intermediate car (over coupler)	24.900 meters
Car height	4.080 meters
Car width	2.924 meters
Seats (total)	455 + 2 tip-up seats + 5 pivoting seats in the meeting room

4.2.3. New Vessel Fleet

Another opportunity might be represented using a two-way ferry equipped with a track layout arranged to receive the rolling stock of the standard 8-carriage composition of ETR400 and, therefore, a (track) length of at least 204 m. Thus, considering the distance between Messina and Villa San Giovanni (about 3.8 nautical miles) and using a bidirectional (two-way ferry), should allow a crossing time of around 17-20 minutes. Then, the use of this type of vessel could therefore reduce the crossing by about 15 minutes.

Referring to the last order (March 2019) for a ferry for connections in the Strait of Messina of the one-way Ro-Ro type, 147 meters long, 19 meters wide, 2500 tons capacity, and 18 knots speed, the total investment was around 57 million of Euros with an expected completion time of fourteen months [66].

Considering these data, it is possible to estimate, at first approximation, that the cost for a 225-meters (whose length is fixed considering a cargo capacity equal to 90% of the track length) vessel would be estimated at approximately 78 million Euros. It would also take around 20 months from the date of assignment to complete the order, to which the previous 15 months would be added to activate the administrative procedure for the contract.

5. RESULTS AND DISCUSSION

The proposals illustrated in Section 4 provided an estimation of the costs and times needed to realize the proposed policy (Table **10**).

The train costs assessment assumed the use of two pairs of convoys. The overall balance between the proposed solutions would also add the effect linked to the travel-time savings on the network. The proposed solutions are not mutually exclusive but could be progressively activated to improve the service without significant infrastructure costs. Considering this, as reported in Table **11**, a schedule is also proposed to identify the implementation of various steps for the ETR400 that seems the most promising solution for a long-term service.

Within the preliminary study, where the direct costs and the performance improvement achievable by adopting the single strategy were analyzed (Tables **7** and **10**), it emerged that solution B would require the highest monetary costs and a lead time similar to solution D without, however, offering significant advantages in terms of performance; therefore in the following solution B will not be further considered.

Table 10. Resuming infrastructural costs and times.

ID Solution	Description	Financial Costs [M€]	Lead Time [months]	Strategy
A	Train 4 coaches solutions	none	2/5	Short term
B	*A* & self-embarking on vessel	120	36	Medium term
C	ETR400 with 4 coaches	80	12	Medium term
D	New vessel	78	35	Medium term

Table 11. Scheduling solutions for progressive introduction.

ID Solution	Description	To Do List	Lead Time [months]
A	Train 4 coaches' solution	Planning new scheduling and services	5
C; D	Full ETR400 & new vessel	Planning Assignment procedures and reorganizing docks at the maritime terminals	6
C	ETR400 with 4 coaches on the current vessel supply	Organize new services and scheduling in the timetable	12/15
C + D	Full ETR400 & new vessel	Scheduling new service	35/41

Solution A only considers the necessary times to organize and reschedule new services; all rolling stocks are already available. In this case, the lead time is only necessary for the operators to organize new timetables and fleets, and this would also represent a temporary solution to test the direct effects of introducing the new service. Before introducing solutions C and D, it will be necessary to assign and organize infrastructural procedures and technical solutions to design a new terminal to host the new fleet and trainset; the procedure could take at least six months. Consequently, solutions C and D can be introduced step by step; the procedure will begin with the assignment of new infrastructures and convoy assembly, achieving a primary step (12/17 months). The reduced ETR thus will be ready to embark on ordinary vessels. Finally, introducing a full ETR 400 on a new vessel will require at least three years.

CONCLUSION

The paper analyzed the current crossing condition on the Strait of Messina (South Italy). It proposed planning and infrastructural measures to improve the railway's passenger services.

A better detail about the benefits obtainable from the improvement of the services will consider into account the system of supply and demand concerned: for example, by conducting a related analysis to the overall travel times on the various relations of which the crossing of the Strait of Messina represents a node, quantifying the benefits obtainable from the current demand.

Downstream of what has been explained, it is possible to derive some considerations. Some of the proposed solutions are immediate and would undoubtedly improve the quality of the service without requiring significant financial resources or long-term decisions. The progressive introduction of different measures will help reduce the infrastructural and financial costs and indirect costs associated with the construction site. It also implies not stopping or reducing the services offered. Therefore, the solutions will further improve the services and efficiency offered by the railways. The evidence reported in this paper could help the system managers choose how to improve the train passenger link in the Strait of Messina service with both land and sea-side interventions.

The main weakness of this paper is that there is no information on user behavior as the characteristics of the service vary; the integration of such information could be useful in designing the service. Therefore, the next steps will focus on assessing attitudes and intentions. The operation of a Stated Preferences survey could help determine a suitable trade-off to intercept higher market share levels for train passengers. Therefore, these results would represent an exciting place to organize a scenario hypothesis as a valuable alternative against the air solution, which today means, in 60% of cases [67], the most preferred solution for those people who must organize long-distance trips to reach the central-northern regions. A further advancement that could be made concerns the evaluation of environmental impacts in the assessment of strategies. This can be done both by considering the use of low environmental impact vessels and by evaluating how time reduction influences environmental impacts. A final consideration can be made by considering the bridge over the Strait of Messina. The possible construction of a bridge (currently in an advanced design stage) would be an alternative to the crossing service by ship. Under these conditions, there would be two distinct ways to cross the Strait of Messina, which are not necessarily mutually exclusive.

LIST OF ABBREVIATIONS

EU = European Union

HSR = High-Speed Railway

GDP = Gross Domestic product

IC = Inter-city

UIC = Union internationale des chemins de fer

TCN = Train Communication Network

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

No repositories are available for this paper. All the information presented in the paper refers to public data, that can be consulted directly online following the links provided in the references.

FUNDING

None.

CONFLICT OF INTEREST

Dr. Antonio Polimeni is on the Editorial Advisory Board of the journal The Open Transportation Journal.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

[1] Council Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system, Available from:http://data.europa.eu/eli/dir/1996/48/oj/eng (Accessed: Aug. 11, 2023).

[2] 10 anni di Alta Velocità italiana, Available from:https://www.fsitaliane.it/content/fsitaliane/it/media/comunicati-stampa/2019/12/5/10-anni-di-alta-velocita-italiana.html (Accessed: Aug. 11, 2023).

[3] J. Armstrong, and J. Preston, "Capacity utilisation and performance at railway stations", *J. Rail Transp. Plann. Manag.,* vol. 7, no. 3, pp. 187-205, 2017. [http://dx.doi.org/10.1016/j.jrtpm.2017.08.003]

[4] X. Li, D. Li, X. Hu, Z. Yan, and Y. Wang, "Optimizing train frequencies and train routing with simultaneous passenger assignment in high-speed railway network", *Comput. Ind. Eng.,* vol. 148, p. 106650, 2020. [http://dx.doi.org/10.1016/j.cie.2020.106650]

[5] P. Jovanović, N. Pavlović, I. Belošević, and S. Milinković, "Graph coloring-based approach for railway station design analysis and capacity determination", *Europ. J. Operat. Res.,* vol. 287, no. 1, pp. 348-360, 2020. [http://dx.doi.org/10.1016/j.ejor.2020.04.057]

[6] Ministero delle infrastrutture e della Mobilità Sostenibili Conto Nazionale Delle Infrastrutture e Della Mobilità Sostenibili – Anni 2020-2021, Available from:https://www.mit.gov.it/comunicazione/news/online-il-conto-nazionale-delle-infrastrutture-e-della-mobilita-sostenibili-anni (Accessed on 23 June 2023).

[7] S. Kraus, T. Grube, and D. Stolten, "Mobility trends in transport sector modeling", *Fut. Transport.,* vol. 2, no. 1, pp. 184-215, 2022. [http://dx.doi.org/10.3390/futuretransp2010010]

[8] R. Cordera, R. Sañudo, E. Echániz, S. Nogués, and L. dell'Olio, "Future scenarios for the European railway sector: A methodology based on past trends and a stated preference survey", *Int. J. Sustain. Transport.,* vol. 17, no. 2, pp. 148-162, 2023. [http://dx.doi.org/10.1080/15568318.2021.1999540]

[9] ISPRA, "2022 Inventario Nazionale – Emissioni", Available from:http://emissioni.sina.isprambiente.it/ (Accessed on 23 June 2023).

[10] K. Goldmann, and J. Wessel, "TEN-T corridors - Stairway to heaven or highway to hell?", *Transp. Res. Part A Policy Pract.,* vol. 137, pp. 240-258, 2020. [http://dx.doi.org/10.1016/j.tra.2020.04.010]

[11] O. Taiwo, and N. Moyo, "Eliminating Barriers to Internal Commerce to Facilitate Intraregional Trade", Available from:https://www.brookings.edu/wp-content/uploads/2016/07/01_eliminating_barriers_taiwo.pdf (Accessed on 23 June 2023).

[12] L. Song, and M. van Geenhuizen, "Port infrastructure investment and regional economic growth in China: Panel evidence in port regions and provinces", *Transp. Policy,* vol. 36, pp. 173-183, 2014. [http://dx.doi.org/10.1016/j.tranpol.2014.08.003]

[13] L. Gerlitz, and C. Meyer, "Small and medium-sized ports in the TEN-T network and nexus of europe's twin transition: The way towards sustainable and digital port service ecosystems", *Sustainability,* vol. 13, no. 8, p. 4386, 2021. [http://dx.doi.org/10.3390/su13084386]

[14] P.A. Witte, B.W. Wiegmans, F.G. van Oort, and T.J.M. Spit, "Chokepoints in corridors: Perspectives on bottlenecks in the European transport network", *Res. Transp. Bus. Manag.,* vol. 5, pp. 57-66, 2012. [http://dx.doi.org/10.1016/j.rtbm.2012.10.001]

[15] M. Di Gangi, A. Polimeni, and O.M. Belcore, "Method for the analysis of bottlenecks in passengers transport systems: A framework for supply-demand interaction and performances evaluation", *Proceeding of 5th Euro-Mediterranean Conference for Environmental Integration (EMCEI-23).*

[16] Á. Aparicio, "The changing decision-making narratives in 25 years of TEN-T policies", *Transp. Res. Procedia,* vol. 25, pp. 3715-3724, 2017. [http://dx.doi.org/10.1016/j.trpro.2017.05.223]

[17] F. Witlox, T. Zwanikken, L. Jehee, B. Donners, and W. Veeneman, "Changing tracks: Identifying and tackling bottlenecks in European rail passenger transport", *Eur. Trans. Res. Rev.,* vol. 14, no. 1, p. 7, 2022. [http://dx.doi.org/10.1186/s12544-022-00530-9]

[18] T. Palei, "Assessing the impact of infrastructure on economic growth and global competitiveness", *Procedia Econ. Finance,* vol. 23, pp. 168-175, 2015. [http://dx.doi.org/10.1016/S2212-5671(15)00322-6]

[19] S. Stoilova, N. Munier, M. Kendra, and T. Skrúcaný, "Multi-criteria evaluation of railway network performance in countries of the TEN-T orient–east med corridor", *Sustainability,* vol. 12, no. 4, p. 1482, 2020. [http://dx.doi.org/10.3390/su12041482]

[20] F. De Fabiis, A.C. Mancuso, F. Silvestri, and P. Coppola, "Spatial economic impacts of the TEN-T network extension in the adriatic and ionian region", *Sustainability,* vol. 15, no. 6, p. 5126, 2023. [http://dx.doi.org/10.3390/su15065126]

[21] M. Öberg, K.L. Nilsson, and C.M. Johansson, "Complementary governance for sustainable development in transport: The European TEN-T Core network corridors", *Case Stud.n Transport Policy,* vol. 6, no. 4, pp. 674-682, 2018. [http://dx.doi.org/10.1016/j.cstp.2018.08.006]

[22] OpenStreetMaps, Available from:https://www.openstreetmap.org/

[23] F. De Vita, "Traffic condition estimation at the smart city edge using deep learning: A Ro-pax terminal case study", *IEEE International Smart Cities Conference (ISC2),* Pafos, Cyprus, 26-29 Sep, 2022. [http://dx.doi.org/10.1109/ISC255366.2022.9922581]

[24] O.M. Belcore, M. Di Gangi, and A. Polimeni, "Connected vehicles and digital infrastructures: A framework for assessing the port efficiency", *Sustainability,* vol. 15, no. 10, p. 8168, 2023. [http://dx.doi.org/10.3390/su15108168]

[25] M. Di Gangi, and F. Russo, "Potentiality of rail networks: Integrated services on conventional and high-speed lines", *COMPRAIL 2022,* 2022. [http://dx.doi.org/10.2495/CR220091]

[26] D. Musolino, "Characteristics and effects of twin cities integration: The case of Reggio Calabria and Messina, 'walled cities' in Southern Italy", *Reg. Sci. Policy Pract.,* vol. 10, no. 4, pp. 315-334, 2018. [http://dx.doi.org/10.1111/rsp3.12128]

[27] N. P. Farazi, M. N. Murshed, and M. Hadiuzzaman, "Application of machine learning to investigate heterogeneity in users'

perception of intercity train service quality in developing countries", *Case Stud. Transp. Policy,* vol. 10, no. 1, pp. 227-238, 2022.
[http://dx.doi.org/10.1016/j.cstp.2021.12.004]

[28] D. Albalate, G. Bel, and X. Fageda, "Competition and cooperation between high-speed rail and air transportation services in Europe", *J. Transp. Geogr.,* vol. 42, pp. 166-174, 2015. [http://dx.doi.org/10.1016/j.jtrangeo.2014.07.003]

[29] B.Y. Chen, Y. Wang, D. Wang, and W.H.K. Lam, "Understanding travel time uncertainty impacts on the equity of individual accessibility", *Transp. Res. Part D Transp. Environ.,* vol. 75, pp. 156-169, 2019.
[http://dx.doi.org/10.1016/j.trd.2019.08.027]

[30] J.L. Jiménez, and O. Betancor, "When trains go faster than planes: The strategic reaction of airlines in Spain", *Transp. Policy,* vol. 23, pp. 34-41, 2012.
[http://dx.doi.org/10.1016/j.tranpol.2012.06.003]

[31] A.S. Bergantino, C. Capozza, and M. Capurso, "The impact of open access on intra- and inter-modal rail competition. A national level analysis in Italy", *Transp. Policy,* vol. 39, pp. 77-86, 2015. [http://dx.doi.org/10.1016/j.tranpol.2015.01.008]

[32] C. Jiang, and A. Zhang, "Airline network choice and market coverage under high-speed rail competition", *Transp. Res. Part A Policy Pract.,* vol. 92, pp. 248-260, 2016.
[http://dx.doi.org/10.1016/j.tra.2016.06.008]

[33] M. Takebayashi, "How could the collaboration between airport and high speed rail affect the market?", In: *Transportation Research Part A: Policy and Practice.,* Elsevier, 2016. [http://dx.doi.org/10.1016/j.tra.2016.06.010]

[34] S. Lin, P.R. Dhakal, and Z. Wu, "The impact of high-speed railway on china's regional economic growth based on the perspective of regional heterogeneity of quality of place", *Sustainability,* vol. 13, no. 9, p. 4820, 2021.
[http://dx.doi.org/10.3390/su13094820]

[35] J. Fan, "High-speed railway network development, inter-county accessibility improvements, and regional poverty alleviation: Evidence from China", *Land,* vol. 11, no. 10, p. 1846, 2022. [http://dx.doi.org/10.3390/land11101846]

[36] Z. Chen, and K.E. Haynes, "Impact of high-speed rail on regional economic disparity in China", *J. Transp. Geogr.,* vol. 65, pp. 80-91, 2017.
[http://dx.doi.org/10.1016/j.jtrangeo.2017.08.003]

[37] L. Azzouz, and A. Jack, "Social exclusion and high-speed railways: Evidence from China", *Open Transplant. J.,* vol. 15, no. 1, pp. 133-146, 2021.
[http://dx.doi.org/10.2174/1874447802115010133]

[38] J. Jiao, J. Wang, F. Zhang, F. Jin, and W. Liu, "Roles of accessibility, connectivity and spatial interdependence in realizing the economic impact of high-speed rail: Evidence from China", *Transp. Policy,* vol. 91, pp. 1-15, 2020.
[http://dx.doi.org/10.1016/j.tranpol.2020.03.001]

[39] J.F. Coloma, M. García, and E. Pascual-Pedreño, "Effects of rail freight corridors in low population regions", *Fut. Transport.,* vol. 1, no. 3, pp. 466-485, 2021.
[http://dx.doi.org/10.3390/futuretransp1030025]

[40] Q. Liu, H. Li, W. Shang, and K. Wang, "Spatio-temporal distribution of Chinese cities' air quality and the impact of high-speed rail", *Renew. Sustain. Energy Rev.,* vol. 170, p. 112970, 2022.
[http://dx.doi.org/10.1016/j.rser.2022.112970]

[41] Q. Yang, Y. Wang, Y. Liu, J. Liu, X. Hu, J. Ma, X. Wang, Y. Wan, J. Hu, Z. Zhang, X. Wang, and S. Tao, "The impact of China's high-speed rail investment on regional economy and air pollution emissions", *J. Environ. Sci.,* vol. 131, pp. 26-36, 2023.
[http://dx.doi.org/10.1016/j.jes.2022.07.020] [PMID: 37225378]

[42] Y. Yue, T. Wang, S. Liang, J. Yang, P. Hou, S. Qu, J. Zhou, X. Jia, H. Wang, and M. Xu, "Life cycle assessment of high speed rail in China", *Transp. Res. Part D Transp. Environ.,* vol. 41, pp. 367-376, 2015.
[http://dx.doi.org/10.1016/j.trd.2015.10.005]

[43] M. Danapour, A. Nickkar, M. Jeihani, and H. Khaksar, "Competition between high-speed rail and air transport in Iran: The case of Tehran-Isfahan", *Case Stud. Transp. Policy,* vol. 6, no. 4, pp. 456-461, 2018.
[http://dx.doi.org/10.1016/j.cstp.2018.05.006]

[44] C. Behrens, and E. Pels, "Intermodal competition in the London-Paris passenger market: High-Speed Rail and air transport", *J. Urban Econom.,* vol. 71, no. 3, pp. 278-288, 2012.
[http://dx.doi.org/10.1016/j.jue.2011.12.005]

[45] A.Y. Nurhidayat, H. Widyastuti, Sutikno, and D.P. Upahita, "Research on passengers' preferences and impact of high-speed rail on air transport demand", *Sustainability,* vol. 15, no. 4, p. 3060, 2023.
[http://dx.doi.org/10.3390/su15043060]

[46] W. Yang, Q. Chen, and J. Yang, "Factors affecting travel mode choice between high-speed railway and road passenger transport-evidence from China", *Sustainability,* vol. 14, no. 23, p. 15745, 2022.
[http://dx.doi.org/10.3390/su142315745]

[47] A.S. Bergantino, and L. Madio, "Intermodal competition and substitution. HSR versus air transport: Understanding the socio-economic determinants of modal choice", *Res. Transp. Econ.,* vol. 79, p. 100823, 2020.
[http://dx.doi.org/10.1016/j.retrec.2020.100823]

[48] P. Chiambaretto, C. Baudelaire, and T. Lavril, "Measuring the willingness-to-pay of air-rail intermodal passengers", *J. Air Transp. Manage.,* vol. 26, pp. 50-54, 2013.
[http://dx.doi.org/10.1016/j.jairtraman.2012.10.003]

[49] M. Aminatou, Y. Jiaqi, and S. Okyere, "Evaluating the impact of long cargo dwell time on port performance: an evaluation model of Douala International Terminal in Cameroon", *Arch. Transport,* vol. 46, no. 2, pp. 7-20, 2018.
[http://dx.doi.org/10.5604/01.3001.0012.2098]

[50] A. Comi, A. Polimeni, U. Crisalli, and A. Nuzzolo, "A methodology based on floating car data for the analysis of the potential rail-road freight demand", *Riv. Int. Econ. Trasp.,* vol. 48, no. 3–4, pp. 315-337, 2021.
[http://dx.doi.org/10.19272/202106704002]

[51] R. Sañudo, E. Echaniz, B. Alonso, and R. Cordera, "Addressing the importance of service attributes in railways", *Sustainability,* vol. 11, no. 12, p. 3411, 2019.
[http://dx.doi.org/10.3390/su11123411]

[52] Z. Chen, J. Xue, A.Z. Rose, and K.E. Haynes, "The impact of high-speed rail investment on economic and environmental change in China: A dynamic CGE analysis", *Transp. Res. Part A Policy Pract.,* vol. 92, pp. 232-245, 2016.
[http://dx.doi.org/10.1016/j.tra.2016.08.006]

[53] C. Rohr, J. Fox, A. Daly, B. Patruni, S. Patil, and F. Tsang, "Modeling long-distance travel in great britain", *Transp. Res. Rec.,* vol. 2344, no. 1, pp. 144-151, 2013.
[http://dx.doi.org/10.3141/2344-16]

[54] G.D. Erhardt, J. Freedman, A. Stryker, H. Fujioka, and R. Anderson, "Ohio long-distance travel model", *Transp. Res. Rec.,* vol. 2003, no. 1, pp. 130-138, 2007.
[http://dx.doi.org/10.3141/2003-16]

[55] P.J. Mackie, S. Jara-Díaz, and A.S. Fowkes, "The value of travel time savings in evaluation", *Transp. Res., Part E Logist. Trans. Rev.,* vol. 37, no. 2-3, pp. 91-106, 2001.
[http://dx.doi.org/10.1016/S1366-5545(00)00013-2]

[56] S. Flügel, "Accounting for user type and mode effects on the value of travel time savings in project appraisal: Opportunities and challenges", *Res. Transp. Econ.,* vol. 47, pp. 50-60, 2014.
[http://dx.doi.org/10.1016/j.retrec.2014.09.018]

[57] O. D. Karmarkar, A. Jana, and N. R. Velaga, "Willingness to pay for reduced travel time: Case study of mumbai - ahmedabad high speed railway", *Case Stud. Transp. Policy,* vol. 12, p. 100974, 2023.
[http://dx.doi.org/10.1016/j.cstp.2023.100974]

[58] ISTAT, "Istituto nazionale di Statistica Demo - Statistiche Demografiche", Available from:https://demo.istat.it/ (Accessed on

23 June 2023).
[59] Germany InterCity Express High Speed Rail Network operated by Deutsche Bahn, Available from:https://www.railway-technology.com/projects/ice-high-speed-rail/ (Accessed on 20/06/2023).
[60] The ferry site, Available from:https://www.ferry-site.dk/ferry.php?id=9151539&lang=en (Accessed 10/08/2023).
[61] Territorial Circulars, Available from:https://normativaesercizio.rfi.it/NormativaEsercizio/ (Accessed on 11/08/2023).
[62] Trenitalia, Gruppo Ferrovie dello Stato Italiane, Available from:https://www.trenitalia.com/it.html (Accessed on 12/08/2023).
[63] H.I. Trains, "Class 800 Series", Available from:https://www.hitachirail.com/products-and-solutions/rolling-stock/intercity/ (Accessed on 20/06/2023).
[64] Hitachi Class 800 series train selected by DfT to provide more seats and greater comfort for passengers as part of capacity improvements on East Coast Main Line, Available from:https://www.hitachi.eu/en/press/hitachi-class-800-series-train-selected-dft-provide-more-seats-and-greater-comfort-passengers/ (Accessed on 05/07/2023).
[65] ETR1000/300 Il treno del Futuro, Available from:https://www.cifi.it/UplDocumenti/AV_Freccia1000/BOMBARDIER%20ETR1000.pdf (Accessed on: 20/06/2023).
[66] RFI, "Inaugurata Iginia, la nuova nave green per lo Stretto di Messina", Available from:https://www.rfi.it/it/news-e-media/comunicati-stampa-e-news/2022/3/7/rfi---inaugurata-iginia--la-nuova-nave-green-per-lo-stretto-di-m.html (Accessed on 19/06/2023).
[67] MIMS, "La valutazione di soluzioni alternative per il sistema di attraversamento stabile dello Stretto di Messina", Available from:https://www.mit.gov.it/sites/default/files/media/notizia/2021-05/Relazione%20-%20GdL%20Attraversamento%20stabile%20stretto%20%281%29.pdf (Accessed on 19/06/2023).