

A Preliminary and Aggregate Analysis Relating to the Italian and Balkan Intermodal Corridors for the Development of International Freight Trade

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Abstract. In recent years, the maritime transport industry has found itself discussing the problem of international trade between Europe and Asia, namely the direct connection between Asian ports and the ports of the Northern Range. The existence of intermodal corridors affecting the Italian and Balkan peninsulas in southern Europe necessitates special attention. In fact, from the time of arrival in the ports of southern Europe until the arrival at the destinations of central Europe, special attention needs to be given to the study of the land components.

The primary goal of this research work is to analyse the key publications concerning the development of the TEN-T (Trans-European Network on Transportation) infrastructure network and the RFC (Railway Freight Corridors) railway services network in 2023. By implementing an aggregate analysis and reviewing the data concerning the supply of the two corridors currently available within the RFC network, the most noteworthy aspects in terms of benefits and critical issues were identified.

The key findings of this research, identify several significant existing challenges on both corridors due to their passage through many states and the uneven status of infrastructure. It is estimated that the two corridors have the potential of improving TEN-T infrastructure, which in turn improves RFC services. It is also highlighted that there is significant potential for growth in the Southern European regions' infrastructure and services, which might serve as a catalyst for the economic development of the areas under study (currently presenting marginal development). Ultimately, possible actions and strategies could provide advantages in terms of time and costs for freight transiting along the Euro-Mediterranean corridors.

Keyword: Intermodal Corridors · Maritime Transport System · TEN-T Networks · Railway Freight Corridors

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1 Introduction

Rail transport represents an alternative in line with community and international sustainability objectives. The ambitious framework guiding these aspirations is Agenda 2030, adopted by the United Nations in 2015. This transformative document, titled "Transforming our world: the 2030 Agenda for Sustainable Development", outlines 17 interconnected goals (SDGs) encompassing various aspects of sustainability. Each goal is further broken down into measurable indicators and targets, providing a clear roadmap for collective action [1–3].

In the context in question, it is useful to recall two objectives:

- Goal 13, "Take urgent action to combat climate change and its impacts", for its general implications on the reduction of CO2 emissions;
- Goal 9, "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation", which represents the focus from companies and therefore supply perspective.

Railway transportation is directly linked to both decarbonization and resilient infrastructure. The sustainability of railroad transportation is emphasized when compared to alternative transportation modes. The European Union (EU) has placed sustainability at the forefront of its transportation goals, outlined in the White Paper Roadmap to a Single European Transport Area [4]. Recognizing the critical role of interconnected infrastructure, the EU established the Trans-European Transport Network (TEN-T) to seamlessly link different countries and transportation modes. Within this network, Railway Freight Corridors (RFCs) play a crucial role in ensuring competitive and efficient freight movement [5]. In order to guarantee a competitive railway freight service in European network, Railway Freight corridors (RFCs) were established [6]. RFC and TEN-T corridors refer to different aspects of the transportation community system: while TEN-T refers to multimodal strategic infrastructure network, RFC refers to the railway operative freight service network.

This research delves into the potential of RFCs in two key regions: the Balkans and the Italian Peninsula. Both regions, strategically positioned at the southern gateway of the EU, vie for dominance in intermodal transportation. By comparing the existing RFC networks in these areas, our research aims to:

- Evaluate travel distances from Central and Eastern Europe to Southern Europe.
- Assess the capabilities of the present rail freight service network.
- Identify opportunities for improvement and optimization [7, 8].

The structure of the current paper is the following: Sect. 2 analyses in-depth the geographical area under study, the corridors studied, and the evolution of European network; Sect. 3 outlines the methodology used for the quantitative analysis; Sect. 4 presents the main findings of the comparison, which are then discussed in Sect. 5.

This research holds significant value for various stakeholders:

- Researchers: Gaining insights into the dynamics of freight transportation networks.
- Intermodal and Rail Freight Operators: Identifying opportunities to enhance efficiency and competitiveness.

- Public Authorities: Informing infrastructure investment decisions and policy development.

2 (General) Framework on TEN-T and RFC

The European Community was founded on trade and economic integration, but the Treaty of Maastricht in 1992 marked the beginning of Europe's true connection. As of 1992, the European Economic Community, focusing on aspects of economic integration became European Community.The same Treaty triggered the definition of the Trans-European Transport Network (TEN-T) to serve the needs of the EU Single Market (established in 1993) and the economic and social cohesion. The definition of the TEN-T was achieved in 1996 with the adoption of a relevant Decision [9]. This became the reference for the coordinated development of transport infrastructure for the various transport modes, setting the criteria for financing projects of common interest. At the same time, a catalogue of 14 priority projects was adopted. Then the decision was amended twice, in 2001 and 2004 [10, 11], the latter of which coincided with the EU enlargement with 10 new member states. Accordingly, the list of priority projects was extended to 30. The evolution of the TEN-T guidelines followed the EU enlargement process and hence they were amended again in 2007 due to the accession of Bulgaria and Romania. In 2010 it was recast in the interest of clarity [12], while in 2013 the TEN-T Regulation was adopted [13], in the same year of Croatia's accession to the EU. In a parallel process, the Pan-European Transport Networks, established through three Pan-European Transport Conferences (Prague in 1991, Crete in 1994 and Helsinki in 1997) and consisting of the TEN-T in EU countries, ten Pan-European Corridors and transport network components in EU candidate countries and four Pan-European Areas, became obsolete with the consecutive EU enlargements. The Pan-European Corridors were defined to facilitate the operation of the TEN-T in the non-EU regions with the development of relevant infrastructure in the EU acceding countries, as well as in the candidate or potential candidate countries for accession. In 2013, with the adoption of the TEN-T Regulation, a major change was the inclusion of indicative extensions of the TEN-T to neighboring countries, including to those in the Western Balkans region.

The TEN-T network is a tool for integration between various countries. The network involves transport infrastructures by rail, road, sea, inland waterways, as well as the specific infrastructures associated with them (sea and river ports, airports, railway stations terminals, urban nodes and border crossings). The network serves to coordinate the infrastructural efforts of the various countries involved, improve their accessibility, and enhance their competitiveness at both a national and international level. The TEN-T policy is a key community-level planning tool [14]. The network is defined through two levels: a central network and a global network. The core network acts as the backbone of the entire multimodal network, promoting sustainability and connectivity at a European level; the global network has the function of guaranteeing accessibility and connectivity to all regions of the EU, even the most peripheral. It is within the TEN-T that projects of international importance are defined, within the framework of the corridors defined the TEN-TRegulation. Nine corridors was envisaged to facilitate the implementation of the Core TEN-T and were integrated in the Connecting Europe Facility (CEF) Regulation 1316/2013: (a) Atlantic, (b) Baltic-Adriatic, (c) Mediterranean, (d) North Sea-Baltic, (e)

North Sea-Mediterranean, (f) Orient/ East-Med, (g) Rhine-Alpine, (h) Rine-Danube and (i) Scandinavian-Mediterranean [5, 15]. Currently, an expansion of the TEN-T network has been proposed, with the aim of modernizing the entire network and ensuring new sustainability standards. An amended proposal from the European Commission intends to include Moldova and Ukraine in the extended network, expanding the corridors of Eastern Europe to them [16], as shown in Fig. 1. Furthermore, this new regulation proposal was created with the aim of integrating the Core Network Corridors with the Rail Freights Corridors (RFCs) [17].

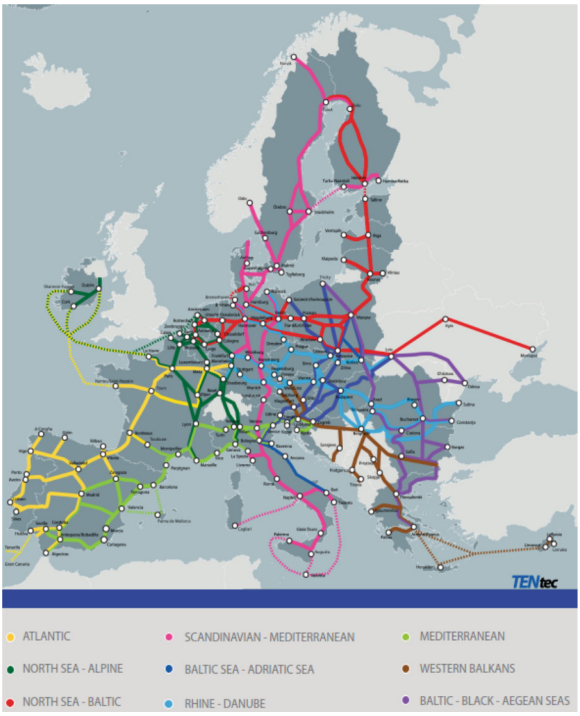


Fig. 1. TEN-T Corridors (Source: European Commission [18])

The TEN-T network therefore constitutes the main reference structure on a strategic scale for the European transport system. At the same time, it was necessary to define a network that could allow better use of the available railway infrastructures, allowing services to be provided which were competitive with all road services. The RFC network is the network that, on an operational scale, allows the best use of the available infrastructure. The RFC network is aimed at pursuing different objectives. In EU Regulation 913/2010 [6], various other aspects are referred to, in addition to that of competition with other modalities, which are central to the development of the network. These include improving connections between member countries and encouraging coordination between authorities of member countries and railway service managers. To this

end, it is emphasized that each established corridor is subject to a single corridor authority. It is underlined that, unlike the TEN-T network, the RFC network does not have competence over the design and planning component of new infrastructures. Figure 2 presents the corridors of the RFC network.

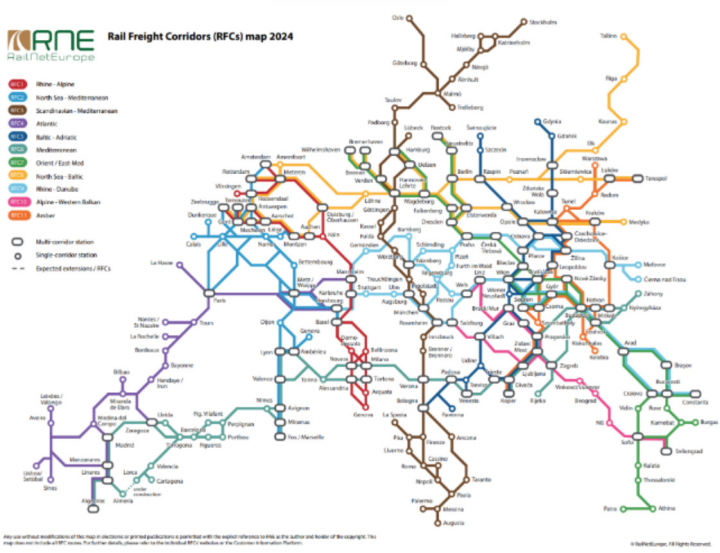


Fig. 2. RFCs (Source: RailNetEurope, 2024. https://rne.eu/corridor-management/rfc-network/ [19])

This paper takes a critical look at the current state of transport corridors in two strategic peninsulas: Italy and the Balkans. Its aim is to position these regions at the forefront of the discussion on efficient and sustainable freight movement between Europe and the East. While maritime transport currently dominates global trade [20], with the Suez Canal serving as a key artery [21], the future demands a multimodal approach. In this evolving landscape, the Mediterranean Sea emerges as a potential southern gateway to Europe. Its geographically advantageous location offers a unique opportunity to bridge the gap between East and Europe [22, 23, 24, 25]. Italy and the Balkans, strategically situated on either side of the Mediterranean, hold the potential to play a leading role in this transformation. By improving existing transport infrastructure, including railway freight corridors, these regions can create a competitive and efficient intermodal network. This, in turn, can attract trade flows and unlock significant economic benefits for both regions and Europe as a whole. In this context, reference is made to the RFC corridors which run through the two peninsulas, as presented in Table 1.

Table 1. Main RFCs considered

Corridor	Countries involved	Reference
RFC 3 Scandinavian-Mediterranean	Norway, Sweden, Denmark, Germany, Austria, Italy	[26]
RFC5 Baltic-Adriatic	Polonia, Czechia, Slovakia, Austria, Slovenia, Italy	[27]
RFC7 Orient – East/Med	Germany, Czechia, Slovakia, Austria, Hungary, Romania, Bulgaria, Greece	[28]
RFC10 Alpine-Western Balkan	Austria, Slovenia, Croatia, Serbia, Bulgaria	[29]

3 Methodology

To study the system under analysis, the main elements of graph theory for modeling the supply system are recalled. Consider a graph $G = G(N,L)$, it has $N = [n_1, n_2, \ldots, n_N]$ nodes and $L = [l_1, l_2, \ldots, l_j, \ldots, l_k, \ldots, l_L]$ links. Each link is characterized by a quantitative measurement c_l. Furthermore, let this quantitative measure be considered constant and independent of other attributes.

In the network thus defined, referring to Cascetta, 2013, the Dijkstra algorithm is considered for the calculation of the shortest paths between two known ones in the network [30]. So, C is considered equal to the length of the path of the arc to which it is associated. Starting from the definitions mentioned, the study comes through the following formulation:

- Scenario "0:" given a generic node o and a generic link l_j, given a set of destination $D = [d_1, d_2, \ldots, d_i \ldots, d_s]$, the paths originating in o, with destination d_i and passing through l_j are identified.
- Scenario "1": given a generic node o, generic links l_j, l_k, given a set of destination $D = [d_1, d_2, \ldots, d_i \ldots, d_s]$, the paths originating in o, with destination d_i and passing though l_j are identified; the paths originating in o, with destination di and passing through l_k are identified, under the condition $l_k \neq l_j$.
- Scenario "2": given a generic node o, generic links l_j, l_k and a set of destination $D = [d_1, d_2, \ldots, d_i \ldots, d_s]$; let $p(o, d_i, l_j)$ and $p(o, d_i, l_k)$ be the shortest paths previously identified; distances $D(p(o, d_i, l_j))$ and $D(p(o, d_i, l_k))$ are identified. Difference between distances is evaluated; condition for which this distance is lower than a specified quantity Δ is verified.
- Scenario "3": given generic nodes $o_1, o_2, \ldots, o_w,\ldots,o_h$, generic links $l_{j,ow}$, $l_{k,ow}$, given a set of destination $D = [d_1, d_2, \ldots, d_i \ldots, d_s]$, the paths originating in o_w, with destination d_i and passing though $l_{j,ow}$ are identified; the paths originating in o_w, with destination di and passing though $l_{k,ow}$ are identified, under the condition $l_{k,ow} \neq l_{j,ow}$.
- Scenario "4": given generic nodes $o_1, o_2, \ldots, o_w,\ldots,o_h$, generic links $l_{j,ow}$, $l_{k,ow}$ and a set of destination $D = [d_1, d_2, \ldots, d_i \ldots, d_s]$; let $p(o_w, d_i, l_{j,ow})$ and $p(o_w, d_i, l_{k,ow})$ be shortest paths previously identified. Distances $D(p(o_w, d_i, l_{j,ow}))$ and $D(p(o_w, d_i,$

$l_{k,ow}$)) are identified. Difference between distances is evaluated; condition for which this distance is lower than a specified quantity Δ is verified.

Different criteria for the destination nodes can be considered. A change in the set D imply a modification in the results of the study. Considering the formulation defined, Fig. 3 summarizes the methodological steps of the work.

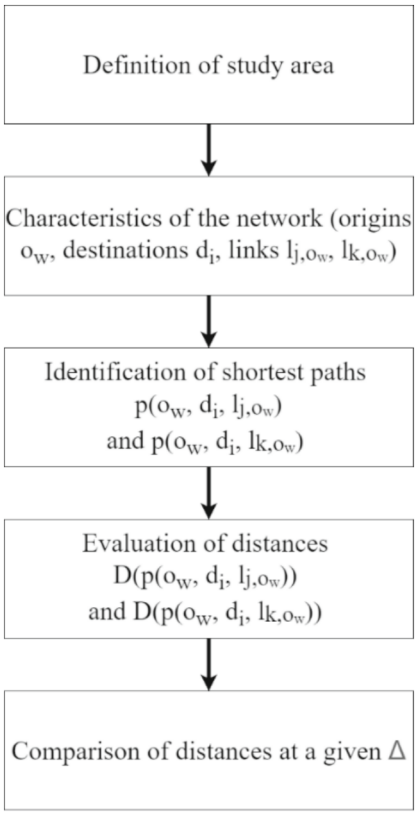


Fig. 3. Methodological framework

4 Results

Our research examines the possibility for railway corridors originating from Italy and the Balkans to become the leading and most preferable transport mode serving at the same time as the southern gateway for freight between Europe and the East. In this aspect, our research identified two cities as key players:

- Gioia Tauro, a strategic Italian port city, poised to leverage its efficient infrastructure, and

- Thessaloniki, a vibrant Greek metropolis, aiming to capitalize on its geographical proximity to Eastern markets.

Both cities set their sights on a lucrative destination: the central and eastern region of Germany, Austria, and Czechia. This area acts as a magnet for freight demand, attracting goods and services from across the continent. It's also the "battleground" where the two peninsulas compete for dominance in this crucial trade route. The corridors considered are the following:

- the Scandinavia-Mediterranean corridor is considered between Hamburg and Gioia Tauro, considering only the Adriatic line in Italy;
- the Baltic-Adriatic from Bologna to Ústí nad Orlicí in Czechia;
- the Alpine-Western Balkans from Sofia to Linz and Salzburg;
- the Orient/East-Med from Thessaloniki to Berlin and Hamburg.

The region under consideration might be a segment of Central Europe that includes the cities of Hamburg, Berlin, Budapest, Salzburg, and Bologna. Several different segments of RFC corridors are taken into consideration in order to formulate a connected network. The four primary corridors under consideration are oriented mostly North-South; additional links primarily follow the main direction of West to East. A portion of the Mediterranean, Rhine-Danube, Amber, and North Sea-Baltic corridors were taken into consideration. The network under consideration and the region are presented in Fig. 4. For modelling the problems, the network was discretized along the main nodes of the network, as suggested by RailNetEurope [33].

For the comparisons, the following assumptions were made:

- The origins are placed in Gioia Tauro (Italy) and Thessaloniki (Greece). They represent the land southern gateway of each peninsula;
- To correctly model the routes in Italy, the portion of the Scandinavian-Mediterranean between Ancona and Gioia Tauro was considered as common to both routes; between Ancona and Bologna, both routes share the route; the two corridors diverge at the Bologna node. For commodity's sake, points placed outside Italy are modelled in this way: routes that considered the Brennero node at the Italian-Austrian border are labelled "Scandinavian-Mediterranean"; routes that considered the Tarvisio or Villa Opicina node are labelled as "Baltic-Adriatic";
- To model the routes in the Balkans, a common portion between Thessaloniki and Sofia is considered, even if it only belongs to the Orient/East-Med corridors; the two corridors have no portions in common outside the Sofia node, within the network considered. Point placed outside of Greece and Bulgaria are labelled as follows: points reached through the Bulgaria/Serbian border at Kalotina/Dimitrovgrad are "Alpine-Western Balkans"; points reached through the Bulgaria/Romania border at Vidin/Golenți border are "Orient/East-Med";
- Destinations are chosen considering all the points, in the study area, in which RFCs have a discontinuity;
- For the definition of a competition area, $\Delta = 150$ km is considered. For each node, and for each corridor referring thee ach node, the average value of distance, from the origin to all the nodes analysed, is calculated. The difference between the lowest average and the medium average is approximately 200 km; the difference between

the highest and the middle average is 100 km; then it is considered, as Δ, the value of 150, that is the intermediate value between 200 km and 100 km.



Fig. 4. Network considered (Source: Authors' elaboration based on openstreetmap [31] and QGIS [32])

4.1 Scenarios 0 – 1 – 2 Balkans

Railway distances have been evaluated for Orient/East-Med and Alpine-Western Balkans corridors. Considering a $\Delta = 150$ km, the competition area for which distances from Thessaloniki through Bulgaria-Romania border (Orient/East-Med) and Bulgaria-Serbia border (Alpine-Western Balkans) is defined. Results are shown in Fig. 5.

The route from Bulgaria/Romania border is the dominant corridor for points between Sofia and Budapest. The route from Bulgaria/Serbia border is the dominant one until Wien, along the Alpine-Western Balkans route, and until Hannover, considering the continuation on other corridors, especially on the Scandinavian-Mediterranean one. The dominance of the Alpine-Western Balkans route, and its continuation, is extended to the South-West of Hungary, the greater portion of Austria and some areas of Germany. Also, Italy and other Balkans countries (Slovenia, Croatia) are comprised in this zone. A large area is made of points for which distances from Thessaloniki along the two corridors are lower than 150 km. This area comprises the North of Hungary, Slovakia, Czechia and almost the entire Eastern Germany, until the city of Hamburg in North-western Germany.

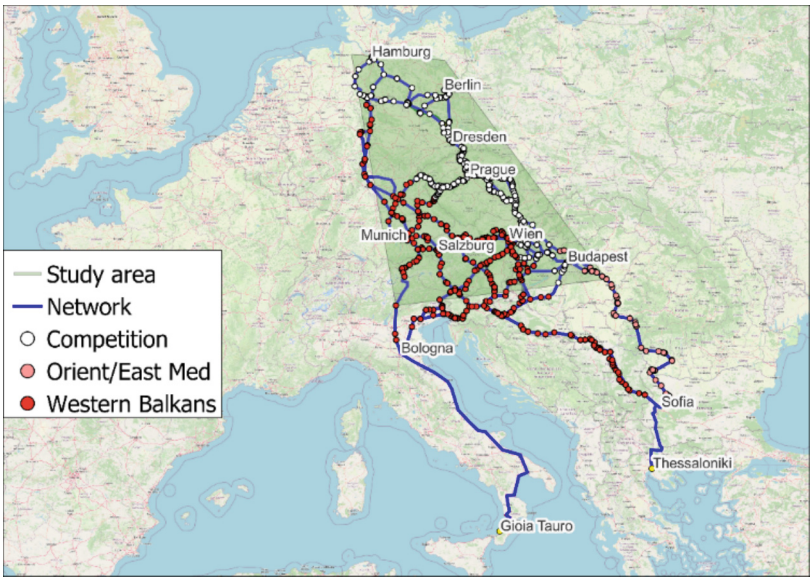


Fig. 5. Points from Thessaloniki (Source: Authors' elaboration based on openstreetmap [31] and QGIS [32])

4.2 Scenarios 0 – 1 – 2 Italy

Distances have been evaluated for Scandinavian-Mediterranean and Baltic-Adriatic corridors. A $\Delta = 150$ km, for defining the competition area between the two corridors is considered. Results are shown in Fig. 6.

Scandinavian-Mediterranean corridor is dominant for almost the entirety of Germany and a vast portion of Czechia, until Prague. Baltic-Adriatic is dominant for Balkans and, at north, the southern part of Slovakia, Austria and Hungary until Budapest. Central and northern part of Austria and Slovakia, among Eastern Czechia, are shaping the area of competition between the two corridors.

4.3 Scenarios 3 - 4 Greece vs. Italy

Considering both origins (Thessaloniki and Gioia Tauro) optimal routes are evaluated. Also, the area for which $\Delta = 150$ km is evaluated. This area is made of points for which distance from Thessaloniki and Gioia Tauro is less than 150 km, considering the shortest path. Results are shown in Fig. 7.

Corridors from Gioia Tauro are dominant mainly for points in Western Germany, Austria and Italy; on the other side, Balkans, Romania, Hungary and Eastern Germany are mainly dominated by the corridors from Greece. Competition area is the area comprised between Hamburg and Berlin, on the North of Germany; also, area between Prague, Linz, Ljubljana, Trieste, almost until Munich, Regensburg and the entirety of Czechia is a competition area between the two-node considered.

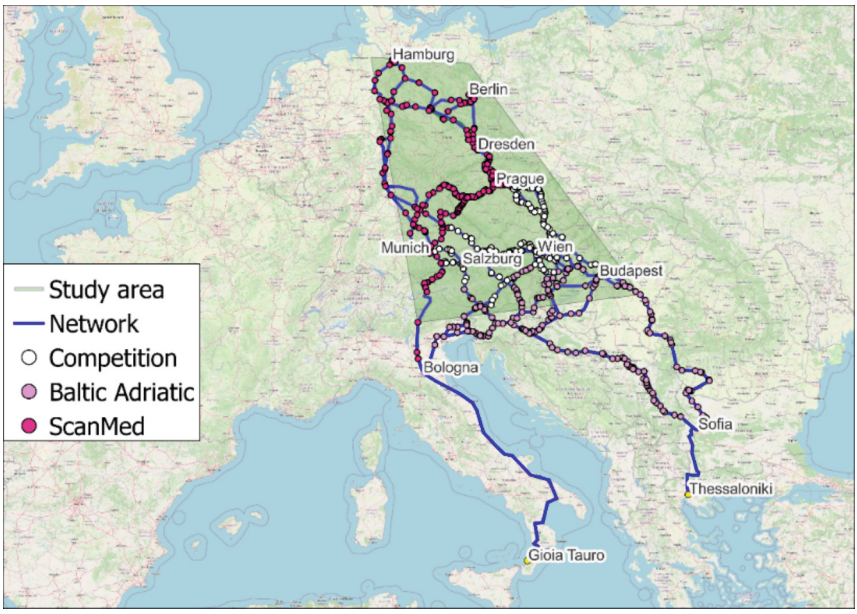


Fig. 6. Points from Gioia Tauro (Source: Authors' elaboration based on openstreetmap [31] and QGIS [32])

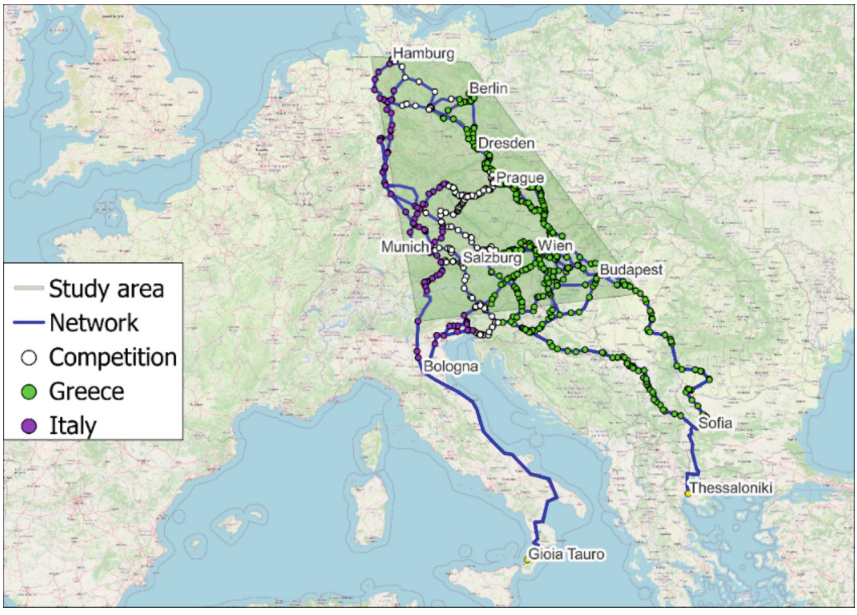


Fig. 7. Points from Thessaloniki and Gioia Tauro (Source: Authors' elaboration based on openstreetmap [31] and QGIS [32])

5 Discussion and Final Remarks

The findings of the above-described research are quite interesting. The Mediterranean countries can serve as the entry points for freight into the European Union thanks to the European Union's rail freight network. Two Italian and two Balkan corridors are taken into consideration. For the Balkans, Orient/East-Med and Alpine-Western Balkans, passing through borders that are, respectively, Bulgarian/Romanian and Bulgarian/Serbian. For Italy, Scandinavian-Mediterranean and Baltic-Adriatic considering the borders of Italy at Tarvisio or Villa Opicina and Brennero.

Thessaloniki was viewed as the origin hub for the Balkans. According to analysis, there are less kilometres between Serbia and Romania on the way to central Europe. Points closer to Thessaloniki through Serbia cover a larger area than those through Romania. There are several things to think about. Places on the Orient/East-Med between Budapest and Berlin/Hamburg are situated on the same corridors of the Bulgarian/Romanian border, even if they are in the competition region. As a result, it is evident that occasionally, network users may find it more beneficial to consider the Orient/East-Med alternative for destinations in Western Germany; focusing on a single corridor is simpler in terms of bureaucracy and administrative issues, and it may also be simpler for users and customers in general. Furthermore, Serbia is not a member of the European Union, adding an element of uncertainty in this research.

However, the Italian corridors display a sharper split, with the Baltic-Adriatic connecting eastern Europe in less than a hundred kilometres, while the Scandinavian-Mediterranean gives Germany priority. Austria, Slovakia, and Czechia all contain sizable areas that are in the competition zone. When the shortest routes between Thessaloniki and Gioia Tauro are compared, the Italian port is shown to be more important in western Germany, whilst the Greek port is more significant in the Balkan region, Hungary, and parts of Czechia, Slovakia, and Eastern Germany. There are still a number of other things to think about in this situation. Generally speaking, the Italian rail network has congestion, which makes the system less attractive for the transport industry; conversely, the infrastructure deficit in Greece frequently dissuades the use of these routes. It's important to keep in mind that Greek corridors may be integrated into intercontinental railway and intermodal corridors; in the context of intermodal corridors Europe-China, nodes in Greece, Bulgaria, and Romania may be gates in Europe for intermodal services from the North Sea and Caucasian region and for railway services arriving from Türkiye. This research presented a preliminary examination of these corridors in a static context, solely taking the distance attribute into account. Several elements may be added to avoid this limitation. Other factors could be considered, such as the quantity of distinct corridors, the duration of stops at borders, or other particular nodes. Additionally, demand components could be used to better understand the reasons rail freight services customers prefer RFC network.

The study is of interest for different categories of stakeholders; public authorities in the context of EU, for the description of different areas and their interest in the rail freight corridors; and logistic companies, for the analysis of the network and the indication of corridors suggested for different needs.

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