Sustainable Maritime Passenger Transport: A Network Analysis Approach on a National Basis

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Abstract. The goals of United Nations Agenda 2030 for Sustainable Development push the need for a modal shift from the road towards more sustainable modes. The mitigation of the environmental impacts and guarantee of effective connections between distant areas are objectives to be pursued in the logic of greater environmental, economic, and social sustainability. Geographical areas characterized by a big percentage of coastal lines must rethink the potential of their port system. The geographical position of Italy, in the center of the Mediterranean Sea, with the highest length of coast line respect to the national surface, have made it necessary to have a vast port system. The presence of two major islands, Sicily and Sardinia, and many smaller ones has made necessary the creation of a network of passenger transport services. In 2017, 16 Port System Authorities were identified on the Italian territory, including the ports considered to be of national strategic interest. The objective of this research is concentrated on the analysis of maritime passenger transport focusing on the services that connect the ports belonging to the abovementioned network, evaluating their centrality within the national services network. The results highlight an imbalance of the network towards the Tyrrhenian Sea, with the Adriatic mainly delegated to connection services with the Balkans and the East, while the single most central port authorities are the Sicilian and Sardinian ones. This article represents a first step for a better understanding the interconnection between ports around a closed basin in terms of passenger traffic.

Keywords: Maritime transport · Ports Systems · Sea network · Agenda 2030

1 Introduction

For several years, the document entitled 'Transforming our world: the 2030 Agenda for Sustainable Development' has been a guide to the UN's 2030 Sustainable Development Goals (SDGs) [1]. The 17 goals and their subsequent specification in targets, international indicators and national indicators are aiming at the pursuit of economic, social and

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environmental sustainability. The transport sector, by its nature, is largely involved in this process. The problem of passenger transport on a national scale is particularly relevant due to the high number of pax-km.

These concepts are closely connected with some of the goals of Agenda 2030. The first is SDG 13 'Take urgent action to combat climate change and its impacts'. Combating climate change and the need to reduce the carbon footprint is, in the context of the study to be presented, the main goal. Considering how different modes of transport are characterised by different carbon footprints [2] and how it is therefore necessary to pursue a reduction of the same; among the available instruments, it is important to recall the modal shift towards less emissive modes of transport, an objective also pursued by the 2011 White Paper in the European context [3].

SDG 9, 'Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation' is also closely connected to the development of sustainable infrastructure. In this sense, Target 9.1 "Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all" should be specified; of this target, it is interesting to note the specification on cross-border and regional infrastructure.

SDG 11 'Make cities and human settlements inclusive, safe, resilient and sustainable' expresses the necessity to pursue the sustainability of urban settlements. These three SDGs, which describe concepts related to the reduction of pollution, the spread of better infrastructure and the sustainability of cities, represent the reference goals for this work. Among the measures promoted by the Transport White Paper, the aforementioned modal shift must push a share of demand from road to the rail and maritime-port systems.

In all countries, geographical areas characterised by a high ratio of total km of coastline to surface area must naturally pay special attention to the maritime traffic system. Italy is a valid case study because it is geographically positioned at the centre of a Mediterranean port network and has significant maritime traffic with neighbouring countries [4]. The railway relationship with other countries is different, considering that Italy only borders other European countries along the Alps [5]; moreover, its geography includes two major islands and a large number of smaller ones.

To complete the picture, there is a substantial asymmetry in land transport between the southern part of the peninsula and the northern part; as a result, those who need to travel from the southern regions to the northern regions, albeit characterised by land continuity, are forced to turn to air transport.

The 2016 reform [6] identified 15 port system authorities, which were later increased to 16 following the spin-off of the ports of the Strait Area from the Port System Authority of the Southern Tyrrhenian and Ionian Seas [7]. Of the 16 areas, five are on the Adriatic Sea, two entirely on the Ionian Sea, one between the Tyrrhenian and Ionian Seas and the remaining eight on the Tyrrhenian Sea.

There is the need of identifying the degree of centrality in passenger services, freight services and Ro-pax services. Specifically, for passenger services it is necessary to consider both those that take place under ordinary conditions and those that take place with a tourist demand [8]. For freight and Ro-Pax services it is important to know what happens in large national and international basins such as the inland Mediterranean [9,

10]. The present study represents a first step in evaluating the relationships, in terms of passenger and Ro-pax traffic, between these port authorities. In this work, Ro-pax services are studied having systematicity and repetitiveness characteristics during the year and which therefore constitute the lower bound on the relationships to be considered. This is conducted by considering, as data, the passenger traffic services present between ports belonging to different port authorities. The objective is to reconstruct the centrality, in terms of passenger and Ro-pax services, of the various port authorities, in order to identify which are most affected by passenger traffic services, using the centrality tools provided by Network Analysis [11]. Knowledge of the importance of the various nodes makes it possible to enhance them in order to change further demand shares and to adequately support less important ones.

The most important aspects concerning the evolution of ports are recalled in Sect. 2 and contextualised on the basis of the existing literature; in Sect. 3 the methodology adopted for the study is presented in detail by recalling the theoretical cornerstones, in Sect. 4 the dataset and the results obtained are presented. Conclusions and future developments are reported in Sect. 5.

2 State of the Art of Port Evolution

The definition of ports is important to correctly specify the scope of the article. Note that following the UNCTAD approach the notion of generation does not imply a concept of improvement, i.e. ports of generation k are not better than ports of generation $k - 1$. The United Nations Conference on Trade and Development (UNCTAD) approach associates each generation with certain main functions as recalled above. Four generations of ports are identified in the literature [12–16]:

- First-generation ports are the ports directly connected to cities. Often, for first-generation ports, the birth of the port precedes that of the city itself. It is the presence of the port that determines the birth of the urban agglomeration; the port represents the main channel of communication and supply to the urban area. It is the first model to be born in chronological order. Some examples of ports emerging as the first-generation ports in Italy are Trieste, Genoa, Naples, Cagliari, Catania [17–19];
- Second generation ports developed after the Second World War. They are large industrial ports that, as such, must have adequate infrastructure and technology, and are often positioned to serve large industrial agglomerations. In Italy, Taranto and Augusta are examples of second-generation ports, serving their respective industrial systems [20];
- Third-generation ports have emerged since the 1980s. They are ports specialising in container traffic, and must contain all the equipment needed for container handling. The ships serving these ports must also be hyper-specialised [12, 21]. In general, these ports serve the longer Short Sea Shipping and Round the World routes. In Italy, an example of a fourth-generation port is the port of Gioia Tauro;

- Finally, the definition of fourth generation ports is closely connected to the creation of port areas located in different areas but with the management and presence of common operators [13]. Such an example is the joint administration of the ports of Malmoe (Sweden) and Copenhagen (Denmark).

Studying the Italian case is interesting and of reference on a European scale because with the reform of the Port System Authorities, the fourth-generation ports model was tried for different areas. As a result, ports with different characteristics are subject to the same administration. For example, there are different case study such as the Western Sicily Sea Authority, which sees in the same administration the ports of Palermo (mainly passenger port), Trapani and Porto Empedocle (tourist ports serving the system of Sicilian Minor Islands and fishermen) and Termini Imerese (commercial port); the same administration can exploit synergies and differences between the ports subject to it to increase competitiveness [22]. In addition to competitiveness and thus internal efficiency, the Agenda 2030 goals mentioned above must be achieved: reduction of environmental impact, resilient infrastructure, sustainable cities and communities. Central importance is given to first-generation ports, i.e. urban ports where better planning can be directly perceived by communities. Furthermore, the focus is on passenger traffic, and thus the main focus on first-generation ports derives from the better accessibility values that generally characterise these ports, which are not far from historical centres [23–25].

3 Methodology

The methodological tools used are derived from network analysis. Network analysis has a wide range of applications in the literature. Applications of network analysis tools have been proposed in the literature in terms of social sciences [26, 27], in urban planning in the analysis of open spaces [28], in economics in the study of economic exchanges [29, 30] and in transport for the analysis of transport networks [31–36].

Considering the punctual nature of the port, which is identified by a node within the transport network, in order to make an assessment of ports, it is interesting to identify centrality indices.

This preliminary research reconstructs the essential network of national passenger transport services by ship. For the construction of the network, port system authorities were considered as nodes and passenger ferry connections as arcs.

The characteristic of centrality measures is to provide an indicator to classify nodes according to a criterion in terms of weight within the network. The differences in the formulations between the different indicators make it necessary to identify several of them in order to be able to compare the results obtained.

According to Cascetta, 2013 [37], it is possible to represent a transport network with a graph $G = (N, E)$, where N is the number of nodes and E the number of arcs. The generic pair ij represents the arc with nodes i and j as ends. In the case of an undirected graph, it is possible to define the adjacency matrix as A_{ij} as $A_{ij} = [a_{ij}]$ where $a_{ij} = 1$ if i is connected to h, 0 otherwise. One can also define w_{ij} as the weight ascribed to arc ij. Each link ij is referred to direct connection. In the present paper, $a_{ij} = 1$ means the existence of a direct connection between node i and node j.

From these definitions, it is possible to specify the measures adopted in this work to assess the centrality of nodes:

- Degree centrality represents the centrality of the i-th node expressed as

$$c_i = \frac{\sum_j^N a_{ij}}{N-1} \tag{1}$$

  It represents the number of links the i-th node has with other nodes, relative to the total number of nodes. The maximum value of the number of links a node can have is $N-1$. A value of $c_i = 1$ identifies that the i-th node is directly connected with each of the nodes in the network, while it is worth $1/(N-1)$ if it is connected with only one other node in the network. This measure is relevant if the links in the network all have the same weight, and it is not essential to distinguish the arcs from each other.
- Strength centrality represents the centrality of the i-th node expressed as

$$s_i = \sum_j^N a_{ij} w_{ij} \tag{2}$$

  It represents the sum of the weights of the arcs affecting the generic i-th node, having indicated with w_{ij} the weight of the generic link between node i considered and the generic directly connected node j. This measure is important to define when it is necessary to define the weight of a single arc on the network; the sum of the services from i to j and j to i is considered
- Eigenvector centrality, is a measure that is important because it not only con-siders the number of links and the weight of the direct links of the i-th node, but also the values associated with the generic j-th nodes with which the i-th node is connected. One can define the value of v that satisfies

$$Av = rv \tag{3}$$

  where A is the adjacency matrix defined above, and v is the eigenvector associated with the eigenvalue r. Each value of v_i component of the eigenvector v associated with r expresses the eigenvector centrality of the i-th node. According to Perron [38], the matrix A has the following properties: a real square matrix with positive elements has a single largest real eigenvalue; the corresponding eigenvector has a strictly positive real eigenvector.

4 Results

For the identification of the network under examination, only ports belonging to one of the 16 Port System Authorities in Italy were considered as nodes.

Some ports were not considered because they are not equipped with passenger and Ro-pax services. For the evaluation of the arcs, the existence of direct passenger ferry services between two ports represented by previously identified nodes was taken into consideration.

The arcs are only considered between ports belonging to different Port System Authorities. In addition, seasonal connections and connections with only seasonal characteristics were not considered. In this work, $a_{ij} = 1$ indicates the existence of a Ro-Pax transport service of direct, systematic, collective connection between nodes i and j.

The data were obtained by analysing the websites of the Port System Authorities and the main shipping companies.

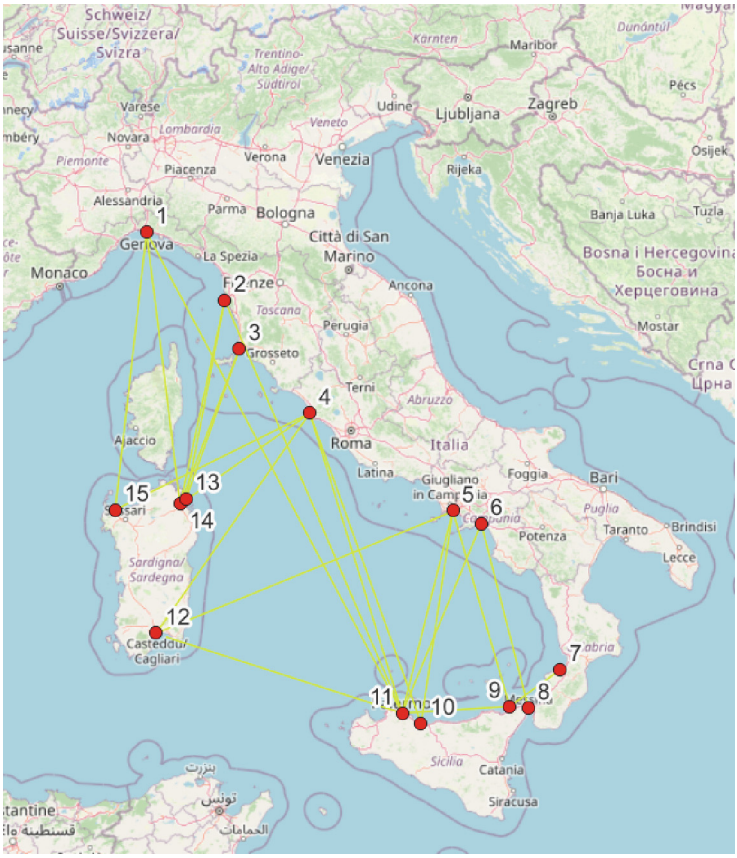

Fig. 1. Considered port network (Authors' elaboration on QGIS https://gisgeography.com/)

The network considered is presented in Fig. 1. The legend is shown in Table 1.

The study takes the first step by aggregating the services of the different ports of each Port System Authority.

This allows the linking strategies between different port authorities to emerge, as well as further emphasising the scale of the link concerned by this article.

The focus of the research is within Short Sea connections and not, for example, related to territorial continuity with smaller islands or tourist navigation.

The final evaluation is carried out on the graph presented in Fig. 2.

Table 1. Port list

ID	Port
1	Genoa
2	Livorno
3	Piombino
4	Civitavecchia
5	Naple
6	Salerno
7	Vibo Valentia
8	Messina
9	Milazzo
10	Termini Imerese
11	Palermo
12	Cagliari
13	Golfo Aranci
14	Olbia
15	Porto Torres

Table 2 presents, in addition to the legend, the reference Core Ports for each Port Authority considered, with reference to the European TEN-T network.

Table 3 presents the main results considering the 3 different indicators introduced in the previous section. For the evaluation of c_i, s_i and v_i, Eqs. (1), (2) and (3), respectively, are considered:

The nodes characterised by greater centrality are the two island nodes and the North Tyrrhenian Sea node. In particular, the West Sicilian Sea sees the highest values of c_i and v_i, having the greatest number of links: the Ports of Palermo and Termini Imerese, in fact, count a total of six direct links with other ports, out of the seven in total. This guarantees the highest values of centrality c_i; moreover, the only port with which they are not connected (South Tyrrhenian Sea and Ionian Sea) is also the one with the lowest number of links. This explains Palermo's centrality in the network.

The Sardinian Sea, although characterised by slightly lower values of c_i and v_i (only 5 out of 7 possible connections), sees a greater number of services (the 221 per week against the approximately 104 on average of the Western Sicilian Sea). This is because in the case of Sardinia, services to the Peninsula are counted as node-to-node connections. The case of Sicily is different, where a large part of the services connecting with the Peninsula pass through the Strait and are therefore intra-nodal connections, which are not reported in this work.

The Strait area is characterised by a lower c_i value (3 out of 7 connections), which is the same value as the Central Tyrrhenian area (Naples). However, the Naples area has a greater number of services, and therefore a higher c_i value; similarly, the Naples links

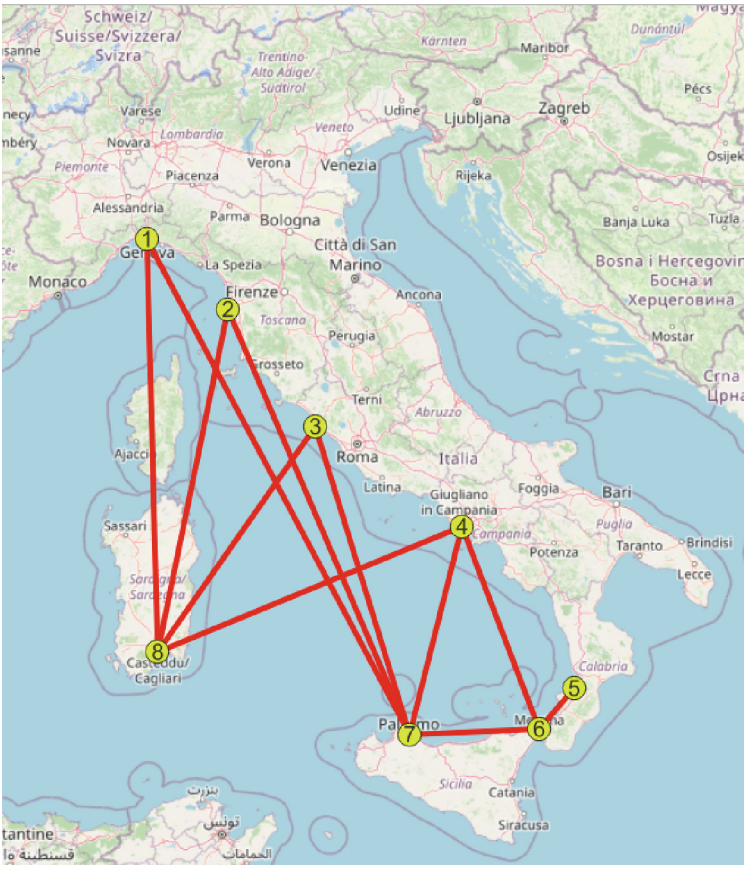

Fig. 2. Port System Authorities network studied (Authors' elaboration on QGis)

Table 2. Port System Authorities list

ID	Port System Authority	Core Port
1	Mar Ligure Occidentale	Genoa
2	Mar Tirreno Settentrionale	Livorno
3	Mar Tirreno Centro-Settentrionale	Civitavecchia
4	Mar Tirreno Centrale	Napoli
5	Mar Tirreno Meridionale e Ionio	Gioia Tauro
6	Stretto	[-]
7	Mar di Sicilia Occidentale	Palermo
8	Mare di Sardegna	Cagliari

Table 3. Values of centrality indicators for each Port System Authority

i	Port System Authority	c_i	s_i	v_i
1	Mar Ligure Occidentale	0,29	60	0,44
2	Mar Tirreno Settentrionale	0,29	107	0,44
3	Mar Tirreno Centro-Settentrionale	0,29	78	0,44
4	Mar Tirreno Centrale	0,43	82	0,56
5	Mar Tirreno Meridionale e Ionio	0,14	4	0,12
6	Stretto	0,43	38	0,42
7	Mar di Sicilia Occidentale	0,86	104	0,85
8	Mare di Sardegna	0,71	221	0,75

are more central than the Strait area links. The two authorities share a link with Western Sicily, they have a link in common, but while Naples is connected with Sardinia (as seen, one of the main nodes of the network) the Strait is connected with the South Tyrrhenian Sea node and Ionio.

The Southern Tyrrhenian and Ionian node is the least central on all three indicators: the only connection considered is the Vibo Valentia - Milazzo link that tours the Aeolian Islands. The geographical continuity on the Italian peninsula of this area makes continuous connections throughout the year by ship unnecessary. This is also essentially due to the nature of this Port Authority, which serves the port of Gioia Tauro, Italy's leading container port and least affected by passenger traffic.

The three nodes in the centre-north show the same values of c_i and v_i, while the Northern Tyrrhenian Sea has a higher value than the others of s_i, the highest after the s_i associated with the Sardinian Sea, precisely because of the high number of weekly connections between Tuscan and Sardinian ports.

Finally, it is useful to highlight a general result that emerged in the work: the role of the closed basin in the activation of maritime services. The Tyrrhenian Sea represents to all intents and purposes a closed basin which is bounded to the east and north by the Italian peninsula, to the south by Sicily and to the west by Sardinia. The Adriatic, considering Italian services, is an open basin. It turns out that in the open basin, services are practically nil because evidently all travel is by land or air. This result, although intuitable, is largely confirmed quantitatively.

5 Conclusions and Future Developments

Three measures of centrality, widely adopted in the literature for undirected graphs, were proposed. Each of the three measures proposed for the proposed Ro-pax port network has its own characteristics and expresses a different dimension of centrality.

A first conclusion concerns the geography of the country, which is reflected in the geography of services. The substantial absence of services on a national scale on the Adriatic and the non-significance of services on the Ionian make these two basins negligible for the evaluation of passenger ship traffic on a national scale. The network, as

presented, essentially concerns the Tyrrhenian Sea and some areas immediately adjacent to it (part of the Ligurian Sea and the Sardinian Sea).

On the basis of this conclusion, and of the general result identified in Sect. 4, subsequent developments should include the possibility of extending this research to the Adriatic basin as a whole, considering all the countries bordering the basin, and not limiting it to the Italian ports. In this sense, it should be considered how the Tyrrhenian Sea is, with the exception of Corsica, an Italian basin, while the two eastern seas, the Adriatic and the Ionian, lap up Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania and Greece. The study of the network of passenger services connecting Italian Adriatic and Ionian ports with Balkan ports is the next step in this research to validate the general results obtained in the international case. Similarly, it is particularly important to study other closed basins in Europe, such as the one between the Balearic Islands and Spain and that of the Aegean Sea. In order to better understand the relationship between the different countries and basins, the study of the relations within the entire Mediterranean basin should be considered. An analysis on a Mediterranean scale would make it possible to evaluate the centrality at the port level and consequently the weight of each port in the Southern Range system. This is essential since maritime relations on the Mediterranean, being covered by Short Sea Shipping type services, often represent a valid alternative to land services where available, both in passenger transport and in freight transport. It is highly important that Mediterranean Ports should always aim to increase their capacities in respect to sustainable urban mobility planning [39].

With regard to national traffic, which can be reduced to the single Tyrrhenian basin, it was seen that the highest centrality values are linked to the two largest islands, Sicily and Sardinia. Where Sardinia has a higher value of s_i, Western Sicily has a higher value of overall connections (c_i and v_i). In this regard, the importance of Palermo in national passenger traffic is evident; in a complementary way, the 'ship' mode of transport is also central to Palermo's connections with Italy. Considering how the East Sea of Sicily, on the same island but in the eastern zone, is not considered in the graph: passenger traffic from Catania to Italy is shifted to the aeroplane, in the absence of a stable rail link with the continent. Palermo, which also has an airport, has a position of geographical centrality in the Tyrrhenian and a natural 'push' towards the sea that is reflected in an analytical centrality in the network. This second consideration must lead to the development of studies to verify the modification of the service network, and the centrality of the various ports, in the presence of new modal forms in Sicily. In particular, it is necessary to evaluate whether the centrality of the port of Palermo and the airport of Catania would change in the face of a reduction in rail times.

A further line of development of the research is linked to the possibility of studying the nautical tourism sector, considering the high tourist and seasonal flow of some of the nodes that were found to be more central in the study, like Sardinian Sea port Authority and Western Sicily Port Authority. The study would present different characteristics according to the type of traffic. Specifically, particular attention should be paid to the connections between the ports of the mainland and the smaller islands, like Lampedusa for Sicily and Isola d' Elba for Tuscany. To develop this line of research it is important to move from the aggregate node relating to the port authority to a graph in which the individual ports are represented. This approach would make it possible to study

both the national and international scale basins and the regional and local scale basins, often characterized by a strong seasonality of services. The concrete growth capacity of our economy depends on the maritime-port system, considering that 85% of our country's non-EU goods are managed by it. It turns out to be a key sector that in these tragically particular years (due to the pandemic, wars and other events) has demonstrated all its resilience by managing to resist the factors of crisis better than others. This is thanks to a context of clear rules which favours the necessary balance between business competitiveness and job protection. Also guaranteed by the public nature of the Port System Authorities. This research can serve at different levels: public administrators, executives of shipping companies and port companies.

In particular, as regards the administrators, the assessment of the centrality of the ports is fundamental for the planning and design of strategies and actions aimed at improving the port-city connections and at creating sustainable and more accessible solutions both from the point of view of passenger transport and goods.

In addition, shipping and management companies can draw inspiration from the evaluation for an improvement in investments and interconnections between the ports themselves.

References

1. https://sdgs.un.org/2030agenda
2. http://docplayer.it/amp/15743061-Ecocalcolatore-ffs-relazione-di-base-versione-1-0-settembre-2010.html
3. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0144:FIN:IT:PDF
4. Comi, A., Polimeni, A.: Assessing the potential of short sea shipping and the benefits in terms of external costs: application to the Mediterranean Basin. Sustainability **12**(13), 5383 (2020)
5. Di Gangi, M., Russo, F.: Potentiality of rail networks: integrated services on conventional and high-speed lines. In: Computers in Railways XVIII: Railway Engineering Design and Operation, vol. 213, p. 101 (2020)
6. Decreto Legislativo 4 agosto 2016 n.169. https://www.mit.gov.it/sites/default/files/media/notizia/2016-09/Testo%20Decreto%20riorganizzazione%20porti%2031_8_16.pdf
7. Decreto legge del 23/10/2018 n.119. https://def.finanze.it/DocTribFrontend/getAttoNormativoDetail.do?ACTION=getSommario&id=%7B1391ECFD-6973-46F7-9DF2-BFD94652EB45%7D
8. Russo, F., Rindone, C.: Aggregate models for planning nautical tourism: basic, trend and seasonal demand. Case Stud. Transp. Policy **10**(4), 1980–1987 (2022)
9. Russo, F., Musolino, G., Assumma, V.: Ro-ro and lo-lo alternatives between Mediterranean countries: factors affecting the service choice. Case Stud. Transp. Policy **11**, 100960 (2023)
10. Serra, P., Fancello, G.: Performance assessment of alternative SSS networks by combining KPIs and factor-cluster analysis. Eur. Transp. Res. Rev. **12**, 57 (2020). https://doi.org/10.1186/s12544-020-00449-z
11. Hossmann, T., Spyropoulos, T., Legendre, F.: A complex network analysis of human mobility. In: 2011 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), pp. 876–881. IEEE, April 2011
12. UNCTAD, Port Marketing and the Challenge of the Third Generation Port. Trade and Development Board Committee on Shipping ad Hoc Inter-Government Group of Port Experts, Geneva, Switzerland (1994)

13. UNCTAD, Fourth-Generation Port: Technical Note. Ports Newsletter N. 19, Prepared by UNCTAD D Secretariat, Geneva, Switzerland (1999)
14. Russo, F., Musolino, G.: Quantitative characteristics for port generations: the Italian case study. Int. J. Transp. Dev. Integr. **4**(2), 103–112 (2020)
15. Russo, F., Musolino, G.: Port-city interactions: models and case studies. Transp. Res. Procedia **69**, 695–702 (2023)
16. Russo, F., Musolino, G.: Industrial and oil ports: case studies and theoretical approaches. Transp. Res. Procedia **69**, 703–710 (2023)
17. Balletto, G., Borruso, G., Campisi, T.: Not only waterfront. The Port-City relations between peripheries and inner harbors. In: Gervasi, O., Murgante, B., Misra, S., Ana, M.A., Rocha, C., Garau, C. (eds.) Computational Science and Its Applications – ICCSA 2022 Workshops: Malaga, Spain, July 4–7, 2022, Proceedings, Part V, pp. 196–208. Springer, Cham (2022). https://doi.org/10.1007/978-3-031-10548-7_15
18. Caballini, C., Gattorna, E.: The expansion of the port of Genoa: the Rivalta Scrivia dry port. Development of dry ports, p. 73 (2009)
19. Castigliano, M., De Martino, P., Russo, M.: Napoli: relazioni irrisolte tra porto e città. Urbanistica Informazioni **45**(278–279), 43–45 (2018)
20. Paixão, A.C., Bernard Marlow, P.: Fourth generation ports–a question of agility? Int. J. Phys. Distrib. Logist. Manag. **33**(4), 355–376 (2003)
21. Russo, F., Panuccio, P., Rindone, C.: Structural factors for a third-generation port: between hinterland regeneration and smart town in Gioia Tauro, Italy. In: Urban Maritime Transport XXVII, vol. 204, pp. 79–90 (2021)
22. Meersman, H., Van de Voorde, E., Vanelslander, T.: Port competition revisited. J. Pediatr. Matern. Fam. Health-Chiropractic **55**(2), 210 (2010)
23. Davis, H.C.: Regional port impact studies: a critique and suggested methodology. Transp. J. **23**(2), 61–71 (1983)
24. DeSalvo, J.S.: Measuring the direct impacts of a port. Transp. J. **33**(4), 33–42 (1994)
25. Ignaccolo, M., Inturri, G., Le Pira, M.: Framing stakeholder involvement in sustainable port planning. Trans. Marit. Sci. **7**(02), 136–142 (2018)
26. Borgatti, S.P., Mehra, A., Brass, D.J., Labianca, G.: Network analysis in the social sciences. Science **323**(5916), 892–895 (2009)
27. Das, K., Samanta, S., Pal, M.: Study on centrality measures in social networks: a survey. Soc. Netw. Anal. Min. **8**(1), 1–11 (2018). https://doi.org/10.1007/s13278-018-0493-2
28. Porta, S., Crucitti, P., Latora, V.: Multiple centrality assessment in Parma: a network analysis of paths and open spaces. Urban Des. Int. **13**, 41–50 (2008). https://doi.org/10.1057/udi.2008.1
29. Bhattacharya, K., Mukherjee, G., Saramäki, J., Kaski, K., Manna, S.S.: The international trade network: weighted network analysis and modelling. J. Stat. Mech Theory Exp. **2008**(02), P02002 (2008)
30. De Benedictis, L., Tajoli, L.: The world trade network. The World Econ. **34**(8), 1417–1454 (2011)
31. Guimera, R., Mossa, S., Turtschi, A., Amaral, L.N.: The worldwide air transportation network: anomalous centrality, community structure, and cities' global roles. Proc. Natl. Acad. Sci. **102**(22), 7794–7799 (2005)
32. Scheurer, J., Porta, S.: Centrality and connectivity in public transport networks and their significance for transport sustainability in cities. In: World Planning Schools Congress, Global Planning Association Education Network (2006)
33. Ducruet, C., Lee, S.W., Ng, A.K.: Centrality and vulnerability in liner shipping networks: revisiting the Northeast Asian port hierarchy. Marit. Policy Manag. **37**(1), 17–36 (2010)
34. Wu, J., Zhang, D., Wan, C., Zhang, J., Zhang, M.: Novel approach for comprehensive centrality assessment of ports along the maritime silk road. Transp. Res. Rec. **2673**(9), 461–470 (2019)

35. Wang, Y., Cullinane, K.: Determinants of port centrality in maritime container transportation. Transp. Res. Part E Logist. Transp. Rev. **95**, 326–340 (2016)
36. Wan, C., Zhao, Y., Zhang, D., Yip, T.L.: Identifying important ports in maritime container shipping networks along the Maritime Silk Road. Ocean Coast. Manag. **211**, 105738 (2021)
37. Cascetta, E.: Transportation Systems Engineering: Theory and Methods, vol. 49. Springer, New York (2001). https://doi.org/10.1007/978-1-4757-6873-2
38. Perron, O.: Neue Kriterien für die Irreduzibilität algebraischer Gleichungen (1907)
39. Miltiadou, M., Mintsis, G., Basbas, S., Taxiltaris, C., Tsoukala, A.: Sustainable urban mobility plans in Mediterranean Port-Cities: the SUMPORT project. In: Nathanail, E.G., Karakikes, I.D. (eds.) CSUM 2018. AISC, vol. 879, pp. 410–417. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-02305-8_50