

Sea-Rail Intermodal Transport in Italian Gateway Ports: A Sustainable Solution? The Examples of La Spezia and Trieste

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Abstract. The paper tackles the issue related to the sea-rail intermodal transport in gateway ports. In recent years there has been a renewed interest in land connections and therefore hinge functions, recalling the logic for which the most competitive ports are those equipped with an articulated and efficient network of internal connections. This attention requires an in-depth study of port intermodality and mutual interactions with the territories served by the port. This paper is focused on rail intermodality for container handling, recognizing the gateway port as a strategic node whose competitiveness increasingly depends on sustainable intermodal transport solutions to and from the hinterland. This is also due to the growing attention to green transport solutions such as rail. After highlighting the distinctive features of gateway ports and their key functions, attention is focused on the main Italian ports that play this role. In particular, this study explores the ports of La Spezia and Trieste due to their aptitude for intermodal rail traffic in relation to the hinterland. In both cases, the share of combined sea-rail transport and the importance of rail transport use in terms of environmental sustainability will be evaluated through an ad hoc tool (EcoTransIT World).

Keywords: Sea-rail transport · Gateway ports · La Spezia port · Trieste port

1 Introduction

Geographical research has long suggested the analysis of the close interaction between the port and its hinterland as a key element to correctly analyze the dynamics of port development. This recommendation has taken up a particularly significant value in the most recent context. In fact, we are witnessing the onset of two phenomena. On the one hand, the clear dichotomy between hub ports and gateways ports has disappeared,

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with a reduction in the importance attributed to the pure movement of goods. On the other hand, there has been a renewed interest in land connections and therefore hinge functions, recalling the logic for which the most competitive ports are those equipped with an articulated and efficient network of internal connections. This attention requires an in-depth study of port intermodality and mutual interactions with the territories served by the port.

In terms of port facilities and relationships with the land side, Vigarié [1] devised the model of the so-called "port triptych" in order to represent the spatial relations between the maritime sphere, the port and the continental space. The latter is often referred to as the actual market or geo-economic scope in which the port sells its services [2].

Thanks to the contribution of the geographical research, the concept of gateway emerged to understand the role played by the port in relation to the area in which it is located.

Deepening the work of Bird [3, 4], Vallega [5] emphasizes how it is possible to highlight the nature of the function that the port can assume for the coastal region in which it stands. As concerns the region to which it belongs, the port plays a role as a door through which the region itself maintains relations with the outside. In this case, it is then configured as a gateway. This qualification, however, is not the prerogative of all ports but only of those that perform functions that go beyond the local area (i.e. limited within the coastal region to which they belong), that is, those that define the projection of the port outwards on a national and international scale [5, 6].

The progressive affirmation of containerization has changed the spatial interpretation of the port that has become a strategic intermodal node in the global transport network [6]. This development has determined in parallel on the maritime front the birth of a new type of port called hub, that is, a node that perform transshipment functions. In these ports, the handling of containers takes place from ship to ship and this does not generate land traffic because they are the expression of an organizational method adopted by large shipping companies to optimize global containerized itineraries [7].

The hub port is characterized by an almost total dissociation between the port structure and the territory that hosts it, given that the connections with the terrestrial side are absent or in any case not considered relevant for the development of these nodes [7]. The gateway ports, on the other hand, which can also be defined as hinterland-oriented ports [8], are characterized by an articulated and complex system of relations with the terrestrial context.

Several regional studies have shown that the development of containerization has modified the network of global maritime connections and transformed not only port facilities but also their hinterland, favoring intermodal connection with ports [9–11].

The inland is the area where a port carries out most of its activities; unlike the hinterland, which is a physical space, it is a relational and therefore economic space. Its infrastructure is decisive for the port system of reference [7]. The boundaries of the hinterland vary according to the goods, the dynamics of the global market and, above all, the degree of infrastructure [12].

2 Sea-Rail Intermodality as a Green Solution for Hinterland Connections of Gateway Ports

The development of containerization and intermodal options have pushed ports to prioritize their activities inwards even at great distances [13].

With the continuous growth of unitized load traffic, the mode that is most affected by processes of reorganization of flows between port and territory is precisely the railway one, thanks also to its ability to transport a greater number of containers in a single journey, covering long distances [6].

Through the use of the combined maritime-rail transport, the conditions are created for a higher modal integration between land and sea, with a propulsive role that starts from the port and radiates towards the territory [14]. Thanks to these relationships, the port function finds new possibilities for development towards the hinterland and contributes to the formation of a regional distribution network, which is configured as an organized system characterized by a polycentric structure [15, 16].

Rail connections with internal terminals have become a key factor for the attractiveness of ports as they allow to obtain advantages – distributed over several categories of actors involved along the logistics chain – such as lower urban port traffic, lower transport costs over medium-long distances, higher speed in ports and lower environmental impact [17, 18]. There are also disadvantages such as the need for more detailed transport planning, dependence on economies of scale, higher costs and longer delivery times over short distances. The creation of a well-developed hinterland based on rail connections has the potential to strengthen the maritime transfer segment, increase logistics efficiency and produce a more sustainable global transport chain [19].

Rail-water intermodal transportation is recognized as one of the future transportation methods for being efficient, economical and environmentally friendly. For this reason, the European Union has gradually established a sustainable and collaborative intermodal transport service network with containers as the main cargo-carrying unit and railways as the core. At the same time, the container railway station was built in the main European ports with gateway functions. Railways play an important role in container collection and distribution in the ports [20].

Gateway ports are increasingly becoming multimodal hubs where rail is expected to play a strategic role. Efficient rail operations and links to and from the ports, as well as within the port, are essential to maximize the use of rail as a sustainable transport mode and to comply with the priorities set in the TEN-T legislation [21].

The European Union advocates that railways should take more transportation volumes, which requires an increase in the service level of the multimodal transport chain and in the market share of railway transportation in terms of medium and long-distance freight [20]. However, for combined traffic with an origin or destination in a port, the market segment below 300 km can also be competitive to shift trucks onto the rail. Indeed, many ports have regular rail connections to terminals within a range of 100 km distance and are very important to reduce road congestion and negative externalities in urban areas [21].

3 Italian Gateway Ports and the Case of La Spezia

Currently, in Italy there are about twenty ports that perform gateway functions; the geographical reading of the recent evolution of port traffic shows a particular territorial structure and a tendency to the concentration of these activities.

Using an approach based on port regions, selected using the criteria of the geographical proximity and the functional complementarities, it is possible to identify gateway port systems [6, 7]. In particular, Italy is characterized by two multi-port gateway regions: the first is known as the "Ligurian Range" and is formed by the ports located along the northern Tyrrhenian coast (Savona, Genoa, La Spezia, Marina di Carrara and Livorno); the second one is the so-called "North Adriatic" which includes the ports located in the northern portion of the Adriatic (Koper, Trieste, Monfalcone, Venice and Ravenna) (Fig. 1) [22].

At the national level, the Ligurian Range has emerged for its strategic importance, accounting for over 61% of the domestic gateway traffic in the last six years (Fig. 1). This share is not surprising, given that the ports of the Ligurian Range are nodes connected with a hinterland with many production sites and a large consumer market and constitute the international access/exit points for the territories that support them [23].

Figure 1 also highlights the role of the La Spezia port as the second national gateway port after Genoa (18% of the Italian traffic in the period 2016–2021). For this reason, the case of La Spezia is an interesting area of investigation, considering first of all its marked specialization in containerized traffic that in the last twenty years (2001–2021) has represented 76% (on average) of the total port handling.

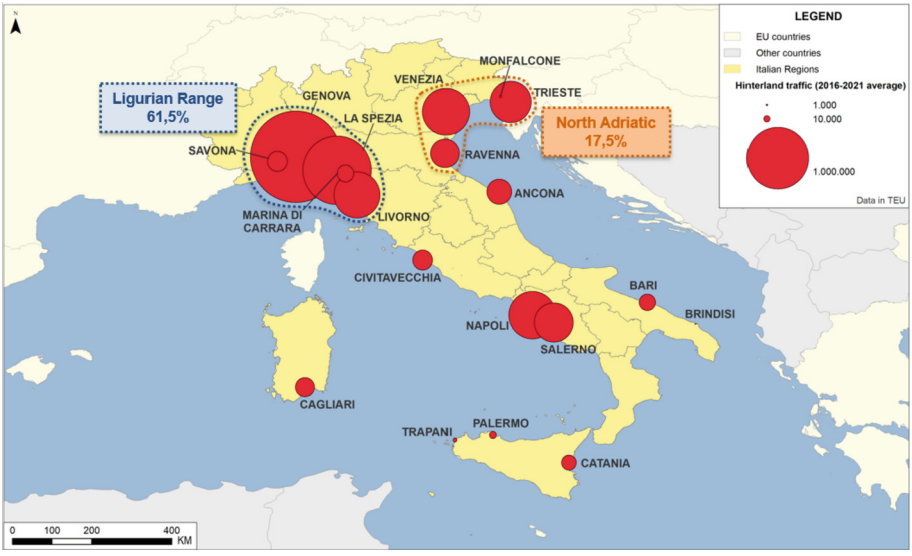

Fig. 1. Container traffic (excluding transshipment) in Italian gateway ports. Source: author's elaboration from [24].

Moreover, this specialization, based mainly on hinterland traffic (on average 88,8% of the total between 2001 and 2021, compared to transshipment movements that account for 11,2%), has led to the development of significant use of railway intermodality in connections with the hinterland.

In this regard, the share of rail transport in the total container hinterland managed in port was significant from 2001 until 2008 (29% on average), considering an amount of average port handling equal to about 920,000 TEUs. The impact of the global crisis of 2009 led to a sharp reduction in the use of rail transport (20.8% in 2010) while starting from 2011 a reversal of the trend took place which, in the face of a marked increase in port container handling (on average 1.2 million TEUs between 2011 and 2021), saw the share of intermodal grow progressively to reach the value of 29.6% in 2020, with an average of 26.6% in the same period [25, 26].

The consistent use of the railway was also possible thanks to the activities of the Santo Stefano Magra backport, which performs functions as a logistics area serving the port. Along the routes that connect the three railway yards of reference of the port (Marittima, Migliarina and Santo Stefano Magra), the management of rail freight maneuvers is unique, with obvious positive effects on handling efficiency [26].

The railway yard of La Spezia Marittima, located inside the port area, in its current configuration is characterized by a bundle of four parallel tracks of limited length to 400–450 m, intended for the composition of trains to be introduced into the network and the decomposition of the convoys before their transfer to the destination ports. La Spezia Marittima has a limited handling capacity (350,000 TEUs/year) repeatedly exceeded in recent years.

Therefore, the further increase in the rail share necessarily requires the improvement (currently underway) of the aforementioned railway yard so that it can have a wider track bundle in line with European standards (750 m).

The above data demonstrate the effective use of the combined sea-rail transport for the transfer of containers. It's useful to examine in more detail the geography of rail connections, evaluating their main directions, origins/destinations and intensity. This allows to define extension and characteristics of the hinterland connected with the port and to demonstrate the role played by the port as a logistic and intermodal node at the service of the national territory.

The connections with the intermodal terminals of Northern Italy were eight in 2011 and rose to nine in 2021, a signal of a strengthening of the relationship with the hinterland. The analysis of the weekly frequencies (coming and departing from the port) with the inland terminals allows interesting observations. As Table 1 shows, the railway connections are divided along three main routes: the Pontremolese is the busiest one, followed by the Ligurian (via Genova) one and by the Tirreno-Brenner corridor. The Pontremolese line is today the most used route by trains entering/leaving the port of La Spezia. However, it is also the oldest and only partially double-track and modernized line. Furthermore, the terminals identified by greater traffic to and from Spezia are Padova (62 trains), Rubiera (34 trains), Bologna (27 trains), Dinazzano (21 trains) and Melzo (21 trains). There is a marked increase in weekly trains from 186 (in 2019 and 2020) to 215 in 2021 as well as a strengthening of relations with Emilia-Romagna and Veneto.

Table 1. The railway relations between the port of La Spezia and inland terminals (trains/week). Source: author's elaboration from [26] (data 2021).

	Via Pontremoli	Via Genova	Via Pisa	Total
Bologna	7	5	15	27
Dinazzano	21	-	-	21
Rubiera	18	4	12	34
Marzaglia	17	-	1	18
Padova	44	17	1	62
Verona	-	5	5	10
Melzo	6	15	-	21
Milano	-	12	-	12
Rivalta Scrivia	-	10	-	10
Total	113	68	34	215

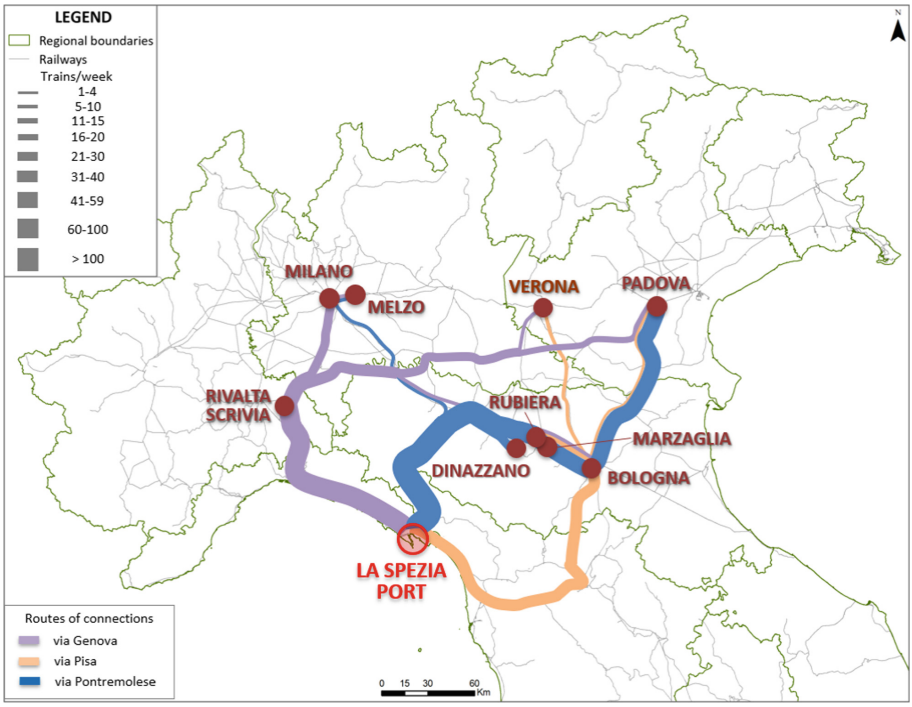

Fig. 2. Routes of container rail traffic to and from the port of La Spezia. Source: author's elaboration from [26] (data 2021).

Figure 2 shows in detail the railway connections for container transport between the port and the hinterland. The traffic flows generated are particularly intense with Emilia Romagna (Rubiera, Bologna, Dinazzano and Marzaglia): 100 trains/week via Pontremoli and via Pisa. The traffic flows with Veneto (Padua in particular) via Pontremoli and via Genova are also relevant (72 trains/week). Less intense are the flows with Lombardy (Melzo, Milano) and Piedmont (Rivalta Scrivia) via Genova. Therefore, in the light of the analysis carried out, it is evident that the port of La Spezia plays a gateway function for the territories of the Po Valley. This freight traffic involves three important TEN-T railway corridors: Mediterranean, Rhine-Alpine and Scandinavian-Mediterranean.

In addition, through these corridors (especially the last two) the port of La Spezia extends its hinterland beyond the Alps, reaching Switzerland, Austria and Germany indirectly, through the railway "relaunches" from the Melzo terminal (managed by the same company that handles most of the containers in La Spezia).

3.1 The Sustainability of the Sea-Rail Intermodal Transport in La Spezia Port

In Sect. 2, the environmental sustainability of rail transport for the relations between the port and its hinterland was highlighted. Therefore, along the routes shown in Fig. 2, the positive impact in terms of emission reduction generated by the railway choice (instead of the more traditional combination with road transport) to reach the destinations was evaluated. In particular, an ad hoc tool was used to carry out this assessment: EcoTransIT World (ETW).

ETW is the most widely used software worldwide to automate the calculation and analysis of energy consumption and freight emissions. The software is accredited by Smart Freight Centre to be in accordance with the GLEC Framework and also meets the requirements of EN 16258 and the GHG protocol (Corporate Standard). The result is worldwide unique because ETW calculates the transport distances, energy consumption, greenhouse gases (GHG) emissions as well as air pollutants (SOx, NOx, NMHC and PM 10) for any global transport chain.

The system boundaries for emission calculation include several processes and are divided into two types: Well-to-Tank (which considers the supply, production and distribution of energy) and Tank-to-Wheel (which considers transport operations). These two types together form the configuration called Well-to-Wheel [28].

Therefore, the use of the aforementioned software appears useful for assessing the different environmental impacts of the modal solutions to reach the nine destinations connected with the port of La Spezia. In detail, it is possible to compare the differences between road and rail in terms of distances travelled by freight, energy consumption and greenhouse gases emissions (Table 2).

The application of the ETW software to compare the use of road and rail along the routes connected with the port allows interesting observations[1].

[1] For the calculation of emissions, we consider Well-to-Wheel values and container transport (1 TEU). Besides, for rail traffic, a load factor value of 68.7% was considered as emerged from the 2021 data communicated by ASPMLO. In the case of road sections, the shorter ones have always been considered. For railway, the routes actually served by the operators managing the connections between port and inland terminals shall be considered. For this reason, in some cases the row values do not appear.

First of all, the lower environmental impact of the railway solution is confirmed, which on average emits 24% of the greenhouse gases compared to the road, when the routes are comparable and distances almost the same. Moreover, seven hinterland destinations (Bologna, Rubiera, Marzaglia, Padova, Verona, Melzo, Milano) are connected via alternative rail routes that do not represent the shortest solution in terms of kilometers. These routes are chosen for issues of saturation of shorter lines or issues of availability of tracks for railway operators. However, even these choices allow a significant reduction in emissions that are 65% lower (on average) than those on the road following the shortest route. Similar observations can also be made for energy consumption. On average the energy consumption of rail transport is 64% lower in the case of comparable routes and 50% in the case of alternative rail solutions.

Finally, it is important to underline how the railway advantages in terms of energy consumption and emissions are particularly evident already for short distances (over 160 km) thus making it a competitive solution even on medium-short distances, especially to the extent that the efficiency of the intermodal service allows reduced transport times at low costs.

Table 2. The emission calculation per TEU along routes between the port of La Spezia and inland terminals (differentiated by rail and road). Source: author's elaboration from [28].

	Truck			Train		
	Distance (km)	Energy consumption (megajoule)	GHG emissions (tons)	Distance (km)	Energy consumption (megajoule)	GHG emissions (tons)
Bologna (via Pontremoli)	211	2,143	0.154	215	760	0.037
Bologna (via Pisa, train)	-	-	-	255	902	0.043
Bologna (via Genova, train)	-	-	-	381	1,347	0.065
Dinazzano (via Pontremoli)	170	1,752	0.126	171	706	0.035
Rubiera (via Pontremoli)	164	1,700	0.122	163	577	0.028
Rubiera (via Genova, train)	-	-	-	329	1,164	0.056
Rubiera (via Pisa, train)	-	-	-	303	1,072	0.052
Marzaglia (via Pontremoli)	168	1,709	0.124	166	588	0.031
Marzaglia (via Pisa, train)	-	-	-	299	1,064	0.054
Padova (via Genova, train)	-	-	-	434	1,534	0.074
Padova (via Pontremoli)	322	3,303	0.238	330	1,167	0.056
Padova (via Pisa, train)	-	-	-	376	1,329	0.064
Verona (via Pontremoli, road)	257	2,613	0.190	-	-	-

(*continued*)

Table 2. (*continued*)

	Truck			Train		
	Distance (km)	Energy consumption (megajoule)	GHG emissions (tons)	Distance (km)	Energy consumption (megajoule)	GHG emissions (tons)
Verona (via Pisa, train)	-	-	-	372	1,314	0.063
Verona (via Genova, train)	-	-	-	369	1,303	0.063
Melzo (via Pontremoli)	225	2,313	0.170	257	902	0.043
Melzo (via Genova, train)	-	-	-	248	875	0.042
Milano (via Pontremoli, road)	223	2,295	0.170	-	-	-
Milano (via Genova, train)	-	-	-	239	843	0.040
Rivalta Scrivia (via Genova)	160	1,697	0.120	155	548	0.027

4 The Port of Trieste

The port of Trieste within the North Adriatic area witnessed interesting dynamics throughout the latest decade, making the most of its historically known and documented – nonetheless little exploited in the recent past - geographical advantages, as its position covered by winds, the natural depths of 18m and an articulated network of rail infrastructure and connections towards a wide hinterland [33], as well as the Free Port regime [30, 34]. After having been part of a gateway in the TEN-T network during the EU Eastwards enlargement, it is playing a crucial role in the connections as the former Corridor V and the Baltic-Adriatic corridor in the new EU's transport policy.

Such dynamics deals particularly with the growth in freight traffic and of the integration with inland logistic nodes and, in parallel, with the further exploitation of national and international rail connections. The overall freight traffic in 2021 saw Trieste ranking first before Genoa with more than 55 million tons[2]. As Port Authority systems, the High Eastern Adriatic Port Authority – with Trieste and Monfalcone – ranks second after the Port Authority of the Western Ligurian Sea – With Genoa and Savona-Vado. The container traffic in Trieste overcame 500,000 TEUs in 2015, and since 2016 it witnessed a period of constant growth, getting close to 800,000 TEUs in 2019 (789,594), then, following the pandemic periods, setting at 757,255 in 2021. The semitrailers and swap bodies traffic was relevant, given the important Ro-Ro[3] ferry flows from Turkey, that bring the equivalent traffic to 1.3 million TEUs.

Still it is interesting to notice how the pure container traffic is split among hinterland and transshipment markets, with shares respectively of 70% and 30%, in a mix of functions between nodal gateway and hub.

[2] This despite a drop of 13% as regards as the maximum value recorded in 2019 as a consequence of the pandemic events. Trieste data, however, are distorted by the liquid bulk, still counting for nearly 70% of total traffic.

[3] These benefits of the Free Port regime are not quoted as it happens in other Italian ports.

Nearly the total of hinterland traffic travelled by train. In 2019 nearly 10,000 trains were moved (9.771 precisely), with figures dropping to 8,523 in 2020 following the Covid-19 pandemics slow down, raising again towards 9,000 in 2021. In 2020 more than 400,000 TEUs were moved by train, more than 80% of the hinterland traffic[4].

Central and Eastern Europe (Germany and Austria, followed by Slovakia, Czech Republic, Hungary and Luxemburg), with an articulated network of important connections towards the major Euro-Asiatic traffic routes and flows and with the Northern Range Ports, for a total of 231 weekly connections.

The national connections are mainly linked to the important inland logistic nodes of Padua and Milan, other than, locally, the production systems of Friuli Venezia Giulia Region, with 22 weekly connections, less than 10% of the total.

The port of Trieste is inserted into High Eastern Adriatic Port Authority together with the Port of Monfalcone, and it is integrated with the inland terminal Interporto Trieste, this including the recent free-zone FreeEste, within the port region of Trieste. These latter proximity dry ports are dedicated to warehousing and freight train composition, these latter including RO-LA and similar for the movement of semitrailers, swap bodies, containers and other rolling materials (Fig. 3), before them being sent towards main international destinations.

Table 3. Rail cargo traffic from the Port of Trieste and inland terminals. Source: author's elaboration from [29–31] (data 2020).

O/D National		O/D International	
Padova	10	Karlsruhe (Germania)	14
Pordenone	6	Komarno (Slovacchia)	7
Milano	6	Krefeld (Germania)	4
Total national	**22**	Linz (Austria)	2
		Ludwigshafen (Germania)	28
		Monaco (Germania)	16
O/D International			
Bettembourg (Lux)	24	Ostrava (Repubblica Ceca)	6
Bratislava (Slovacchia)	1	Paskov (Repubblica Ceca)	8
Budapest (Ungheria)	23	Salisburgo (Austria)	2
Burghausen (Germania)	2	Villach (Austria)	8
Colonia (Germania)	48	Wels (Austria)	19
Dunajska (Slovacchia)	7	Wien (Austria)	3
Giengen (Germania)	4	**Total international**	**231**
		Total connections	***253***

[4] Data from Port of Trieste; Adriafer.

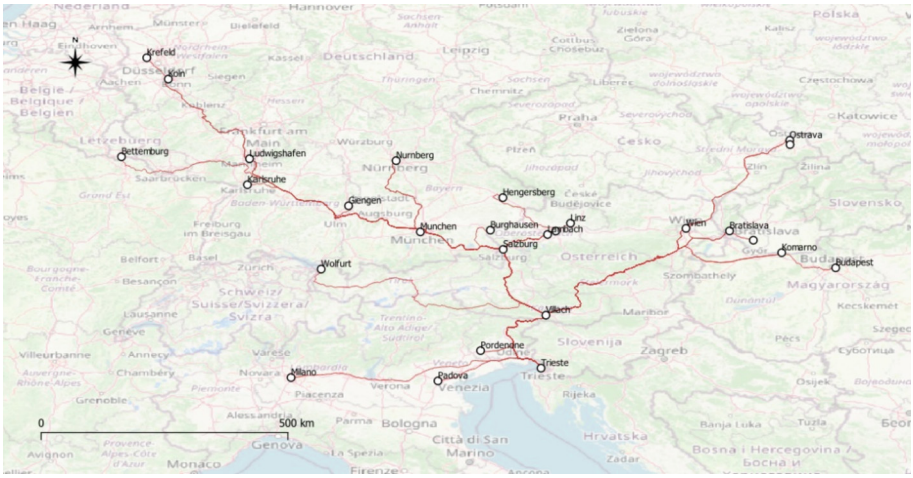

Fig. 3. Rail traffic routes to and from the Port of Trieste. Source: author's elaboration from [29–31].

In the Port of Trieste region, the Port-owned Adriafer company manage shunting operations among inner and regional terminals, as Interporto Trieste and FreeEste node, as well as Interporto of Cervignano, as well as increasing interactions are ongoing with the nodes of Gorizia, Tarvisio and Pordenone. Such a region can be considered as a 'case study' although characterized by a smaller dimension if compared to other international, bigger port systems around the World [32]. The gateway role is further enhanced, particularly considering the land component, by the possible integration with the infrastructure systems of the deep internal regions, bordering the traditional hinterlands. It is worth reminding on one side the historical competition among some ports – as Trieste and Hamburg – and, to-date, an ongoing integration, realized by means of the participation of the company shares among Duisport – Duisburg inland river port – and Interporto Trieste – inland dry terminal. German presence is also represented by the Hamburg port terminal operator holding shares into the new logistic platform in Trieste. These transformations represent a stage of an evolution of the long-distance freight transport systems towards the Euro-Asian traffic routes, also through the Mediterranean gateways.

4.1 The Sustainability of the Sea-Rail Intermodal Transport in Trieste Port

Similarly to the analysis performed in Sect. 3 and Sect. 3.1, an evaluation of the sustainability of rail routes if compared to the equivalent road ones was performed. In particular, routes as in Table 3 and Fig. 4 were examined in terms of their energy absorption (MJ) and greenhouse gases (GHG) emissions. The analysis was performed using the EcoTransIT World (ETW) platform.

As in case of the port of La Spezia, we considered the Well-to-Wheel approach for computing energy consumption and emissions [28]. The calculations were performed considering a loading factor of 77% for the road component and 90% for the train one – this latter figure based on the figures as obtained from the shunting company Adriafer. The

comparison was performed considering the national and international rail connections and simulating the equivalent road routes. The case of Trieste is related mainly to the international routes, with just 3 national destinations over a total of 26. Also in this case, we can compare the differences between road and rail in terms of distances travelled by freight, energy consumption and greenhouse gases emissions (Table 4).

Interesting observations can be done after the application of the ETW software over the selected routes. It is worth noting that the positive environmental impacts can be observed at all distances and destinations. The energy consumption of rail cargo compared to the road one spans from 26.77% to 38.04%, while the quota of GHG emissions from 11.83% to a maximum of 24.10%, with a not appreciable relation with the distances travelled, that possibly depending also on the Alpine routes implying covering hills and mountain elevations.

Finally, it is important to underline how the railway distances considered so far span from a minimum of 113 km to a maximum of 1,130 km, thus observing a coverage over short, medium and long distances of rail cargo systems into local-regional and international inland ranges, with considerable benefits in terms of environmental impacts.

Table 4. The emission calculation per TEU along routes between the port of Trieste and inland terminals (differentiated by rail and road). Source: author's elaboration on ETW data [28].

	Truck			Train		
	Distance (km)	Energy consumption (megajoule)	GHG emissions (tons)	Distance (km)	Energy consumption (megajoule)	GHG emissions (tons)
Lambach (Austria)	469	4,894	0.341	464	1,510	0.050
Linz (Austria)	269	2,818	0.199	302	980	0.037
Salisburgo (Austria)	373	3,886	0.272	378	1,226	0.043
Vienna (Austria)	554	5,778	0.400	569	1,849	0.058
Villach (Austria)	186	1,907	0.137	189	609	0.028
Wels (Austria)	488	5,088	0.336	487	1,582	0.048
Wolfurt (Austria)	692	7,131	0.505	673	2,283	0.079
Ostrava (Czech Republic)	843	8,769	0.613	833	2,624	0.099
Paskov (Czech Republic)	849	8,833	0.618	835	2,630	0.099
Burghausen (Germany)	430	4,483	0.315	480	1,436	0.062
Colonia (Germany)	1074	11,023	0.780	1,114	3,677	0.180
Giengen (Germany)	636	6,572	0.460	712	2,256	0.100
Hengersberg (Germany)	518	5,426	0.379	638	1,824	0.066
Karlsruhe (Germany)	794	8,178	0.580	847	2735	0.130
Krefeld (Germany)	1130	11,593	0.830	1,174	3,889	0.190

(*continued*)

Table 4. (*continued*)

	Truck			Train		
	Distance (km)	Energy consumption (megajoule)	GHG emissions (tons)	Distance (km)	Energy consumption (megajoule)	GHG emissions (tons)
Ludwigshafen (Germany)	838	8,638	0.61	870	2,817	0.130
Monaco (Germany)	508	5,255	0.37	521	1,585	0.066
Norimberga (Germany)	664	6,846	0.48	722	2,295	0.100
Budapest (Hungary)	683	6,942	0.506	783	2,641	0.083
Milano (Italy)	393	4,004	0.288	393	1,268	0.061
Padova (Italy)	180	1,840	0.132	179	569	0.028
Pordenone (Italy)	113	1,158	0.083	126	408	0.020
Bettembourg (Luxemburg)	1007	10,365	0.74	1,091	3,662	0.160
Bratislava (Slovakia)	620	6,471	0.449	616	1,733	0.055
Dunajska (Slovakia)	664	6,953	0.482	648	1,861	0.057
Komarno (Slovakia)	624	6,519	0.458	682	2,155	0.069

5 A Comparison Between Two Rail Ports

Italian North Tyrrhenian Sea and North Adriatic Sea Ports have been fighting an "internal competition" in Italy to attract maritime traffic through the Mediterranean Sea from the Far East, towards the national and European markets. The North Tyrrhenian ports, on one side, have been always winners in terms of freight volumes, movements and dynamicity of port systems, given, in particular, the wider geographic area covered by the range and, in the recent past, by the presence of major urban and industrial systems. These ports granted important services to the old Italian Industrial Triangle – Genoa, Turin, Milan – as well as a connection of these dynamic areas with the European core – Germany and France in particular.

On the other side, the North Adriatic Sea has long been a dead end, because of the presence of several borders – between European Union and Eastern Europe before, and next with the presence of several different states and related borders, including those coming out from the fragmentation of former Yugoslavia – and for the presence of a less dynamic economic system. As a consequence, these ports suffered in terms of minor traffic and port system performances. More recent years, however – with a still pending evaluation over the more recent years as 2020 and 2021, given the effects of the pandemic and post-pandemic periods – witnessed an important increase of performances in the North Adriatic Sea, with particular reference to the Port of Trieste – now in the wider context of the High Eastern Adriatic Port Authority with the Port of Monfalcone.

The changed port dynamics witness an increase of both the Tyrrhenian and Adriatic ports and can be also related to the changed role of ports, with a weakened traditional distinction among pure hubs and gateways as in the late Nineties end the first decade of 21st century. The changes intervened in the international shipping, in terms of container ships dimensions and routes chosen by companies, led changes in the hub ports, with a further consolidation of roles of the bigger ones, and fading of the smaller ones, together with a resizing of minor ones and a reconfiguration towards mixed hub-gateway functions of those better connected with inland infrastructure and networks.

Recent examples of such dynamics can be related, in the Italian case, to the loss of a hub role of a port like Cagliari[5], after the operator's choice of moving its operations on a gateway, continental port as Leghorn. Still, a traditionally pure hub port as Gioia Tauro is expected to enhance the railway connections to allow a higher infrastructure integration with the hinterland and obtain a functional mix of hub and gateway functions, in line with the TEN-T policies and the aim of creating a Third-generation port integrated with its territory [35][6]. Still, we can recall a recent increase of maritime traffic in Taranto after phenomena of congestion in the hub of Malta – Marsaxlokk[7].

While pure hubs are experimenting important transformations, other changes involve gateway ports, whose hub functions are increasing, with a consequent changing role into their land systems. In such a context, in fact, developing pendulum routes in the recent years led to a higher importance of port and their port systems in the mixed movements of freight, as destined to both a hinterland as for transshipment operations, with a number of containers stored on quays ready to be re-embarked on other ships towards other, shorter destinations.

In the case examined the internal connections become particularly important to allow and encourage the sea-rail modal integration and, particularly, to reduce vehicle congestion and carbon footprint moving freight from road to rail. In doing so, and observing the cases of the gateways in Trieste and La Spezia, they appear particularly relevant in reaching this important role. It is interesting to notice a comparison among the rail hinterlands of the two ports. The two ports are specialized in terms of their markets (Fig. 3 and 4). La Spezia is particularly dominant in a context of internal national destinations, well connected to the industrial and production system of Northern Italy, as the classical Industrial Triangle and its more recent evolutions and changes enlarging it towards Northeastern Italy, as the industrial district areas of Veneto and Emilia Romagna regions. Trieste is traditionally connected to international destinations in Central and Eastern Europe, and, from there, towards the Asian markets. It is interesting to notice how a competition among the two ports is quite difficult to detect. Only the important national nodes as Padua and Milan are, in fact, common destinations from the two rail ports, quite a natural one and not the space for a competition on the national markets. A similar consideration is valid for the local markets. A part from the long-distance connections, the two ports serve the macro-regional production system of their territories – Northwestern Italy for

[5] https://www.internazionale.it/reportage/monia-melis/2019/07/08/porto-canale-crisi-cagliari.

[6] https://www.uominietrasporti.it/professione/logistica/il-terminal-container-di-gioia-tauro-cresce-e-apre-al-treno/.

[7] https://www.shippingitaly.it/2022/01/01/taranto-nuovo-hub-per-le-navi-di-cma-cgm-dirottate-da-malta-causa-congestione/.

La Spezia and Friuli Venezia Giulia and Eastern Veneto Regions for Trieste – again without a real competition but, likely, a possible integrated cooperation.

In terms of sustainability, although the analysis showed for La Spezia a national range, therefore characterized by a shorter distance range, and for Trieste an international one, advantages from the rail transport in terms of energy consumption and greenhouse gases emissions are visible and quite evident at all scales.

6 Conclusions and Policy Suggestions

We can derive some policy suggestions from the analysis of these local case studies. The two cases are quite different, both in terms of markets, and in terms of connections to the national and international transport systems, and in terms of the dimensions of the overall freight movements. Nonetheless, it is possible to synthetize some common challenges and similar necessities, that can bring interesting suggestions for port systems overall. One consideration needs to be done in the direction of the needs to reinforce the waterfront (quays) – inner harbor connections, both those strictly close, and those located farther in the port region.

The modal shift towards rail, more and more desired at EU level, involves necessarily dedicated spaces for freight train composition – according to the European standard of 750 m – with the need of adequate and fitted for purpose spaces. Also, there is the need for warehousing, handling and shunting. There is the need for a higher functional integration among the strictly port component, facing the sea, and the internal one, creating 'systemic port regions', in which a unique and coordinated management can be proficient in keeping more efficient operations.

Further strategic considerations follow. The current configuration of the maritime transport is based on long-distance maritime and land networks, where gateways are meant both in terms of port regions, therefore not limited to the waterfront, but involving the inland logistic nodes, both as transit and bulk transfer towards farther national and international destinations. This can be seen as an opportunity, but also as a matter of threat. The opportunity lies in the fact that reinforced logistic systems per se can generate local development. Threats can be found in the consideration of long-distance networks, that implies local nodes, as port, becoming just transit points that, in a world becoming more and more IT-based and therefore with an increasing reduction of the human workforce in logistic operations – see the semi-automatic terminals as Savona Vado, or the autonomous guidance transport systems – can potentially reduce the local development effects and a wealth transfer towards other, not necessarily local or national, destinations. Further opportunities can be found in the needs to integrate new forms of manufacturing industrial local development with transport systems, in this intercepting the already existing industrial systems – i.e., the old and new Industrial Triangles – but also enhancing the opportunities offered by reshoring and the development of the Special Economic Zones and Free Zones [36]. From the environmental point of view, rail transport is successful in counting for a limit share of energy consumption and greenhouse gases emissions if compared to container unit (TEU) moved over different distances. Also considering a shorter range - within 200 km from the node of origin – the advantage in terms of reduced consumption and emissions is considerable. Advantages in sustainability can

be highlighted when considering longer distances, where rail transport become even more environmentally friendly. In particular, as from the analysis on the two ports, the national destinations – those at a shorter distance – are as well convenient in terms of unitary emissions and consumption. Investments need to be done in order to tackle with the infrastructure limits affecting Italian ports – i.e., rail length, network bottlenecks and turning angle, that currently very often limit the capability of realizing longer block trains that can gain a higher level of efficiency.

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