The Evolution of Italy-Greece Passenger Maritime Transport: a Multi-level Study to Estimate the Factors Influencing the Demand and Supply of Passenger Ferry Transport

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In recent years, the shipping and maritime transport segment has undergone profound changes. Faced with the need to achieve the sustainability goals set by Agenda 2030, different sustainable modes of transport must therefore be evaluated. Passenger transport by ship has proven to be the least polluting per pax/km. Different European regulations are moving in the direction of limiting transport by air when there are fewer polluting methods on average lengths, mainly on a national scale. The tourism sector is one where the impacts on the Agenda 2030 goals are often not properly assessed. Ship connections with a tourism function are central in connections to smaller islands which, due to their size and relatively small flows, do not have airports. In medium-sized basins, tourist traffic by ship is changeable and often dependent on specific characteristics of the basin. The aim of the present research work is to analyse the general case of an open basin, with an application to the Adriatic-Ionian basin. The system of connections between eastern Italy and western Greece by ship is analysed. The case study refers to the characteristics of travel from Italy to Greece by ship, with reference to the Ionian Islands. The overall method proposed is articulated in several successive steps, which can be summarised as follows: analysis of the characteristics of services; analysis of supply with network analysis methods applied to services; analysis of demand with estimation of a regression model. The methodologies identified make it possible to highlight the temporal and central characteristics of the network considered, and at the same time to verify the influence that certain attributes have on tourism for the area studied. The results show, on the one hand, that not all services have a significant summer component and, on the other, that the centrality of the various ports within the network changes, even heavily, with the season. The work is expected to be of particular interest to policy makers, planners, and researchers, considering centrality as closely linked to the distribution of services for passengers in ports and related port-city areas, and considering the possibility of better planning the distribution of funding in relation to the ports' development and resilience to address disruptive events.

KEY WORDS

~ Maritime transport
~ Ports centrality
~ Sustainable mobility
~ Network analysis method
~ Adriatic-Ionian area
~ Italy/Greece ship connections

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1. INTRODUCTION

Maritime transport carries 90% of global trade in goods. This has a significant impact on the international market for the exchange of goods (CS 2014; Smith et al., 2015).

Critical issues in global supply chains emerged with the COVID-19 outbreak. As well as the recent war in Ukraine, they have brought to attention the increasing relevance of regional trade and the risks associated with dependence on a few and often distant suppliers (European Parliament, 2022). They also focus attention on how maritime transport is the backbone of trade, not only along transoceanic routes (deep sea), but also in macro-regions (short sea) (Meersman et al., 2014).

The recent acceleration towards sustainable development goals, imposed by the UN with the 2030 Agenda, has, in fact, resulted in a push for change in all transport sectors, including maritime transport (Sciberras & Silva, 2018; Monios & Wilmsmeier, 2020; Dominioni, 2023).

While ports and maritime logistics are evolving very rapidly in the Mediterranean, both in Europe and worldwide, according to increasingly complex organisational and industrial schemes, Italy had not developed an integrated maritime strategy until 2014. Therefore a specific national plan was drafted, taking into consideration the current situation of maritime ports and logistics, as well as prospective analyses of the evolution of demand. It sets strategic objectives, proposes as many actions as possible, the implementation of which will take place through regulatory and/or administrative activities. In the last decade, some countries, like Italy, have had to rethink port system planning, linking it to concepts of sustainability and resilience.

Furthermore, numerous works in literature have highlighted the need to strengthen the planning of port-city systems to improve the relationship of city users with this area (tourists. workers, commuters, etc.) (Russo & Musolino, 2020: Balletto et al., 2022).

A 'Sea System' is characterised by several aspects, relating respectively to scenarios present:

- in the port;
- in the surrounding territory;
- in the national territory;
- in Italy's relations with the Mediterranean;
- in Italy's relations, as a leading player in the Mediterranean, with the rest of the world.

The growth of the Sea System, through a system of involvement of the maritime cluster in the Euro-Mediterranean policy, and with the strengthening of strategic partnerships, both inwards and outwards, can guarantee a more prominent position of the country, with positive repercussions, not only in the port and logistics sector. In transforming the strategic vision elements of the Plan into specific objectives, certain policy guidelines common to all the planning of the national transport system were followed, and in particular:

- attention and priority to all port traffic segments due to their ability to contribute to economic and social growth;
- attention and priority to the maintenance and safety of often-obsolete facilities; infrastructure heritage;
- attention and priority to innovation and technological development.

The Ionian-Adriatic basin is of fundamental importance to the two nations, and the Italy-Greece connection plays a key role in terms of passenger traffic, for example transshipment via ferries.

This is due to a series of factors that can be correlated to the economic, tourist, but also working sector. The present work therefore analyses the main factors that make it possible to estimate the centrality of the ports in the aforementioned basin, highlighting which parameters can play a crucial role in the definition of transport analyses and thus in the optimisation of urban, port, and neighbouring service planning. Greece, as well as Italy, is a tourist destination of excellence, and several maritime connections are currently in place for both tourist and business purposes. Greece is connected to Italy both from the north, the port of Ancona, and from the south, the port of Brindisi. Passengers can choose the solution that best suits their needs. The routes, having been upgraded since 2022, have departures with afternoon and night schedules, allowing passengers to disembark at the port of arrival at a functional time for all their needs.

In recent months in Italy, after the end of COVID-19 restriction, there has been a positive trend in the demand for mobility for all modes of transport. In particular, there has been an increase in the first quarter of 2023 compared to the same period in 2022, with increases ranging from 3% for bus transport on the Anas network to 378% for maritime cruise services (Mitgov, 2023).

Specifically, comparing data from the first quarter of 2023 with that from the period before the COVID-19 pandemic (the same period in 2019) shows that the 2019 levels for the national road and rail sector for both passengers and freight have now been reached (with deficits of between -3% and +4%). Numerous articles in the literature analyse the financial and economic indicators and components in the maritime transport sector in many countries (Kamal et al., 2022; Nguyen et al., 2022).

In 2022, 490 million tonnes of goods were handled in Italian ports (+1.9%) and 61.4 million passengers transited, including 9 million cruise passengers (Port Infographics, 2023).

Several research activities have been conducted in the last ten years on Greece-Italy transshipment, some of which have highlighted economic aspects (Vlasenko et al., 2022) or peculiarities of different services, such as ferries for short duration transshipments and the parameters characterising these services, such as ads example vessel fleet, prices and operations, evaluating the level of service, prices and seasonality (Papaioannou & Naniopoulos, 2019). Furthermore, a research conducted by Mella & Pentucci in 2022, analyses the main sustainable passenger transport projects in cross-border maritime areas, financed in the last EU programming period (2014-20). This research made it possible to map measures aimed at promoting better permeability and accessibility of 'maritime' border areas between EU Member States and to gather insights on the implementation of principles related to the sustainable mobility paradigm.

The present work highlights the importance of analysing travel trends between Italy and Greece by ship by adopting a threefold analysis:

- the analysis of service characteristics (e.g. frequency and distribution of services);
- the analysis of the network of passenger transport services;
- the estimation of demand through the definition of a doubly constrained gravity regression model, i.e. paying particular attention to the choice of attributes to be considered for the analysis of centrality and for the calibration of a demand model that can be easily replicated in other contexts and can also be of help in the optimisation of urban planning and sea transport services.

Most Italian ports are still not competitive in terms of efficiency, speed of customs and control procedures, transport costs, and delivery times, and there are several infrastructural criticalities overall. In addition, an advanced logistics system based on intermodality, connections between port and road and rail networks, and between port and TEN-T corridors, is currently lacking. To all this is added the poor environmental quality of the port areas. It is necessary to analyse all the different forms of demand from logistics to tourist transport by promoting *ad hoc* strategies for the improvement of the related infrastructure and services. The assessment of the centrality of ports makes it possible to understand which ports play a preponderant role in the transport of specific demand components, and in the case of tourist transshipment, it makes it possible to hypothesise actions that can improve not only the frequency of services, but also the services that characterise port-city areas. Finally, there is no doubt that implementing maritime intermodality can help to reduce road accidents, as well as carbon dioxide emissions, to the benefit of the environment, as well as local societies.

Furthermore, the decision makers will be able to better understand and decide how to distribute available funds to ports authorities, aiming to enhance their resilience to address disruptive events.

In particular, Section 2 presents an analysis of the evolution of some projects implemented to improve the sea connection between Italy and Greece, emphasising the importance of the passenger share. Section 3 proposes the methodological steps followed for the representation and analysis of the network of services and the methodology for forecasting demand. Section 4 presents comments on the results obtained by applying the proposed methodology to the case study considered. Finally, Section 5 presents final comments, limitations, and future developments.

2. THE EVOLUTION OF ITALY-GREECE SEA CONNECTIONS

Maritime routes have always been vital and strategic factors in the social and economic development of the Mediterranean peoples. The main connections between Italy and Greece concern the ports in the Ionian-Adriatic basin, namely Venice, Ancona, Bari, and Brindisi for Italy, and the Island of Corfu,, Patra, Igoumenitsa, and the Island of Kefalonia (City of Sami) for Greece.

The type of traffic that characterises the Adriatic-Ionic area most is the movement of passengers and trailers in Ro-Pax ferries. From the 90s until 2000, there has been an increase in connections between Italy and Greece, and then they stabilised. Since 2009, however, there has been a constant contraction and almost a million passengers have disappeared due to the changes of the connections between the Italian ports and those of the Ionian Greece.

The same dynamics apply to the world of lorries/trailers, i.e. the rolling stock on ferries. Here too, in traffic with Greece, the market has considerably shrunk (ISTAO, 2014).

The Ionian Sea connects the Adriatic Sea, southern Italy, and the western regions of Greece: the Ionian Islands and some areas of Epirus and the Peloponnese. This area is socially, economically, culturally, and touristically developed (Esteve-Perez et al., 2022).

The network of contemporary cruise ports in Southern Europe is dynamic and has recently increased the number of known connections (Rodrigue, J. P., & Notteboom, T. ,2013; Zanne, M., & Beškovnik, B., 2018), thereby becoming a more complex network.

At the same time, a study conducted by (Esteve-Perez et al., 2022) proposes an analysis of high cruise activity in Southern Europe by evaluating the influence of the seasonality of cruise traffic on the centrality dynamics of the cruise port network.

A series of projects have been developed over the last decade to make these ports smarter (Makkawan & Muangpan, 2023). The ports of Brindisi and Igoumenitsa represent the gateways to the European Motorway of the Sea Brindisi - Corfu - Igoumenitsa, which connects through the intermodal (sea-road) maritime port of Igoumenitsa to the European project of the Egnatia Motorway (Greek Corridor), which completes the Italian Adriatic intermodal rail route, with continuation through Igoumenitsa, on the Egnatia land motorway, on the Thessaloniki-Athens-Constanta route, which anticipates Corridor 8 by fifteen years. Furthermore, ports of Igoumenitsa and Patra are parts of the Orient/ East-Med TEN-T Corridor, connecting Greece with the Scandinavian-Mediterranean TEN-T Corridor through the maritime port of Bari in Italy.

In the project territories there is a multitude of services for logistics offered by both organisations and small operators. The fragmentation of the supply and the lack of institutional communication plans in the specific sector make the use of services complex. The lack of an overview of the existing range of services does not allow the organisation of a comprehensive and integrated supply. This proposal consists in implementing a series of organisational and communication actions preparatory to the creation of an Intermodal Logistics System related to the Adriatic-Greek corridor.

The actions, in particular, will focus on the nodes of Brindisi - Corfu - Igoumenitsa, which have been identified as the terminals of the Logistics System in Italy and Greece and are aimed at contributing towards raise the level of intermodal and logistic services offered by the three ports, in order to increase their attractiveness towards the reference market. In particular, connections between Italy and Greece have recently been made easier thanks to recent developments at the port of Corfu (extension of quay for additional 2 to cruise ships berthing, construction of a tourist shelter for yachts, separate domestic ferry lines from the rest by constructing the eastern windward mole, etc.) (Corfuport, 2017).

These developments fit in with the upward trend in traffic, including passenger and vehicle ferries and cruise ships. The final steps at the port of Corfu have brought state-of-the-art facilities in the maritime transport sector.

The port expansion is expected to cover the island's maritime transport needs until 2025, improve the current level of passenger services, and attract more tourists to the port of Corfu, thus helping to boost the economy. The project extended the port's capacity, which is now expected to cover transport needs until 2025. The expansion of the port has also covered the needs of vessels transporting vehicles for domestic trips to the ports of Igoumenitsa and Patra.

These actions have resulted in a number of benefits, namely:

- easier travel for boats in the country and abroad;
- an increase in the level of services offered to tourists; an increase in the attractiveness of the port of Corfu as a tourist destination; and
- an increase in employment during the construction period of the project and the creation of permanent jobs after the completion of the project.

The significance of Igoumenitsa's port is recognised by a number of European co-funded research project to which the port participated (ADRI-UP, POSEIDON MED II, DOCK BI, NEW BRAIN, EcoWaVes, ADRION SUPPLY CHAIN, ADRIPASS, SUMPORT and PoWER) (Igoumenitsa Port Authority, 2023). Through these projects, novel solutions and tools are tested in the port of Igoumenitsa, for example an application has been developed during ADRIPASS project which allows the users to "see some points of interest in the port using an augmented reality application"(ADRIPASS AR, 2023). Furthermore, through the SUMPORT project the bike-sharing system of the city has been was refurbished in an effort to improve city's mobility conditions and additionally allowing cruise visitors to use these bikes stationed at the port to visit the city of Igoumenitsa (SUMPORT, 2023).

Considering the port of Brindisi, thanks to the Dock-Bi project (Dock-Bi, 2023), infrastructural measures have been implemented to enhance maritime transport and improve integration and accessibility to the areas adjacent to the ports. The parking area in front of the Costa Morena terminal has been redeveloped to allow trucks and cars in transit to and from Greece to park there. In addition, the lighting system of the lighthouse towers in the Costa Morena West area of the port of Brindisi has also been upgraded, rendering it functional for the safety and energy efficiency of the existing towers. In addition, the Municipality of Brindisi has built a roundabout to connect the main roads between the city centre and the port area (embarkation area). Thanks to the infrastructural interventions foreseen by the DOCK-BI project, not only passengers, tourists, and economic operators, but also inhabitants, various stakeholders in the transport sector, and port authorities are directly and indirectly beneficiaries of an improved and modernised cross-border mobility between Italy and Greece. The innovative approach of the above-mentioned projects has proved to be useful for the integration of transport modes in the areas involved, thereby promoting growth, both for Italian regions, such as Apulia, and Greece in terms of the competitiveness and attractiveness of the entire region across the Adriatic-Ionian maritime border.

The development of the intermodal transport offer of the two ports allows them to be included in the European intermodality network, in the Community projects of the TEN-T infrastructure network, and the Motorways of the Sea, also allowing new and more efficient trade relations between the territories to be set up.

The research examines a basin and a portion of transport demand that has not so far been sufficiently covered in the literature. Therefore, starting from the concept of centrality of the ports of the Ionian-Adriatic kiss, the objective was to underline the strategic importance of some ports for tourist purposes and therefore to lay a basis for the definition of strategies for improving connections and increasing transshipment services and services characterising the port city areas.

3. METHODOLOGY

This section presents the supply and demand models used for the proposed analysis. The approach follows the Transportation System Analysis (TSM) approach, defined in the main references in the literature (Cascetta, 2013; Ortuzar & Willumsen, 2011). In this specific case, the models refer to two macro-areas:

Concerning supply, the reference models refer to the centrality analysis, within the class of network analysis models. The analysis conducted contains information both on the general topological characteristics of the network and on the specific characteristics of each arc;

Concerning demand, the reference models belong to the class of gravitational models. Gravity models, as will be discussed below, have the advantages of simplicity of form and of lending themselves well to aggregate descriptive analyses.

The match between the two models occurs to the extent that there is the possibility of describing both the centrality potential of the network nodes and the relationships, expressed by the potential arcs considered, which identify the demand between two nodes, starting from the specific characteristics of the services and knots. This hypothesis is easily verified by considering the characteristics of the services which, by definition, do not foresee exceeding capacity.

3.1. Supply analysis by means of Network centrality

According to (Cascetta 2013), a graph may be represented as G=G(N,E), with N nodes and E links. To define the typology of analysis, there is a need to describe the network characteristics, explaining nodes and connections.

The elements considered for this study are:

- Ports, network nodes, indexed as i=1,2,…,n;
- Route p=[i1,i2,…,ip] is an ordered set of nodes i; it express the existence of a service between considered nodes in a certain order;
- Time t=1,2,…,12, in which each time unit is a generic month;
- R(t,p) is the average weekly number of services regarding route p in month t;
- $R^*(t) = \sum_p R(t,p)$; it is the sum of all the services in a certain month t. It describes the total value of average weekly services in month t for all active routes.

The study of R*(t) is the first element to highlight in the part on the study of the time evolution. The R*(t) value varies between max and min values and is used to evaluate, by aggregating the routes, in which months t the system is more loaded. The study of R*(t) has the function of providing a first rough assessment of the conditions of the system during the time interval considered.

Considering the system of routes p, it is necessary to study the centrality of the generic node i within the network. The main objective of this work is to analyse the specific characteristics of the nodes. The set of mathematical tools most useful for this purpose is represented by a network analysis. The network analysis allows you to evaluate the relationships between the elements of a graph. In particular, in the case of a transport system, such as the port one, network analysis allows for an overall evaluation of the relationships between the elements; the class of elements to which reference will be made is linked to the centrality analyses. The objective of the analysis of the supply system, in this paper, is to evaluate the centrality of services. The problem of the centrality of the nodes within a network is studied in the literature and present in different fields. The study of network centrality is extended in economics exchanges (De Benedictis & Tajoli, 2011; Iapadre & Tajoli, 2014; Yan & Ding, 2009, in urban planning (Porta et al., 2008; Sevstuk & Mekonnen, 2012 and in transportation network analysis (Tesoriere et al., 2023; Haznagy et al., 2015). The different measures of centrality serve to reflect, in particular, different parameters that can be brought out. Two indicators of centrality are studied:

- Centrality as the number of connections per node;
- Centrality as the number of connections per node, expressed as the number of services.

Starting from these two indicators, it is possible to define the adjacency matrix, $A_{ij}(t)$, where each element is defined as follows:

$$a_{ij}(t) = \begin{cases} 1, if\ a\ generic\ p\ including\ i\ and\ j\ exists \\ 0, otherwise \end{cases} \quad (1)$$

The adjacency matrix therefore makes explicit the existence of service links between one node and another, even if not directly contiguous.

Each ij link is also characterised by the following equation:

$$s_{ij}(t) = \sum_p R(t,p), \text{ for each p including i and j} \quad (2)$$

It expresses the weight of each connection between nodes i and j, and is indicated as the total of services which, in the time t, involve nodes i and j.

The two centrality indicators are defined in the following:

$$c_i(t) = \frac{\sum_j a_{ij}(t)}{N-1} \quad (3)$$

$$s_i(t) = \sum_j s_{ij}(t) \quad (4)$$

Where ci(t) expresses the percentage of nodes j with which node i is linked. si(t) expresses the number of relationships that each node has with the network at time t.

ci(t) expresses the centrality of a node considering the number of connections. The more central a node is, the greater the number of nodes with which it is connected. The maximum is ci(t)=1, equivalent to the case where node i is connected to all other N-1 nodes. In summary, the centrality measure ci(t) is a topological measure, which provides information on the positioning of the node within the network.

si(t), therefore does not capture all the nuances of centrality, limiting itself to the relationships that a node i has with the other nodes. The measurement si(t) is used to partially compensate for this limit. Once an edge weight has been defined, the centrality of node i can be considered as the sum of the weights of the edges connected to node i. In this way, this indicator expresses a weighted and not simply topological centrality.

The two indicators, combined, return an exhaustive representation of the relationships within the graph. Centrality analysis is particularly useful in cases such as those analysed in this paper. The specific factors of the fields studied, linked to a network of services, allows us to identify which areas are less covered by services and which are more central in the network considered.

3.2. Demand analysis by means of model estimation

The mathematical models used to simulate travellers' mobility demand proposed in the literature and used in practice are numerous and very different from each other. The classification elements to be considered in the literature on models are different: the typology of the choices made, the hypotheses on the chain of decisions, the aggregation of the variables used, and the assumptions made at the basis of the models (Cascetta,2013). A particularly important classification is that into behavioural and descriptive models. Models are said to be behavioural if they derive from explicit hypotheses on the choice behaviour of users, and descriptive if they describe the relationships between demand and the variables of the transport activity and supply system, without formulating specific hypotheses on the behaviour of decision-makers. In formal terms, a mobility demand model can be expressed as follows:

$$d[K_1, K_2, \dots, K_n] = d(SE, T, \beta) \quad (5)$$

where the average flow of trips with characteristics K1, K2,… Kn is expressed as a function of a vector SE of socio-economic variables, a vector T of service level variables, and of a vector β of coefficients. In the most general case, the characteristics of the model are:

- o/d origin and destination zones;
- s trip purposes;
- h time reference period;
- m trip mode;
- k path.

The class of templates you plan to use are deployment templates. They provide the travel rate between a zone o and a zone d. One of the best known non-behavioural distribution models is the gravitational model, deriving from its expression formally analogous to Newton's law of gravitation (Cascetta et al., 2006).

The choice of gravity models is particularly interesting mainly for one reason: the simplicity with which it transmits the relationship between the independent variables and the dependent variable studied. This is particularly true in descriptive models, such as the models that are proposed in this paper. The first application of the equation formalised as in eg. (5) is given by (Casey, 1955), in the following form:

$$d_{od} = k \frac{P_o P_d}{{Dist_{od}}^2} \quad (6)$$

In which the travel demand between two cities, Origin (hereafter mentioned as **o**) and Destination (hereafter mentioned as **d**) is expressed as directly proportional to the product of the populations and inversely proportional to the square of the distance. In this work we have used the descriptive models, expressed in gravitational form for applications related to the tourism motif and the ferry mode. It is necessary to define the vector of socio-economic attributes SE and the service level vector T. The beta vector will have to be suitably calibrated. To define the model, the demand or a valid proxy variable must be identified. It hypothesises the proportionality between the demand on the network and the services on each pair o/d. Starting from this hypothesis, the following arises:

$$D(t,p) \propto R(t,p) \quad (7)$$

where D(t,p) is the average weekly demand per month t on the route p.

In the demand analysis, consider a route composed as follows: p=[o,d1,d2,…,dnp] in which the origin o is the initial node and the nodes after the first are destinations. It is necessary to know the demand of passengers who choose the generic destination d on route p. Assuming the equiprobability of the destinations, it is possible to have:

$$D(t,p)_d = \frac{D(t,p)}{n_p}, \forall d \quad (8)$$

$$PAX(t)_{ij} = \sum_p \frac{D(t,p)}{n_p}, \forall p \; comprising \; i \; and \; j \; ordered \quad (9)$$

PAX(t)ij is the number of passengers on the generic link ij, obtained in eq. (9), starting from the single elements evaluated by means of eq. (8).

For the specification of the model, it is possible to elide the proportionality in eq. (7), combining eq. (t) and (9), obtaining:

$$y = PAX(t)_{ij} = \sum_p \frac{R(t,p)}{n_p}, \forall p \; comprising \; i \; and \; j \; ordered \quad (10)$$

Eq. (10) gives the observed quantity relative to demand for each o,d pair.

Once the value of demand (y) has been obtained, the general formulation of the model can be expressed by the following equations:

$$y = f(E_o, A_d, C_{od}, \alpha, \beta, \gamma) \quad (11)$$

$$y = f(E_o, A_d, C_{od}, \beta)$$

where:

- Eo is an emission attribute of the zone o;
- Ad is an attraction attribute of the zone d;
- Cod is a cost attribute of the relation od;
- α, β, γ are the parameters to be calibrated.

The different specifications relating to the function f allow identifying the quantitative model to be calibrated. These specifications are proposed in the following Section, using those mentioned above as reference attribute classes.

Figure 1 shows the scheme of the methodology followed.

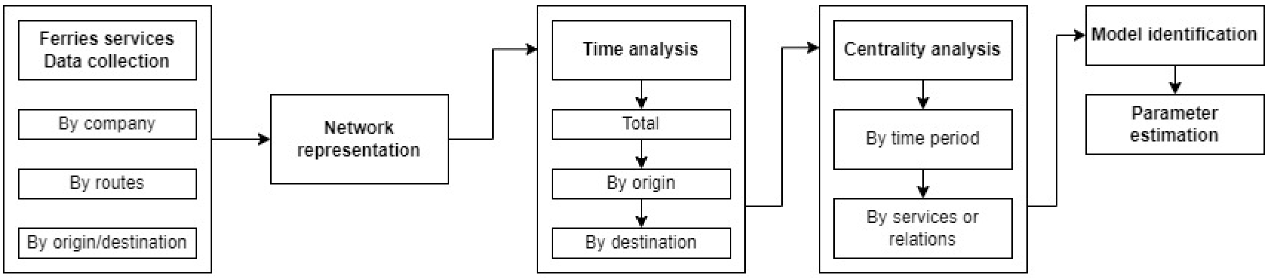

Figure 1. Flow chart for the definition of the steps of the research conducted (Source: Authors' elaboration)

4. RESULTS

The model presented in Section 3 is fully applied to different steps within this Section. The case study of application is a European Mediterranean international sea basin, which is presented in Section 4.1. The analysis of the temporal evolution is developed for the basin in question, and it was not necessary to present the model in the general method.

4.1. Case study description

The first step was obtaining the data. The data was obtained considering 2023 as the year and taking as reference the four companies operating in Ro-pax services between Italy and Greece: Minoan Lines (Minoan Lines, 2023), Grimaldi lines (Grimaldi Lines, 2023) Anek Superfast (Anek Lines, 2023), e-Ventouris Ferries (Ventouris Ferries, 2023). Overall, for the sub-system identified, eight ports are highlighted, shown in Fig. 2: Ancona, Bari, Brindisi, and Venice for Italy; Corfu, Igoumenitsa, Patra, and Sami (Kefalonia) for Greece. Some of these ports are part of the TEN-T networks (Orient/ East-Med and Scandinavian-Mediterranean) (EC, 2023).

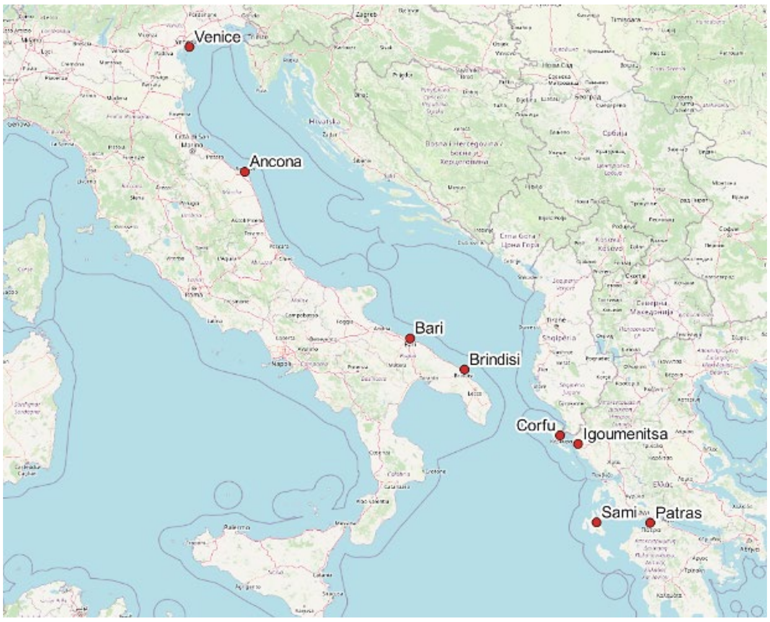

Figure 2. Ports considered as node of the network (Source: authors' elaboration on (QGIS,2023) and OSM (Openstreetmap, 2023).

Ancona, the capital of the Marche region, is one of the main ports on the central-northern Adriatic. Its port is the main one of the Port System Authority of the Central Adriatic Sea [CAPA, 2023]. It is a core port within the TEN-T network and is part of the Scandinavian-Mediterranean corridor, of which it represents the final node of the eastern axis in Italy. As of 2021, it is the first Italian port for international traffic of vehicles and passengers (ISTAT, 2021).

Its position allows it to be a reference port for all of northern and central Italy on the Adriatic; Bari, the regional capital of Puglia, is one of the main ports on the Southern Adriatic. Its port is part of the Port System Authority of the Southern Adriatic Sea (AdSPMAM, 2023). It is mainly a passenger port; Brindisi, like Bari, is part of the Port System Authority of the Southern Adriatic Sea. It is a tourist, commercial, and industrial port serving Southern Italy. Both Bari and Brindisi, belonging to the area of Southern Italy, generally poorer than Central and Northern Italy, are mainly favoured by the geographical proximity with the East. Both ports are part of the TEN-T network in the Scandinavian-Mediterranean corridor; Venice is the capital of Veneto. Its port is important in the northern Adriatic. It is part of the Port System Authority of the Northern Adriatic Sea (Port of Venice, 2023). Its position and the tourist importance of the city of Venice make it a reference port for cruise traffic, which balances, in terms of flows, the minor commercial importance due to its geographical proximity to the ports of Ravenna and Trieste. The Mediterranean corridor and the Baltic-Adriatic corridor are part of two TEN-T corridors; Corfu is an island within the Eptanese, Region of Ionian Islands. The main inhabited centre on the island bears the same name. It is among the largest Ionian islands (592 km^2), the most populated and is the northernmost border of Greece. Igoumenitsa' s (in the Region of Epirus) port is the main one in North-Western Greece, and the one closest to Italy, performing as a hub, at the same time, for Western Greece, relatively poor and agricultural, and for the Ionian Islands, richer areas affected by tourist flows. It is part of the Orient/East–Med Corridor. With more than 300,000 passengers in the 4th quarter of 2022, in the biggest passenger port in the Greek side of the network considered (ELSTAT, 2022);

Patra, the third largest city in Greece, is the capital of the Region of Western Greece, in the north of the Peloponnese. Due to its location, it is the main maritime hub serving mainland Greece from the west, although it is further away from Italy. Its position makes it interesting for tourist and commercial flows concerning the Peloponnese, western Greece and Attica. Like the port of Igoumenitsa, it is part of the Orient/East–Med corridor;

Sami is the main inhabited centre on the Island of Kefalonia. Its position, facing the entrance to the Gulf of Patra, makes it more distant from Italy. The island of Kefalonia is the largest of the Greek islands in the Ionian Sea (773 km^2) (Wikipedia, 2023).

The description given for the ports highlights the degree of complexity and the large quantity of different services that each port offers, both for passengers and goods. As specified, they are both ports with a mainly tourist significance vacation and ports where passenger transport is marginal. Tourist routes and the quantity of services see modest growth from year to year, with the confirmation or modification of the company offering the service. Therefore it is necessary to use aggregate data on all the services offered, regardless of the individual company, to avoid distortions in centrality assessments, both with respect to supply and demand.

4.2. Time analysis

For the purpose of partial levelling of the data considered, the reference value will be defined as R(t,p), the average weekly number of routes, referring to month t, on route p, where t=1,2,…,12 , while p=[i1,…,iP].

Figure 3 shows the value of the sum of R(t,p) with respect to p. The trend over the months of the total average weekly services present in the considered subsystem is shown in Figure 3.

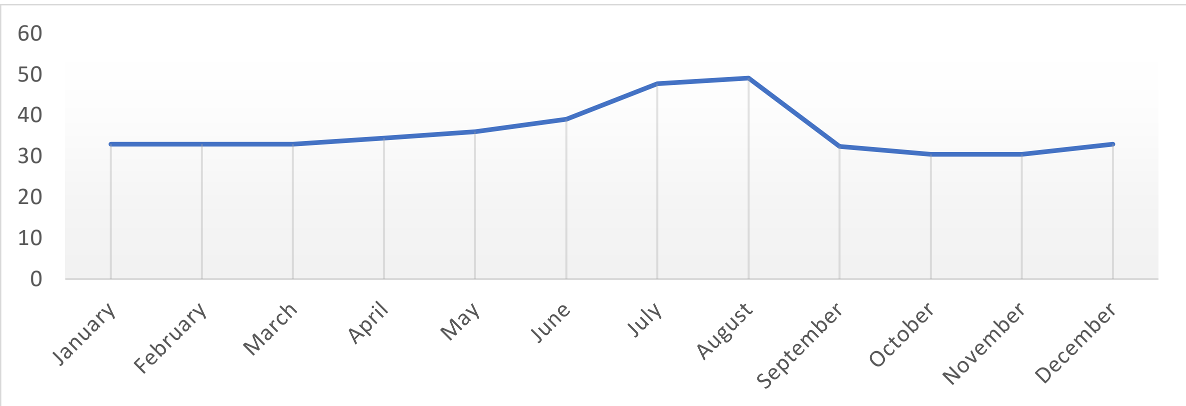

Figure 3. Sum of Average weekly number of services (per month), R(t)*

Figure 4 presents how the evolution for 2023 shows a constant trend in the winter and spring months, while a clear peak occurs in the summer. The overall value goes from the average of 30.5 after the summer to 33 in the spring and to 50 in August. A difference of about 20 services on a weekly basis occurs between the months of August and October-November. To determine which services are most affected by seasonality, Figure 4 and Figure 5 present the evolution of services, respectively, by origin and by destination.

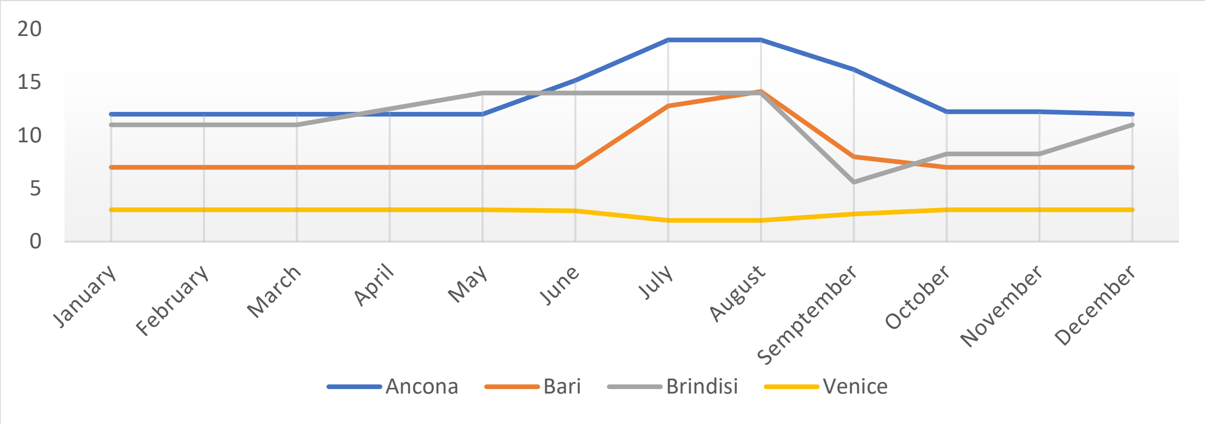

Figure 4. Evolution of R(t,p) aggregated by origin

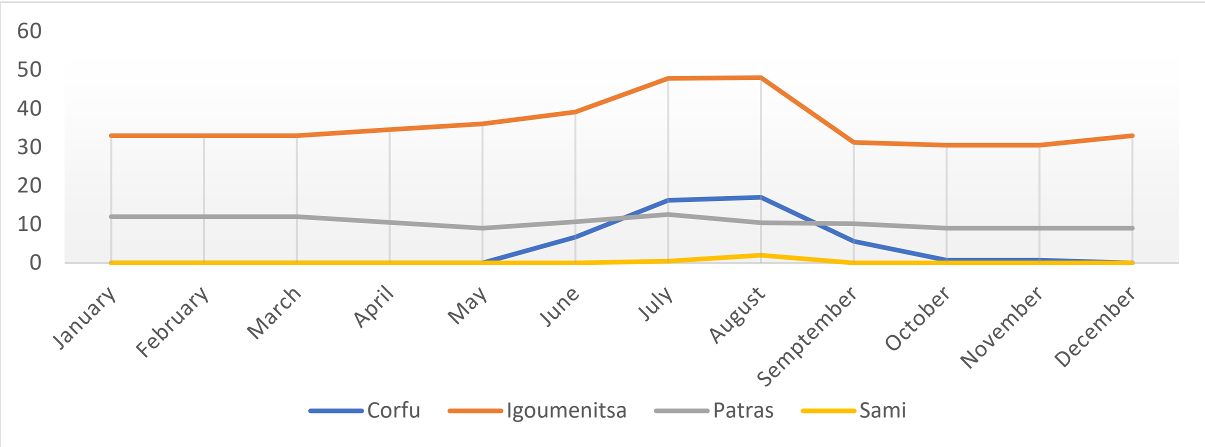

Figure 5. Evolution of R(t,p) aggregated by destination

In this phase of the study, each route considered originates in Italy and ends in Greece. Each route has an origin in Italy and several stops in Greece. Figure 4, therefore, for each t presents four curves which, if added together, provide the total curve of Figure 5 (the one above). Figure 5 does not contain this because each route p makes several stops in Greece.

Interesting results emerge from Figure 4: while the services from Ancona, Bari, and Brindisi show a characteristic of evident seasonality and similar trends, the same cannot be said for Venice. In this case, service does not show an increase in value in the summer months; on the contrary, the total of services originating from Venice decrease from the average of three (3) weekly to the average of two (2). This is probably related to the fact that the services from Venice are mainly systematic. At the same time, it is possible that companies that manage the routes from Venice and other routes prefer to converge tools and resources and ships towards routes more affected by seasonal flows. Similarly, Figure 5 presents a similar trend for destinations. It is advisable to specify a characteristic of each of the ports considered. Corfu and Kefalonia are both very large and touristic islands and as tourist flows are important. Due to their size, the use of a car is often recommended. For tourism from Italy to these two destinations, the possibility of using the ferry for the purpose of transporting the vehicle should be considered.

Corfu and Sami, attractive tourist locations, are often chosen as final destinations. Instead, the routes to Igoumenitsa, the main port of North-Western Greece, are interesting not only for holidays in mainland Greece, but also as intermediate stops towards other Ionian Islands (therefore, in addition to Kefalonia and Corfu, also Lefkada, Ithaka, Zakynthos). Finally, Patra, the most distant of the cities, represents to all intents and purposes a gateway to mainland Greece and the Peloponnese.

The routes to Corfu show a high seasonality, due to the highly touristic nature of the northernmost of the Ionian Islands. An even more marked trend is shown for Sami (on the Island of Kefalonia), more southern and therefore less close to Italy, where direct services from Italy exist only in the winter season. Igoumenitsa is the port most affected by these services, and also shows a marked seasonality. Furthermore, as can be seen, the trend is very similar to that of Corfu, showing that most of the summer routes cover both ports. Patra, as a destination, presents a similar trend to Venice in origin (linear trend with little variability). The conclusions made for Venice can also be considered for Patra: the value of services to Patra remains almost constant throughout the year, showing minimal variability, without the seasonal peak that characterises the other routes. The results may be summarised as follows:

- Venice and Patra, the two ports at the northern and southern ends of the studied basin, are characterised by a lower seasonality;
- For Italy, Bari, Brindisi, and Ancona share a similar pattern, with a peak in the summer months;
- For Greece, Igoumenitsa, the main Greek port on the Ionian Sea, has a constant value of R(t,p) throughout the year and a peak value in summer. Furthermore, consider how Igoumenitsa is the reference port for connections with the Ionian islands, even with those not directly connected to Italy.

The two islands connected to Italy, Corfu and Kefalonia, have a marked seasonality: Corfu has a peak in the summer, while Sami, the port of the island of Kefalonia, is connected to Italy only in the summer months.

4.3. Centrality analysis

The study of centrality, which is partly based on research conducted by Russo et al. in 2023 shows how the most central port is the barycentric one in the destination area. Among the future developments of the study, the study of the centrality of the entire Adriatic-Ionian basin will be included, thus considering, in addition to Greece, also the ports of Albania and the countries of the former Yugoslavia. In particular, it is interesting to verify the connections between Venice and the Croatian ports, given the high number of existing services. The calibrated model shows a positive relationship between number of services and GDPpc and number of hotels; the time attribute is the one that markedly negatively affects the demand. The study has been carried out considering, in destination, the number of structures in the area to which the port of destination refers. This specification is necessary to better highlight the characteristics of each destination area. The calibrated model's results have statistically significant parameters and a discrete value of R2. The hypothesised development for this work is in the direction of applying the model to other basins, having characteristics like those of the Adriatic-Ionian area for the Italy-Greece relations. The analysis of the centrality in the Italian-Greek network is carried out considering both the Italy-Greece connections and the Greece-Italy ones. Due to the significant differences related to the time of year, two (2) months are chosen: August, in which the value of R(t)* is higher, and October, in which the value of R(t)* is lower.

Results are presented for both indicators, ci(t) and si(t) in Table 1. Calculations are made considering equations provided in Section 3. Specifically, ci(t) is evaluated considering eq. (1) and (3), while si(t) considering e. (2) and (4). The value of si(t) has been evaluated considering the network of services, therefore from the user's perspective. Furthermore, as specified, both incoming and outgoing services from a node are considered.

Consider an example as a further specification: A service p=[Ancona, Igoumenitsa, Patra] is broken down into three relationships: Ancona to Igoumenitsa, Ancona to Patra, Igoumenitsa to Patra. A system composed only of this relationship would see a si(t)=2 for Ancona (connection with Igoumenitsa and Patra), a si(t)=2 for Igoumenitsa (connection with Ancona and Patra) and a si(t)=2 for Patra (connection with Ancona and Igoumenitsa). Similarly, the same evaluation is made for ci. Recalling the previous example, ci(t)=100% for the three nodes of the identified subsystem. Each of the three nodes is connected to the other two through a service, although the Ancona - Patra connection does not take place directly, but provides for an intermediate stop in Igoumenitsa.

	ci(t)		**si(t)**	
i	t=8	t=10	t=8	t=10
Ancona	42.9%	33.3%	61.86	36.50
Bari	57.1%	33.3%	59.71	28.00
Brindisi	28.6%	16.7%	34.00	16.50
Venice	28.6%	50.0%	8.00	13.50
Corfu	85.7%	50.0%	69.71	4.50
Igoumenitsa	100.0%	100.0%	157.86	94.50
Patra	71.4%	83.3%	67.14	65.50
Sami	42.9%	0.0%	12.00	0.00

Table 1. Summarised values for t=8, t=10, ci(t) and si(t).

For the evaluation of this, explaining the number of connections with respect to the total of possible connections, some results require further study and analysis.

Except for Venice and Patra, the value of ci(t) decreases for all nodes considered from August to October 2023. The lack of connections to and from Sami determines the value of ci(t) in August equal to 0; moreover, it causes a modification in the size of the network, which from n=7 passes to n=6 from August to October. The increase in centrality of Venice is because the connections with Corfu take place only in spring and autumn, while they are suspended in summer.

Therefore, in August Venice has connections only with Igoumenitsa and Patra. Instead, the increase for Patra is simply due to the decrease in the value of N, while Patra maintains connections with five (5) ports both in August and in October (Ancona, Bari, Venice, Igoumenitsa and Corfu). In both months, Igoumenitsa is the only port that is connected to the entire network, resulting in a unitary centrality value. The decrease in connections in the autumn months determines a reduction of ci(t) for Ancona, Bari, Brindisi and, above all Corfu, which in summer is well connected with the whole network (except the already mentioned Venice).

Evaluating si(t) returns values similar to those observed for ci. However, it is appropriate to underline some of the most evident findings from this study. Sami has relatively few connections even in the summer months. Venice si(t) value increases from August to October, while still maintaining few connections overall. Conversely for Corfu, in which the value goes from about 70 in August to 4.5 in October, showing that the island is largely affected by flows from and to Italy mainly in summer.

The value of Patra remains substantially unchanged in the period considered, showing that it is the node least affected by seasonal phenomena. The other three Adriatic ports, Ancona, Bari, and Brindisi almost decrease in value. Igoumenitsa reduces the value of si(t) by a third compared to the value of August, but remains largely the most active port as far as services are concerned.

It is interesting to note how the values of si(t) allow evaluations to be made with respect to traffic per port, on an average weekly and monthly basis. In particular, this evaluation allows us to define, for the South Adriatic and Ionian scope of application, with the passenger ships of the lines considered, the volume of traffic per port relating to the services considered. From this emerges, in particular, the overall importance of the port of Igoumenitsa which, with its 157.86 average weekly services in the month of August (t=8), ranks first in terms of traffic volume in the entire network considered. On the Italian side, the ports of Ancona and Bari, with around 60 weekly services on average, represent the two main nodes on the Italian side.

4.4. Model evaluation

For the study under consideration, different attributes are taken into account:

- The first attribute is the emission attribute. It is given by the Gross Domestic Product per capita of origin region (e. g. Veneto) (Eurostat,2020);
- The attraction attribute is defined starting from the number of accommodation facilities present in the reference area of the port of destination (e. g. Corfu) (Eurostat,2023);
- The cost attribute is defined starting from the average crossing time and the average crossing cost (Eurostat,2020).
- For the evaluation of the cost, the crossing of a passenger equipped with a four-wheeled motor vehicle was considered, thus highlighting the role of the ferry as a complement to the road.

Starting from the considerations previously made, the assessment of the bed places in the four destination regions is thus carried out:

- For Sami (the Island of Kefalonia) and Corfu the accommodation facilities of the respective islands are considered;
- For Igoumenitsa, a port traditionally serving the Ionian Islands as well as the Epirus region, the accommodation facilities of Epirus and the Ionian islands have been taken;
- For Patra, a port that can be regarded as a gateway to the west of mainland Greece, the accommodation facilities of Peloponnese, Attica, and Central Greece are considered.

Starting from eq. (11) and considering a gravitational formulation for functions, introducing specifying attributes for each class previously defined, it is possible to specify the models as:

$$PAX(t)_{ij} = \left(\frac{GDPpc_i}{GDPpc_{max}}\right)^{\alpha} hotel_j^{\ \beta} T_{ij}^{\ \gamma} + S(t)\delta \qquad (12)$$

$$PAX(t)_{ij} = \left(\frac{GDPpc_i}{GDPpc_{max}} + S(t)\delta\right)^{\alpha} hotel_j^{\ \beta} T_{ij}^{\ \gamma} \qquad (13)$$

where:

- GDPpci is the emission attribute. It is the Gross Domestic Product per capita of the origin region;
- GDPmax is the maximum between the GDPpcs of the considered regions.

$$GDPpc_{max} = \max_i \left(GDPpc_i\right) \qquad (14)$$

with

$$\frac{GDPpc_i}{GDPpc_{max}} \leq 1, \forall i \qquad (15)$$

- hotel is the attraction attribute of the destination zone j. It represents the number of tourist accommodation in the zone of destination;
- Tij is the cost attribute. It is the average t route time between i and j;

- S(t) is a seasonality variable. Its value is 1 for summer months (t=6, t=7, t=8);
- α is the emission attribute;
- β is the attraction attribute;
- γ is the cost attribute;
- δ is an attribute related to seasonality;

The results of the calibration are shown below; the regression has been developed on R. The regression has been performed using the Least Square Minimisation method. Referring to model defined by eq. (12) the calibrated parameters and relative values are respectively:

- $\alpha = 8{,}87$
- $\beta = 2{,}62$
- $\gamma = -5{,}58$
- $\delta = 0{,}8$

All four parameters have significance above 0.05. Furthermore, the signs of the parameters can be informally validated: the alpha parameter associated with the GDPpc is positive, indicating an increase in demand for higher GDPpc. The GDPpc is an aggregate attribute valid to represent the purchasing power of a given geographical area. The beta parameter, associated with accommodation facilities, also has a positive sign, showing a positive relationship between demand and number of bed place in area of destination; also, it shows that this attribute may be very useful to evaluate the attractive capacity. The travel time between zones i and j has a negative parameter, confirming the well-known results that increasing travel time implies the reduction of demand.

Finally, the parameter δ has a positive sign, indicating an increase in demand in the months for which S(t)=1, that are the summer months. The model is presented as an exponential function of the four parameters in which the contribution of seasonality is an addendum with an overall value equal to 0.8 in the case of the summer months.

For the validation of the model, the R2 has been evaluated as in the following equation.

$$R^2 = 1 - \frac{\sum_j \left(\hat{y}_j - y_j\right)^2}{\left(\bar{y}_j - y_j\right)^2} \quad (16)$$

The obtained result is R2=0.64, confirming the validity of the model.

Model given by eq. (13) proposes a different specification for the seasonality. Considering the second model specification, the calibrated parameters are:

- $\alpha = 7{,}99$
- $\beta = 2{,}39$
- $\gamma = -5{,}06$
- $\delta = 0{,}018$

All four parameters have significance above 0.05. Furthermore, the signs of the parameters can be informally validated: the alpha parameter associated with the GDPpc is positive, indicating an increase in demand for higher GDPpc. The GDPpc is an aggregate attribute valid to represent the purchasing power of a given geographical area. The beta parameter, associated with accommodation facilities, also has a positive sign. The travel time between zones i and j has a negative parameter and finally, the multiplicative parameter g has a positive sign, indicating an increase in demand in the months considered. The model is presented as an exponential function of the four parameters. The contribution of seasonality S(t)*g is an addendum of the emission term. Overall, the model therefore expresses an emission term which is given by two contributions: the GDPpc of the area of origin normalised on the maximum value of GDPCpc and seasonality.

For the validation of the model, the R2 was evaluated as in eq. (16).

The value of R2 is 0.64, confirming the validity of this second model.

Consider how this second model shows calibrated parameters very similar to the model given by eq. (12). By changing only the positioning of S(t) within the model, we can see how the two models actually arrive at very similar results. This consideration confirms the validity of the proposed structure.

5. CONCLUSIONS

The Mediterranean area is characterised by an unequally distributed population (Oliveau & Doignon, 2014); moreover, in countries with different levels of development, populations are growing, and they cannot always have access to sufficient services and resources to satisfy all expectations and needs.

Several research focus on the development of passenger transport by sea for some basins such as, for example, that of the Ionian-Adriatic where there are numerous transshipments from/to Italy-Greece (Čokorilo et al., 2015; Žlaket al., 2016; Niavis et al., 2017).

Italy and Greece are countries characterised by a notable geographical proximity, as well as common cultural and historical elements. The Greek colonisation of southern Italy, the Roman control over Greece and then Eastern Roman control over southern Italy, and the Venetian domination of the islands of the Ionian Sea have determined, over the centuries, cultural closeness between the two countries. Italian tourism in Greece is facilitated by the geographical proximity and the presence of numerous tourist destinations, both archaeological sites and seaside resorts. Membership in the European Union and the adoption of the common currency (euro, €) by both countries has made exchanges even easier.

It is important to analyse the transport offer and define a methodology for estimating demand in order to identify users and improve services, as well as to be able to easily implement the diffusion of smart cities and smart ports.

The paper presents a general methodology for the study and analysis of international open maritime basins. The general methodology proposed summarises and allows to highlight different aspects of the study of sea basins: the evolution of services over the year, their centrality (supply), the relationship with socio-economic and service level variables (demand). In this way, it is possible to develop a valid methodology for the study of all medium-sized international sea basins that are affected by significant tourist flows.

The specified models and the values obtained for the parameters allow us to define some elements and reinforce statistical factors contained in the literature, some of which are recalled in the initial sections. In particular, the synthesis of the results, for the studied area, can be defined starting from the characterisation of the parameters. The parameter associated with GDP is positive, showing more than a linear growth; in this way, richer areas show a greater propensity to emit demand flows. Similarly, the negativity of the sign of the parameter associated with time reaffirms what is present in the literature; also, for this basin, longer travel times have a negative impact on demand. The results obtained for the accommodation capacity of the destination areas, connected to the number of beds, are significant: as this value increases, the demand at the destination grows in a more than linear way. The contribution of seasonality is significant and confirms that this area is characterised by an important component of tourist flows.

There is also no doubt that the development of projects that include ICT in the port transport sector facilitates social inclusion and induces, at least in its potential, a more equitable distribution of available resources, to the benefit of increasingly large segments of the population.

This prospect represents a strategic necessity for the Mediterranean basin and therefore deserves great attention and consideration. It is necessary to develop a strong collaboration between all the countries that wish to lead this process of transformation and innovation in the hope of being able to build a common "house", capable of guaranteeing greater security and wisely controlled, attentive, and sustainable development.

A considerable part of these relationships has been studied in the article; specifically, the network of Ro-pax connections between Italian Adriatic ports and Greek Ionian ports. The Adriatic-Ionian basin, as an open basin, is not endowed with considerable intra-national connections, whereas international connections are significant.

The network shows a marked centrality of the port of Igoumenitsa, the main Greek port hub on the Ionian Sea, while more peripheral realities within the same basin, such as Venice and Patra, have values of centrality that decrease in the summer season. Smaller realities, such as those on the island, despite being equipped with direct connections, are less numerous; in particular, the port of Sami on the island of Kefalonia is characterised by direct services only in the summer season. Furthermore, the greater number of tourist services is mainly related to short distances: within the basin considered, a sub-network represented by the ports of Puglia, Corfu and Igoumenitsa can be highlighted. The services involving the furthest ports, Venice and Patra, present a lower contribution of seasonality.

Therefore, the present work is of interest for policy, due to the sustainability implications. Starting from the hypothesis according to which the ship, as a relatively less polluting means of transport, is often preferable to other modes of transport, the following questions are defined, useful for furthering the research:

- Is there a possibility, in coastal areas, of stimulating tourist transport by ship?
- Conversely, is there a possibility of stimulating tourism in an area where there is a transport network by ship?

Similarly, and for similar reasons, the paper may be of interest to the administrators of tourism and shipping companies, to evaluate the potentials, in terms of tourism development, of other areas and destinations, and the economic opportunity of new routes. Finally, the article is of scientific interest for research in the areas of transport, tourism, and sustainability.

It must be noted that the main objective of the tourist is to reach the destination as quickly as possible at the lowest cost. Therefore, the ferry lines will have to make the journey as comfortable as possible, and the quality of the ships will have to be improved with the aim of increasing the expenses of passengers on board.

The diversity of passengers obliges ports to diversify the accommodation and service conditions on board. The regulations that apply for access and control of vehicles carrying goods are different from the regulations for individual passengers and coaches. This implies complexity in access and flexibility for the authorities to ensure port flow and a good standard of service.

Therefore, ports with ferry traffic must offer an easy and economical way to embark (and disembark) and must be connected to highways. Considering port use for passenger transshipment and, at the same time, logistics can be a key to improving port competition.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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