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Centrality measures and competitive positioning of North Adriatic cruise ports

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ABSTRACT

The article examines the competitive positioning of cruise ports in the North Adriatic Sea cruise network using network analysis and centrality measures such as degree, betweenness, closeness, and eigenvector centrality. The study provides insights into the dynamics of the cruise industry, particularly in the region and its connection to the Mediterranean. The hypothesis states that ports with higher centrality scores have a stronger competitive position and attract more cruise traffic, leading to greater economic benefits. The aim of this study is to determine how centrality measures can reflect the strategic positioning and operational efficiency of North Adriatic cruise ports. The purpose is to offer a data-driven approach to evaluate cruise port connectivity and competitiveness, assisting port authorities and cruise operators in optimizing itineraries and enhancing regional cooperation. Results show that Zadar ranks highest in degree and eigenvector centrality, indicating robust incoming connections, while Venice leads in outdegree centrality, highlighting its role as a primary departure hub. Corfu serves as a critical transit port in betweenness centrality, facilitating connections across the Mediterranean. The study identifies "predator" ports like Venice that act as major departure points from popular destination ports like Piraeus and Barcelona. Findings confirm that integrating centrality measures into competitive analyses is crucial for sustainable growth in the cruise sector and optimizing cruise itineraries.

1 Introduction

The MedCruise 2023 report highlights 33.19 million passenger movements and 14,672 cruise calls in the Mediterranean. The Adriatic region, with 13 MedCruise ports, handled over 4 million passengers and 2,720 cruise calls, ranking third in the Mediterranean system. The Western Mediterranean led with 24 million passengers and 9,007 cruise calls, while the Black Sea ranked last with 22,450 passengers and 52 cruise calls. All regions saw a 36.2% increase in passenger movements compared to 2022, with the Adriatic region growing by 34.8% in passengers and 14.5% in ship calls. This growth reflects the resilience and rising popularity of cruise tourism [1]. Cruise tourism evolves through the interplay of passengers, cruise companies, and port authorities. The MedCruise Association aims to enhance port competitiveness by ensuring equal opportunities and improving network efficiency and infrastructure. Measuring network connectivity and port capacity helps optimize cruise itineraries by reducing travel time and enhancing infrastructure capabilities. Studies show exponential growth in cruise research (1983-2009), reinforcing the importance of these metrics in itinerary planning [2].

A cruise ship itinerary is a comprehensive plan of ports and destinations a cruise ship will visit during a voyage. It includes departure and arrival times, port visits, and excursions. According to [3], a standard cruise itinerary is a loop beginning and ending at a hub port (also called a turn port) and typically lasting seven days with three to five ports of call, depending on their respective proximity. Cruise lines constantly seek new ports to enhance the cruising experience. Several researchers have investigated the optimal routing of cruise ships, namely [4], who highlighted that cruise lines are continually seeking to add new ports. The proximity of ports against popular cruise ship itinerary trajectories in the region defines the potential of a cruise port to be chosen as a port of call or home port. The number of ports they can visit is determined by several factors, including the location of the embarkation port, the port of call, the ship's speed, and the voyage duration [3]. The aim of a cruise liner is to create itineraries that include a variety of ports, as each port's unique attractions offer different experiences for passengers. Moreover, in the quest for new ports of call, cruise lines consider geopolitical factors, political stability, and the level of security at the port during and after tourism activities [5]. This ensures that the itinerary is safe and comfortable for passengers. A cruise port's proximity and characteristics significantly influence a cruise ship's itinerary, impacting passenger safety, navigation, and accessibility. Seasonality also affects cruise demand, with ship traffic influenced by passenger preferences and scheduling. Automatic Identification System (AIS) data helps analyze seasonal trends, itinerary design, and environmental impact. Studies have used AIS data to assess port call patterns and the effects of COVID-19 disruptions on cruise operations [6, 7].

Network analysis in maritime transport has been widely applied. Research on Maersk's container network highlighted the benefits of direct and hub-and-spoke services [8]. Studies on global liner shipping networks revealed strong geographic influences and resilient port structures [9]. The Greek Maritime Transportation Network (GMN) provided socio-economic insights, showing that maritime networks function beyond distance constraints [10]. AIS tracking data has also been used to calculate centrality measures in cargo shipping, refining network models using L-graphs and P-graphs [11, 12]. Moreover, few studies used network science techniques to analyse cruise shipping itinerary designs [11-13]. Furthermore, [12] define the concept of itinerary closeness based on the formula of the well-established network science measure of closeness centrality, which is defined as the inverse sum of the shortest path distances starting from a given node *i* with destinations at all accessible network nodes. Itinerary closeness in the Mediterranean cruise market was defined using a directed cruise network to break down the cruise product's price into its tourism and transport components. Furthermore, [11] demonstrated the dual role of the cruise network, which includes the profit-oriented strategies of cruise companies and port authorities. Cruise itinerary designs are generally designed as one-way itinerate or loop itineraries. According to [14], the design of an itinerary schedule, i.e. a sequence of the port of call to visit and the arrival and departure times at the port of call, is mainly determined by geographical distance. This is due to the cost (less fuel consumption) and time efficiency. Thereafter, cruise itineraries in proximity to the major tourist attractions are loop itineraries. The itinerary schedule design problem was researched by [14] regarding balancing the time spent at sea during the voyage with the time spent at the ports of call. Longer voyage times mean shorter dwelling times at the ports and vice versa. Thus, the proximity of cruise ports is important for itinerary planning and balancing this time ratio. Moreover, other authors, namely [15, 16], identified that the proximity of major tourist attractions has a notable effect on the passenger's preferences among the different itineraries. From this, it can be found that geography is an important part of cruise itinerary planning and, therefore, also part of the cruise industry, which connects different stakeholders in the cruise supply chain, such as ports, cruise lines, passengers, and the hinterland activities providers. First, cruise liners must select numerous cruise ports for their itinerary to attract buyers, i.e. passengers. Cruise lines and their cruise ships formulate different itineraries into a cruise network on specific cruise markets such as the Mediterranean. In this network, cruise ports are presenting nodes to be selected by cruise ships, which formulate cruise networks with their ship itineraries. Those cruise ships visit different ports in one itinerary, or there can also be ports that are selected in one itinerary multiple time. On the other hand, there are cruise ports seeking to be chosen for cruise ship calls and to be involved in the region's cruise network. Numerous authors have focused on the positioning of cruise ports by developing port classifications according to how they are integrated into the cruise network [3-5, 15-18].

Competitive relationships between cruise ports in the Mediterranean have been studied using various methodologies [19, 20], including approaches previously applied to European container port systems [21, 22]. Research has identified both competitive and cooperative dynamics among cruise ports [5], leading to the division of the Mediterranean into four sub-regions: East Mediterranean, West Mediterranean, Adriatic Sea, and Black Sea [23]. Studies have also analyzed North Adriatic ports' connectivity within the Mediterranean cruise network [20], highlighting a gap in research on port interactions and cruise itinerary networks. This study applies network analysis to explore port competitiveness and connectivity, providing insights for port authorities and cruise lines. It introduces a new classification of cruise ports based on network connectivity and addresses the research question: "How do different centrality measures reflect the strategic positioning and operational efficiency of cruise ports in the Mediterranean and North Adriatic networks?".

From this, the objectives of the article are as follows: (1) to investigate the connectivity of cruise ports in the North Adriatic Sea and their interactions within the broader Mediterranean cruise network; (2) to apply centrality measures—degree, betweenness, closeness, and eigenvector centrality—to assess the operational efficiency based on the geographic parameters of selected North Adriatic ports; (3) to understand how centrality measures reflect competitive dynamics among cruise ports in assessing their competitive position, and represent a new competitive ranking list based on the centralities. The competitive positioning of cruise ports can provide insights that can help optimize cruise itineraries, thereby enhancing the operational performance and attractiveness of ports within the cruise network. Ports that are well-connected to other cruise ports can receive more frequent calls from ships. This increases passenger throughput and boosts local economies. Ports that are isolated or harder to reach may struggle to attract the same level of cruise traffic. Moreover, shorter distances between ports and well-coordinated arrival/departure times can improve passenger satisfaction by maximizing the time they spend at destinations and minimizing long travel times at sea. Therefore, the study evaluates the significance of cruise ports in relation to the more extensive cruise ship itinerary planning system using network analysis techniques; moreover, cruise ports and lines continually seek innovative methods, such as present experimental study to assess their competitiveness and enhance efficiency. Thus, this article presents a non-conventional approach to evaluate cruise port connectivity and to see if those centrality measures give important insights into cruise port connectedness and competitiveness. This approach could be particularly useful in understanding the strategic positioning of a cruise port in terms of its accessibility and attractiveness to cruise lines.

The research problem in this study is the lack of a clear, data-driven understanding of the competitive positioning and connectivity of cruise ports in the North Adriatic Sea within the Mediterranean cruise network. Despite the increasing importance of cruise tourism, existing studies mainly focus on passenger volume and ship call frequency rather than how well-connected a port is within the cruise network. Traditional methods fail to explain how different ports function as departure hubs, transit points, or destination ports, and how their connectivity impacts their competitiveness. To address this gap, the study applies network analysis techniques using centrality measures (degree, betweenness, closeness, and eigenvector centrality). The goal is to determine how these measures reflect the strategic positioning and operational efficiency of North Adriatic ports and whether they provide a more accurate assessment of port competitiveness than conventional rankings. This research is significant because cruise ports must compete for inclusion in itineraries and adapt to the growing and evolving cruise industry. Ports with better connectivity attract more cruise traffic, boosting economic benefits. Understanding how cruise ports are connected and how they influence cruise itineraries can help port authorities and cruise operators make better strategic decisions. The hypothesis of the research can be written as follows: "Ports with higher centrality measures (degree, betweenness, closeness, and eigenvector centrality) have a stronger competitive position within the cruise network, attracting more cruise traffic, increasing passenger throughput, and contributing to regional economic benefits". Thereafter, the hypothesis is tested by analyzing the connectivity of North Adriatic cruise ports within the broader Mediterranean network using network analysis techniques. By applying centrality measures, the study evaluates how well-connected ports influence cruise itinerary planning, passenger traffic, and economic impact.

The first section provides an overview of the cruise industry, focusing on geographic aspects and addressing a research gap. The second section describes the methodological framework for network analysis, centrality measures, and data sources. It also describes the specific cruise ports studied, as well as their characteristics and operational aspects. The third section presents the research findings, including the network analysis results and centrality measures for North Adriatic ports, with implications for connectivity and competitiveness. The discussion section discusses the importance of port connectivity, centrality measures in understanding operational dynamics, and their implications for measuring cruise competitiveness. The main findings are summarized in the conclusion, highlighting their relevance to the cruise industry.

2 Materials and Methods

2.1 Methodological explanation

Over the past two decades, interdisciplinary work has developed centrality measures to extract information from network data. In transportation networks, centrality has long been used for evaluating a node's importance particularly in road and shipping networks. These measures are application-specific and rank nodes based on structural attributes. Selecting the right centrality for an application is crucial in network analysis, and research in this area focuses on determining the optimal measure or developing new ones. Centrality is a critical metric in the cruise market that assesses the role and importance of cruise ports within a competitive network. It measures the number of direct connections a port has within the network and provides insight into its competitiveness. This level of connectivity is key to attracting cruise lines, thereby enhancing its market competitiveness. By ranking cruise ports based on centrality, targeted strategies can be developed to improve regional connectivity and operational performance, ultimately strengthening the competitive position of these ports in the Mediterranean cruise market. The aim is ascertain whether such methods could be employed to gain insights into the competitive and cooperative relationships between ports in the cruise market.

The study uses network analysis techniques to assess the importance of cruise ports within the broader cruise ship itinerary planning system, focusing on node centrality measures. Figure 1 shows two cruise port networks, the North Adriatic (NA) Sea network and the Mediterranean network to which the North Adriatic Sea ports are connected. Analysing the network of North Adriatic Sea ports in connection to the Mediterranean ports is important for several reasons: 1. NA ports such as Venice, Trieste, Koper, Zadar and Rijeka—are geographically well-placed to serve as key gateway ports between Central Europe and the broader Mediterranean cruise network. 2. The Mediterranean cruise market is highly competitive, with major hubs such as Barcelona and Piraeus attracting significant cruise traffic. Therefore, North Adriatic ports need to cooperate with each other to strengthen their presence in cruise itineraries and thus gain connectivity to these major hubs in the Mediterranean cruise network. By cooperating, they could form a regional alliance that increases their collective appeal to cruise lines. This allows cruise lines flexible options in terms of embarkation and disembarkation points, which could reduce congestion at any single port (especially important for Venice due to its environmental regulations). Therefore, we analysed the connectivity of NA cruise ports using centrality measures, commonly used in network analysis to assess the importance and influence of nodes (in this case, ports) within a network. This analysis provides insight into how well-connected an NA cruise port is within the cruise itinerary network (NA system) and its importance to the overall Mediterranean cruise system. The question is whether centrality measures provide an effective overview of the connectivity of NA ports and their external connections to the Mediterranean system. If so, this would provide cruise lines with important information on port connectivity to link different cruise regions (ports) or to enable multi-stop itineraries (offering more diverse destinations).

The cruise network is a crucial component of the cruise industry. By analyzing the network structure, we can understand how different ports are interconnected and how these connections influence their competitive

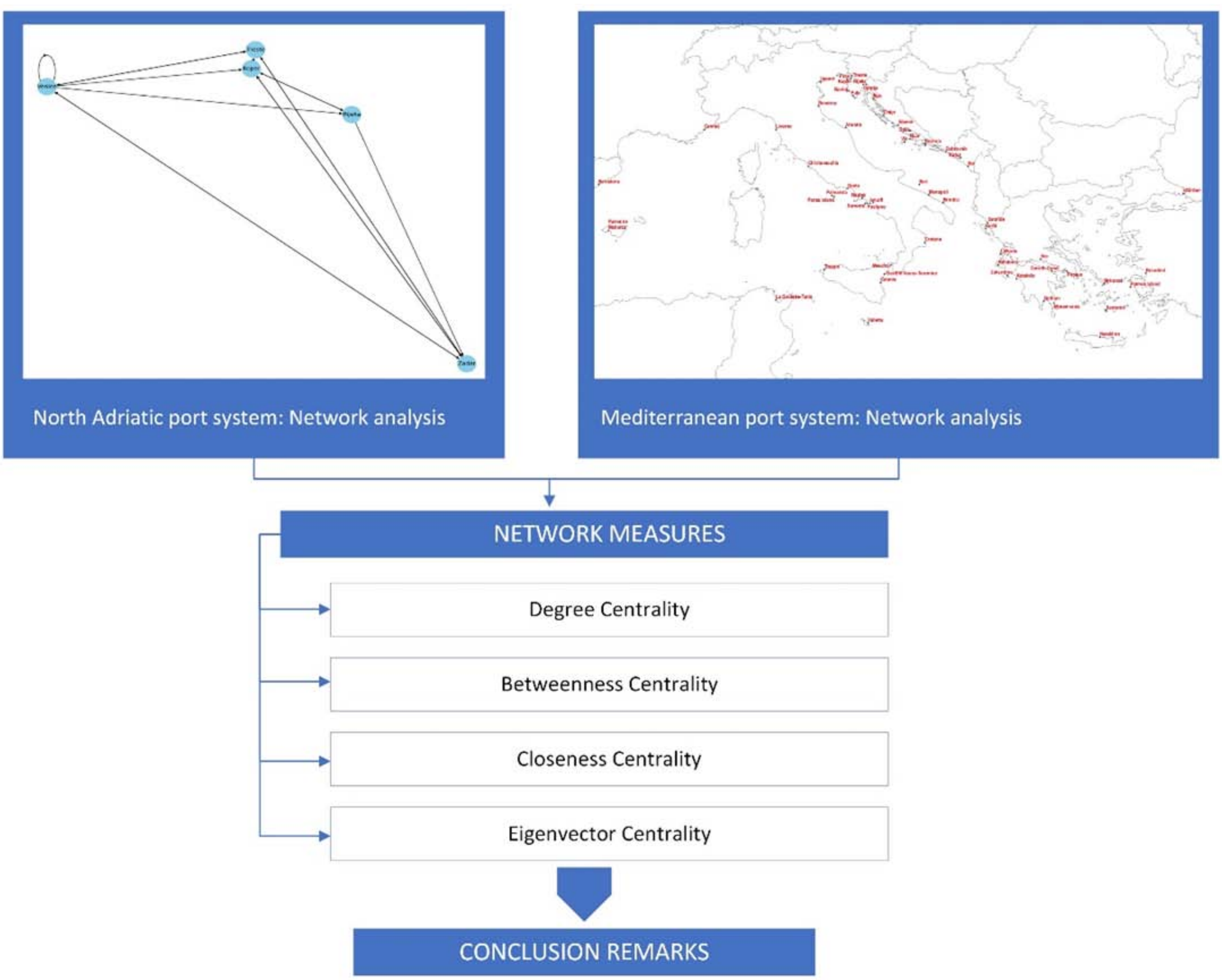

Figure 1 The methodological framework of the cruise port network analysis.

positioning. This understanding is particularly important in the context of the North Adriatic port's competitiveness and its connectivity to other Mediterranean ports. Centrality measures could provide an objective and quantifiable method of assessing the importance of cruise ports. These data-driven measures ensure that the analysis is based on robust and reliable metrics. This study analyzed the number of cruise port calls during August 2024, as June, July, and August are the most stable periods of the cruise season [23]. Moreover, August is the peak month of the cruise season in the Mediterranean and North Adriatic, with the highest traffic volumes in many ports. This data is critical for assessing cruise dynamics during the busiest period of the year. It helps to identify critical ports during peak season traffic and informs decisions on infrastructure, port capacity and cruise ship itinerary planning (e.g. Venice has a problem with high cruise traffic and environmental constraints). August data is valuable for understanding high traffic patterns and ensuring smooth operations during the peak season. Quantitative measures were used to ground the analysis, reflecting each port's operational performance and connectivity. The data for the quantitative analysis was obtained from the website www.cruisemapper.com/ports. The website provides a comprehensive repository of information on the subject, including data on the number of cruise ship arrivals and departures, the duration of each visit, and the itineraries of all cruise ship visits to the NA ports. With respect to the presented methodology, we analyze the following network measures, adopted from [24-26]: 1. Degree Centrality (C^D), where we identify the most connected ports; 2. Betweenness centrality (C^B), where we find critical ports that act as bridges within the network; 3. Closeness Centrality (C^C), where we measure how quickly cruise ships can reach other parts of the network; 4. Eigenvector Centrality (C^E), where we measure a node's influence based on its neighbour's influence.

The network with n nodes is represented by a graph $G(V,E)$, which is described by an $n{\times}n$ adjacency matrix A with elements $a_{ij} = 1$ if there exists a link between nodes i and j and $a_{ij} = 0$ otherwise. In the case of a weighted network, the adjacency matrix is generalized such that element $a_{ij} = w_{ij}$ represents the strength w_{ij} of link between i and j.

1. Degree Centrality (C^D) gives the number of direct connections a node (cruise port) has. It can be written as an equation [24]:

$$C^D(i) = \sum_{j=1}^{n} a_{ij} \tag{1}$$

In our case, the cruise network system is a directed network, as we know the direction of cruise ship itineraries, which is the previous and the next cruise port to visit. Degree centrality can be in-degree or out-degree. The in-degree of a node (in our case a cruise port) is the number of incoming edges (no. of ship arrivals): $C^D in(i) = deg\_in(i)$. The out-degree of a node is the number of outgoing edges (no. of ship departures): $C^D out(i) = deg\_out(i)$. Furthermore, centralities can be assigned a weighting factor. In this context, the weight is not determined by the factor; rather, it is the number of cruise ships arriving/departing in the North Adriatic (NA) system from/to the broader Mediterranean network. The weighted centralities are defined as the number of incoming/outgoing edges (ship arrivals/departures) between nodes (cruise ports) in the NA port system and other nodes in the Mediterranean system. In contrast, unweighted centralities are defined as the number of incoming/outgoing edges (ship arrivals/departures) between nodes within the NA port system.

2. Betweenness centrality (C^B), where we find critical ports that act as bridges within the network or bottlenecks within the network. The betweenness centrality measures the extent to which a node lies on the shortest paths between other nodes. It identifies the crucial transit cruise ports that handle a lot of cruise traffic. It looks at the total number of shortest paths from node to node and the number of those paths that pass through the port. It can be written as an equation [24]:

$$C^B(i) = \sum_{j} \sum_{k} \frac{g(j,i,k)}{g(j,k)}, \qquad i \neq j \neq k \tag{2}$$

where $g(j,k)$ is the total number of shortest paths connecting the node j to the node k; $g(j,i,k)$ is the number of those shortest paths that pass through node i, between two nodes j and k. This metric can identify nodes that play crucial intermediary roles in a network. If the network is directed, the term $g(j,i,k)$ refers to the number of directed paths from the node j to the node k that pass through the node i, and $g(j,k)$ to the total number of directed paths from the node j to the node k. Ports with high betweenness centrality are those that serve as crucial transit points between the ports in the network. They handle a significant portion of cruise traffic because they lie on the most efficient routes between other ports. Ports with high betweenness centrality are more likely to be included in itineraries because they help minimize travel distances between popular destinations, making them logistically efficient for cruise operators. In our study, we present the shortest paths connecting node j to node k, which are determined by the distances between the coordinate points of the cruise ports. This approach differs from the conventional method of identifying the most efficient sea travel path between cruise ports (that is more correct). Nevertheless, there are certain advantages to be gained from such an approach, including: a) From the analysis we can gain an understanding of the fundamental spatial distribution of cruise ports. b) The proximity and geographical clustering of ports could be analysed prior to consideration of operational sea travel path realities. c) To identify those ports which are geographically close, which could subsequently be subjected to further analysis by the addition of real-world sea routes.

3. Closeness Centrality (C^C), where we measure how quickly cruise ships can reach other parts of the network. It indicates how close a node is to all other nodes in the network. It determines which cruise ports can most efficiently reach from other network parts. It searches the shortest path distance between nodes. A node with high closeness centrality can reach all other nodes more quickly, making it an effective point. It can be written as an equation [24]:

$$C^C(i) = \frac{n-1}{s(i)} \quad (3)$$

where the distance sum $s(i) = \sum_{j=1}^{n} d(i,j)$, n is the total number of nodes in the network; $d(i,j)$ is the shortest path distance between nodes i and j. In this metric, the data used to determine the closeness centrality is determined by the distances between the coordinate points of the cruise ports (the same way as for Betweenness centrality).

4. Eigenvector Centrality (C^E), where we measure a node's influence based on its neighbour's influence. It identifies influential ports (nodes) that connect to other influential ports (nodes), i.e. looking for the set of neighbours of the node. In contrast to degree centrality, which is a local measure, eigenvector centrality is a global measure and as such offers a more complete picture of connectedness. It assigns relative scores to all nodes in the network based on the concept that connections to nodes with high centrality values contribute more to the centrality of the node in question. It can be written as an equation of eigenvector centrality [24]:

$$C^E(i) = \frac{1}{\lambda}\sum_{j=1}^{n} a_{ij} \cdot C^E(j) \quad (4)$$

where λ is a constant (the largest eigenvalue of the adjacency matrix), n is the set of all the nodes, a_{ij} is an element of the adjacency matrix which indicates whether node i is connected to node j, $C^E(j)$ is eigenvector centrality of node j, a neighbouring node of i.

2.2 An overview of the North Adriatic Sea cruise port system

The present study examines five ports located in the northern Adriatic Sea: Koper, Venice, Trieste, Rijeka, and Zadar. Figure 2 shows the total number of passengers in each port in 2023 (red and black circle). Venice has the highest number of passengers with 541,341, followed by Trieste with 469,000, Zadar with 174,573, Koper with 120,538 and Rijeka with 37,725 passengers [23]. The five ports were selected based on their strategic importance and their membership in the North Adriatic Ports Association (NAPA), which comprises the most important commercial and cruise ports in the region. NAPA includes Venice, Trieste, Koper, Ravenna, and Rijeka, which are pivotal in cruise and cargo traffic, making them a natural focus for this study. Additionally, instead of Ravenna we used Zadar due to its rising significance in cruise traffic and its central position within the North Adriatic network. Focusing on these five ports enables us to examine their critical role in connecting the North Adriatic network to the broader Mediterranean cruise system in greater detail.

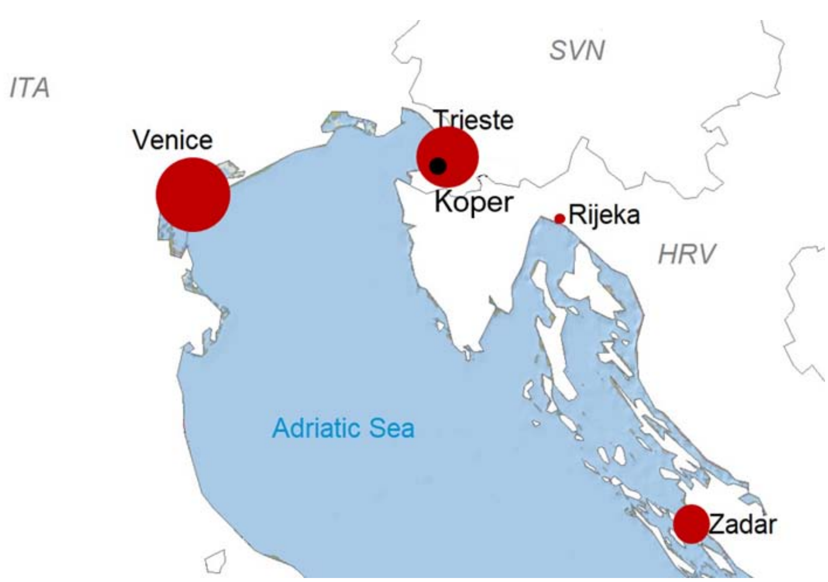

Figure 2 North Adriatic cruise ports used in network analysis

Source: Author using ArcMap GIS

Table 1 Data on the arrivals of cruise ships at each North Adriatic Sea port in August 2024.

Port	No. of different ships arrival	No. of different cruise line arrival	Total number of ship arrivals
Koper	5	4	8
Rijeka	2	2	4
Zadar	17	15	28
Trieste	12	9	22
Venice	16	12	59
Total in the system	52	42	121

We used the complete itineraries of cruise ship arrivals in at least one of the five selected North Adriatic ports during August 2024. The North Atlantic (NA) port system has five cruise ports, with a total of 121 ship arrivals in August. Centrality measures have been calculated for the entire Mediterranean network, which has a total of 860 ship arrivals and 760 links within 60 ports (that also included at least one of the NA cruise port). The North Adriatic (NA) port system repeats the same itineraries 3.7 or almost 4 times. The competitiveness of five NA ports is analyzed and operationally detailed to understand what limits there are in terms of connectivity. The CruiseMapper database (www.cruisemapper.com/ports) was utilized to analyze the full itinerary of 121 cruise ship arrivals in August 2024 at five selected ports. The database provides schedule calendars for arrival and departure dates per month, allowing for a comprehensive tracking of the cruise ship's trajectory before and after arrival at the port. Table 1 presents the data on all arrivals in August 2024 at each NA cruise port.

3 Results

The cruise network system can be presented as an L-space model of the transportation network [9], where the nodes represent the cruise ports, and the edges represent the direct connection between them. It focuses on the actual physical connections and routes in the network. It gives an immediate network topology and shows how directly connected various nodes are. It is important to note that this study's calculation of shortest paths is based exclusively on the straight-line distances between cruise ports (coordinates, not actual sea paths). This approach may result in overestimating a port's role in the cruise network. To gain a deeper un-

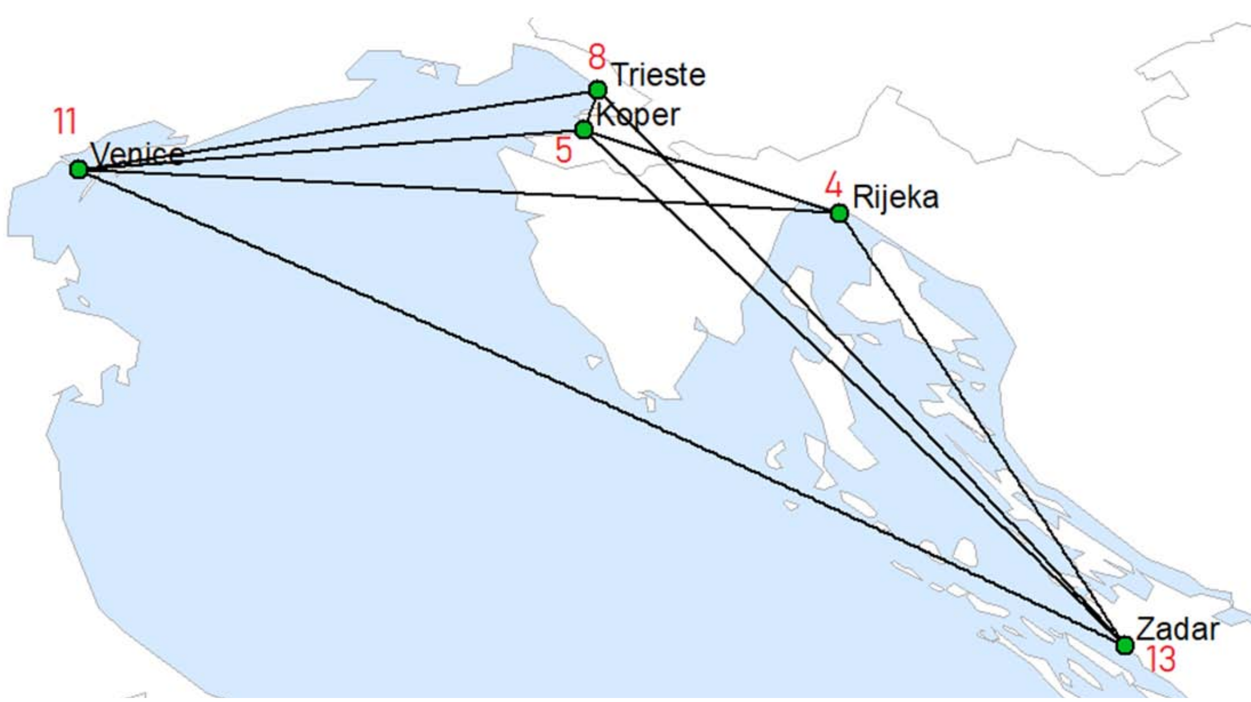

Figure 3 Graphical North Adriatic cruise port system model with direct links to port - indegree unweighted

Source: Author using ArcMap GIS).

Table 2 Degree centralities (C^D) and eigenvector centralities (C^E) of North Adriatic Sea ports.

Port	Indegree unweighted	Outdegree unweighted	Indegree weighted	Outdegree weighted	Eigenvector unweighted	Eigenvector weighted
Trieste	8	7	37	40	0.278	0.204
Koper	5	6	21	21	0.198	0.137
Rijeka	4	3	12	12	0.088	0.036
Venice	11	14	69	76	0.297	0.283
Zadar	13	11	62	62	0.364	0.321

derstanding of cruise ports' competitive and cooperative positioning within the broader cruise port system, we employed non-conventional analytical measures of centralities. The research utilized four analytical techniques — degree centrality (C^D), betweenness centrality (C^B), closeness centrality (C^C), and eigenvector centrality (C^E) — using empirical data (Appendix A and Table 1) to analyze the operational and geographical dynamics of five competitive cruise ports in the North Adriatic Sea ports system and the broader Mediterranean ports network. The study examined the connections between the five ports, resulting in a semantic diagram of connections, which provides insights into the transport geography perspective of the NA port system (Figure 3). The number of ports with which the port is directly connected is indicated by the red number written adjacent to the cruise port name in Figure 3. The highest indegree unweighted port in NA port system is Zadar, which has the most direct connections that come into the port (13 ship arrivals). Venice is the highest indegree-weighted port in the Mediterranean system of those five ports (69 ship arrivals).

Table 2 shows the number of unweighted indegree connections, which is the number of incoming cruise ships (port calls) within the North Adriatic ports system. The number of unweighted outdegree connections is the number of outgoing cruise ships (port calls) within the North Adriatic ports system (where we have only five cruise ports). We get weighted connections if we consider the broader cruise network of Mediterranean ports. The weighted indegree connections are the number of incoming cruise ships (port calls) from all Mediterranean ports to the North Adriatic port. Weighted outdegree connections are the number of outgoing cruise ships (port calls) from the North Adriatic port to all other Mediterranean ports.

Table 2 provides detailed results of degree centralities (C^D) and eigenvector centralities (C^E), while Table 3 provides a more comprehensive analysis of centralities with ranking ports. Zadar is the most important port in terms of ship arrivals in the NA system, as it has the most ship calls from high-scoring nodes (13 ship arrivals). Regarding the outgoing or cruise ship departures within the NA port system, Venice has the most outgoing connections (14). Venice is the most significant port in the Mediterranean system, with 69 cruise ship calls and the highest number of departures. It can be concluded that the port of Venice is the most important port of all NA ports for cruise ships, as it has the highest number of cruise ship arrivals and departures, indicating that Venice is an important gateway port between Central Europe and the wider Mediterranean cruise network.

In Table 3, if the C^D weighted index is equal to 1, it indicates the port of call, while if less or more than 1, it indicates the home port. Venice and Trieste are home ports due to more outgoing connections (ship departures) than incoming (ship arrivals) connections in Mediterranean ports. Venice is the most important cruise port for the NA port system (0.91 < 0.93, i.e. Venice < Trieste, the lower the value, the more important the port). Koper, Rijeka and Zadar are port of calls. Moreover, Koper and Venice in the Mediterranean system have a C^D unweighted index of less than 1, indicating more outgoing cruise ships than incoming cruise ships, resulting in more cruise ship calls to the Mediterranean ports than to the NA ports. It should also be noted that Venice has more departures than the port of

Table 3 Ranking ports by degree centralities (C^D) and eigenvector centralities (C^E) of NA ports.

NA and Mediterranean port system C^D and C^E				
Port	C^D weighted index	C^D unweighted index	C^E weighted Rank	C^E unweighted Rank
Trieste	0.93	1.14	3	3
Koper	1.00	0.83	4	4
Rijeka	1.00	1.33	5	5
Venice	0.91	0.79	2	2
Zadar	1.00	1.18	1	1

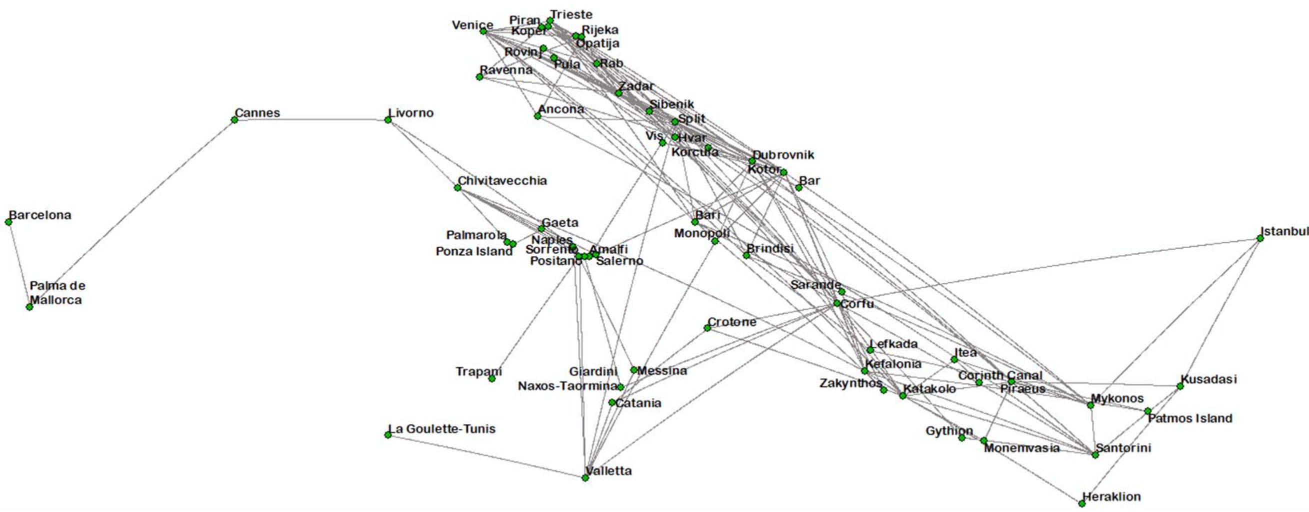

Figure 4 Spatial distribution of the North Adriatic Sea port's connections to the port system in the Mediterranean – straight-line distances between ports

Source: Author using ArcMap GIS

Koper (0.79 < 0.83, i.e. Venice < Koper, the lower the value, the more departures the port has). The vice versa is with arrivals, where Rijeka has the most cruise ship arrivals (1.33), indicating that this is an important NA port for cruise ships originating from the Mediterranean system.

The ranking system in Table 3 reflects ports' significant role within the network. The ranking of ports is done in descending order, with the port with the highest eigenvector centrality C^E being the best positioned competitively in the system. The ranking of cruise ports based on passenger movements in 2023 is as follows: Venice, Trieste, Zadar, Koper, and Rijeka. The ranking of ports based on the C^E weighted and unweighted is as follows: 1. Zadar; 2. Venice; 3. Trieste; 4. Koper; 5. Rijeka. This provides important information for cruise ports regarding their competitiveness in the NA system. The same ranking can be observed in the broader Mediterranean system. This indicates that the port role in the North Adriatic system is the same as its role in the Mediterranean system. Furthermore, Zadar has the highest unweighted eigenvector centrality (0.364), ranked as 1,

Table 4 Degree centralities (C^D) of the NA system and Mediterranean port system (first 16 ports ranked by indegree weighted, other in appendix).

Port	Indegree unweighted	Outdegree unweighted	Indegree weighted	Outdegree weighted	Indegree weighted Rank	Outdegree weighted Rank
Kotor	12	11	75	75	1	2
Dubrovnik	15	12	69	70	2	3
Venice	11	14	69	76	2	1
Zadar	13	11	62	62	4	4
Corfu	11	12	55	55	5	5
Split	12	14	45	44	6	6
Trieste	8	7	37	40	7	7
Bari	6	7	28	28	8	8
Hvar	6	6	26	26	9	9
Santorini	5	8	26	26	9	9
Mykonos	6	4	23	23	11	11
Piraeus	7	5	22	13	12	15
Koper	5	6	21	21	13	12
Rovinj	3	4	21	21	13	12
Katakolon	5	7	20	20	15	14
Rijeka	4	3	12	12	16	16

* unweighted ports related to the NA system (5 ports), weighted ports related to the Mediterranean system (60 ports)

indicating it is connected to many ports and key, well-connected ports in the network. This suggests its strategic position in the North Adriatic cruise system. Moreover, Venice follows with high eigenvector centrality scores (0.297 unweighted ranked 2, and 0.283 weighted ranked 2), indicating its importance, particularly within the broader Mediterranean cruise network. Its connections are also significant because it connects to other important ports. This indicates Venice not only has a large volume of traffic but is also connected to other prominent ports in the Mediterranean, reinforcing its role as a major cruise hub in the NA region.

Figure 4 shows how cruise ship itineraries connect the North Adriatic Sea ports with the Mediterranean port system. The system includes 860 port calls across 60 different cruise ports, with 205 unique port call pairs across 121 itineraries made in the NA and the Mediterranean region in August 2024.

The network analysis also involves analyzing betweenness centrality and closeness centrality to identify critical transit cruise ports. The study analyses the importance of ports in the NA port system (5 cruise ports) and the Mediterranean system (60 cruise ports) using unweighted and weighted C^D (Table 4).

The top-ranked outdegree ports in Table 4 are the origins of many cruise itineraries, making them key in research to gain competing ports in the NA port system. Data analysis shows Split, Venice, Dubrovnik, and Corfu as the largest outgoing cruise ships (outdegree unweighted) for the NA port system (choosing at least one of the five NA ports in the itinerary). Regarding the arriving cruise ships to the NA port system (indegree unweighted), the most important port is Dubrovnik, the second is Zadar, and the third is Split and Kotor. In this respect, we can conclude that Venice and Zadar are the most important ports in the North Adriatic, which indicates strong connectivity and strategic importance also for the Mediterranean port system. The Mediterranean system sees Kotor receiving the most cruise ship arrivals, followed by Dubrovnik and Venice (indegree weighted).

The rank of ports can also be used to define "predator" ports, which are important ports (hubs) from which many ships depart but which are not major destinations themselves, i.e. these ports have significantly

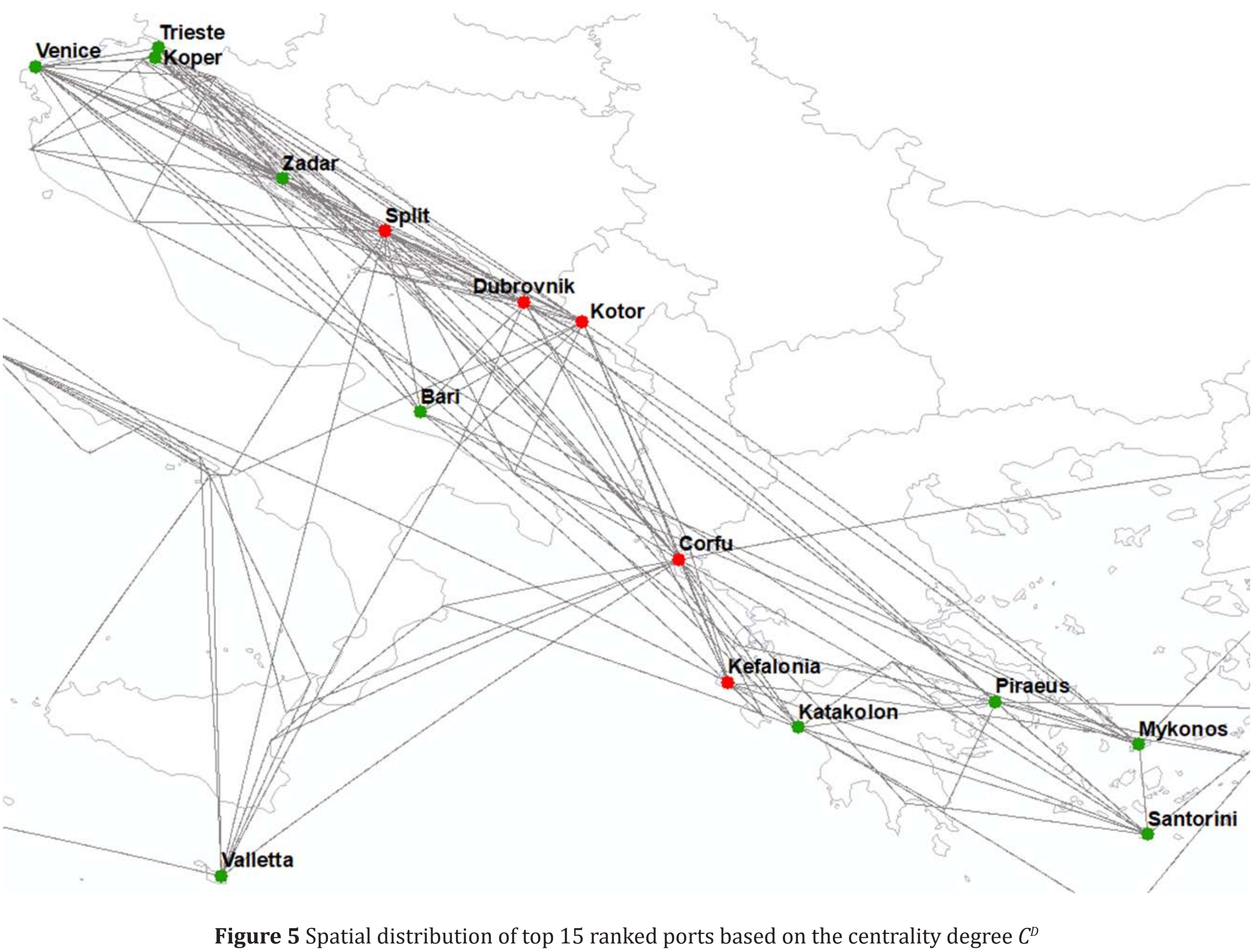

Figure 5 Spatial distribution of top 15 ranked ports based on the centrality degree C^D

Source: Author using ArcMap GIS

higher out-degree (departing cruise ships) than in-degree (arriving cruise ships). Venice, Trieste, and Ravenna are the main Mediterranean "predator" ports in regard to the NA cruise port system. In addition, there are ports that are popular ports, i.e. popular destinations that attract many ships but do not serve as major departure points. They have high in-degree but low out-degree, indicating their role as important stops on itineraries rather than origins. Piraeus is the most popular destination as an important stop on ship itineraries, with 22 in-degree weighted connections and 13 out-degree weighted connections. This is followed by the port of Civitavecchia, Barcelona and Split as the most important destinations for ship itineraries in the NA system. We may also have zero out-degree ports, which are destinations that serve as the last stop or a heavily visited endpoint on cruise itineraries, also known as home ports (e.g., Barcelona in our Mediterranean system).

Figure 5 shows the top 15 cruise ports ranked by C^D, with three different classes of ports according to their connections to the NA system. The first class consists of the first five ports ranked by centrality degree C^D (marked with red), followed by 10 ports ranked 6-15 (marked with green), and the third class includes all other ports ranked above 15. The first five ports ranked by C^D are the most important cruise ports for the NA cruise ports, as most cruise ships enter the NA system from these ports.

We also analysed betweenness centrality (C^B) to identify the major transit cruise ports that handle a lot of cruise traffic and closeness centrality (C^C) to identify which cruise ports can be reached most efficiently from other parts of the network in terms of the shortest path distance between ports. It is important to note that we used direct line distances between the coordinate points of the ports rather than actual sea routes. The results should, therefore, be interpreted with caution. As a result, these centrality measures may not fully reflect the true operational dynamics of cruise itineraries. Nevertheless, such an analysis can provide us with some important insights and allow us:

1. understand the geographical proximity of cruise ports to each other, this can be a helpful starting point for analysing the spatial distribution of ports within a region;

2. it can help to identify which ports, even in a simplified model, are likely to emerge as key transit points or destination hubs;

3. the calculations provide insights into the potential network of cruise ports.

The results still provide a relative measure of the importance of ports in terms of their centrality within the cruise network, and ports with high betweenness or proximity centrality based on direct line distances are likely to play a key role. Moreover, the aim of this article was to use a non-conventional approach to assess the connectivity of cruise ports and to see if these centrality measures provide important insights into the connectivity and competitiveness of cruise ports.

Table 5 shows the top 15 cruise ports ranked according to C^C and C^B. The most efficient port in terms of C^C is the port of Corfu, the second most efficient port is the

Table 5 Betweenness centrality (C^B) and closeness centrality (C^C) of the NA port system and Mediterranean port system (first 15 ports ranked by closeness centrality).

Mediterranean port system C^B and C^C				
Port	**Closeness centrality**	**Betweenness centrality**	**Closeness centrality Rank**	**Betweenness centrality Rank**
Corfu	0.495	0.18	1	1
Split	0.491	0.17	2	2
Dubrovnik	0.468	0.11	3	6
Kotor	0.465	0.11	4	7
Kefalonia	0.461	0.15	5	4
Katakolon	0.431	0.10	6	8
Venice	0.431	0.10	6	9
Valletta	0.428	0.15	8	5
Zadar	0.425	0.06	9	13
Santorini	0.419	0.04	10	15
Trieste	0.419	0.01	10	26
Bari	0.408	0.00	12	28
Koper	0.397	0.01	13	25
Piraeus	0.394	0.05	14	14
Mykonos	0.392	0.03	15	17

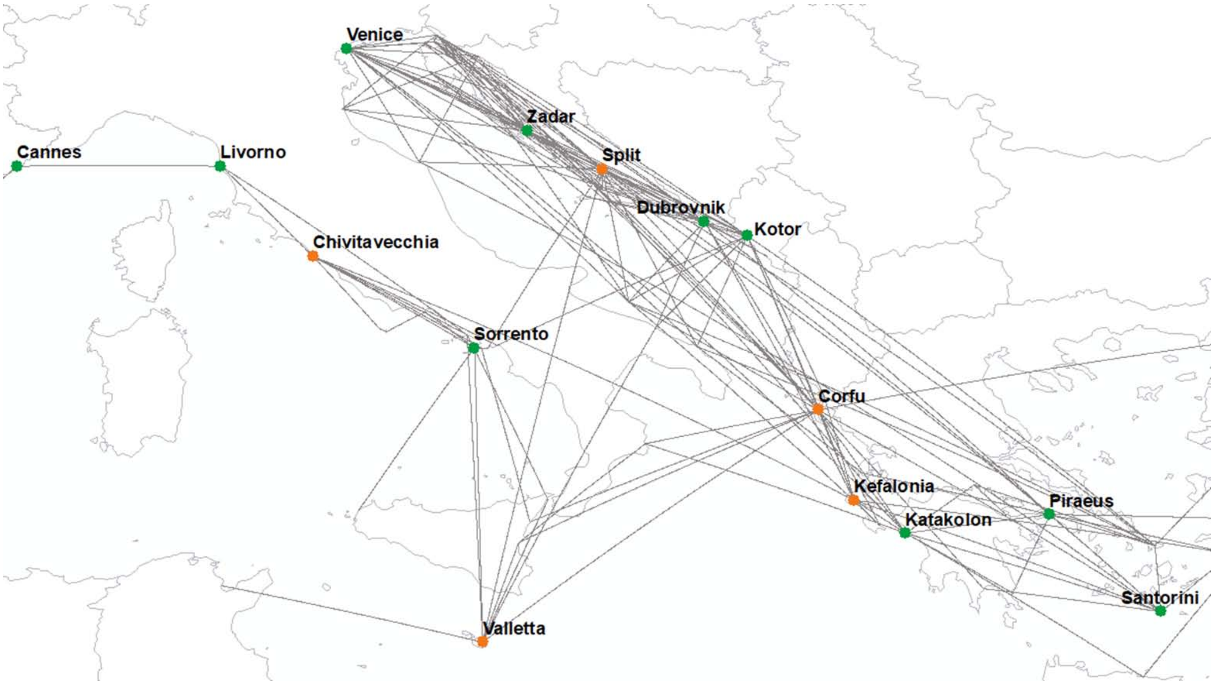

Figure 6 Spatial distribution of top 15 ranked ports based on the betweenness centrality C^B

Source: Author using ArcMap GIS

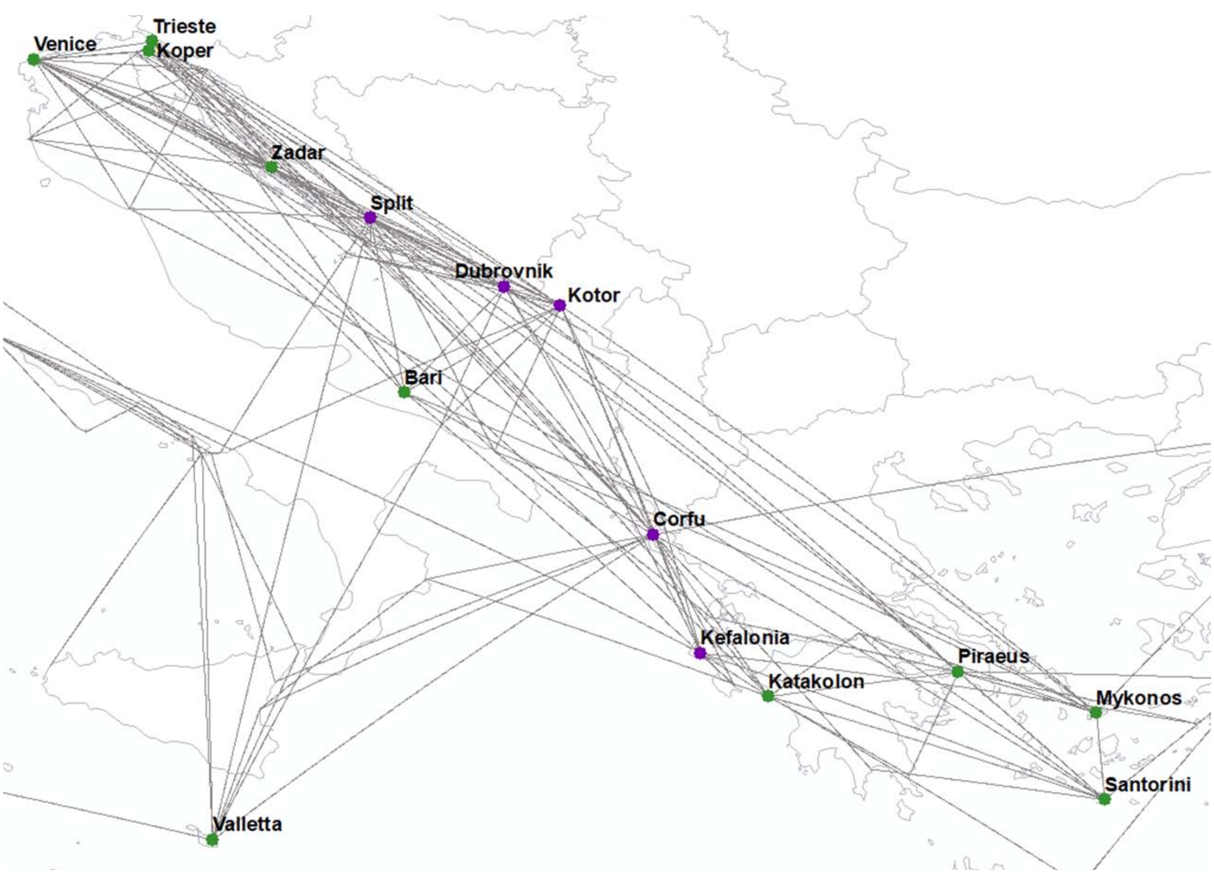

Figure 7 Spatial distribution of top 15 ranked ports based on the closeness centrality C^C

Source: Author using ArcMap GIS

Table 6 Eigenvector centrality (C^E) of the NA system and Mediterranean port system (first 15 ports ranked by eigenvector weighted)

Mediterranean port system C^E				
Port	**Eigenvector unweighted**	**Eigenvector weighted**	**C^E unweighted Rank**	**C^E weighted Rank**
Kotor	0.34	0.480	3	1
Dubrovnik	0.37	0.439	1	2
Corfu	0.18	0.395	10	3
Zadar	0.36	0.321	2	4
Venice	0.29	0.283	5	5
Split	0.32	0.231	4	6
Trieste	0.27	0.204	6	7
Bari	0.21	0.196	8	8
Hvar	0.22	0.142	7	9
Koper	0.19	0.137	9	10
Rovinj	0.10	0.111	15	11
Mykonos	0.11	0.095	14	12
Santorini	0.06	0.093	23	13
Katakolon	0.07	0.092	22	14
Zakynthos	0.02	0.061	34	15

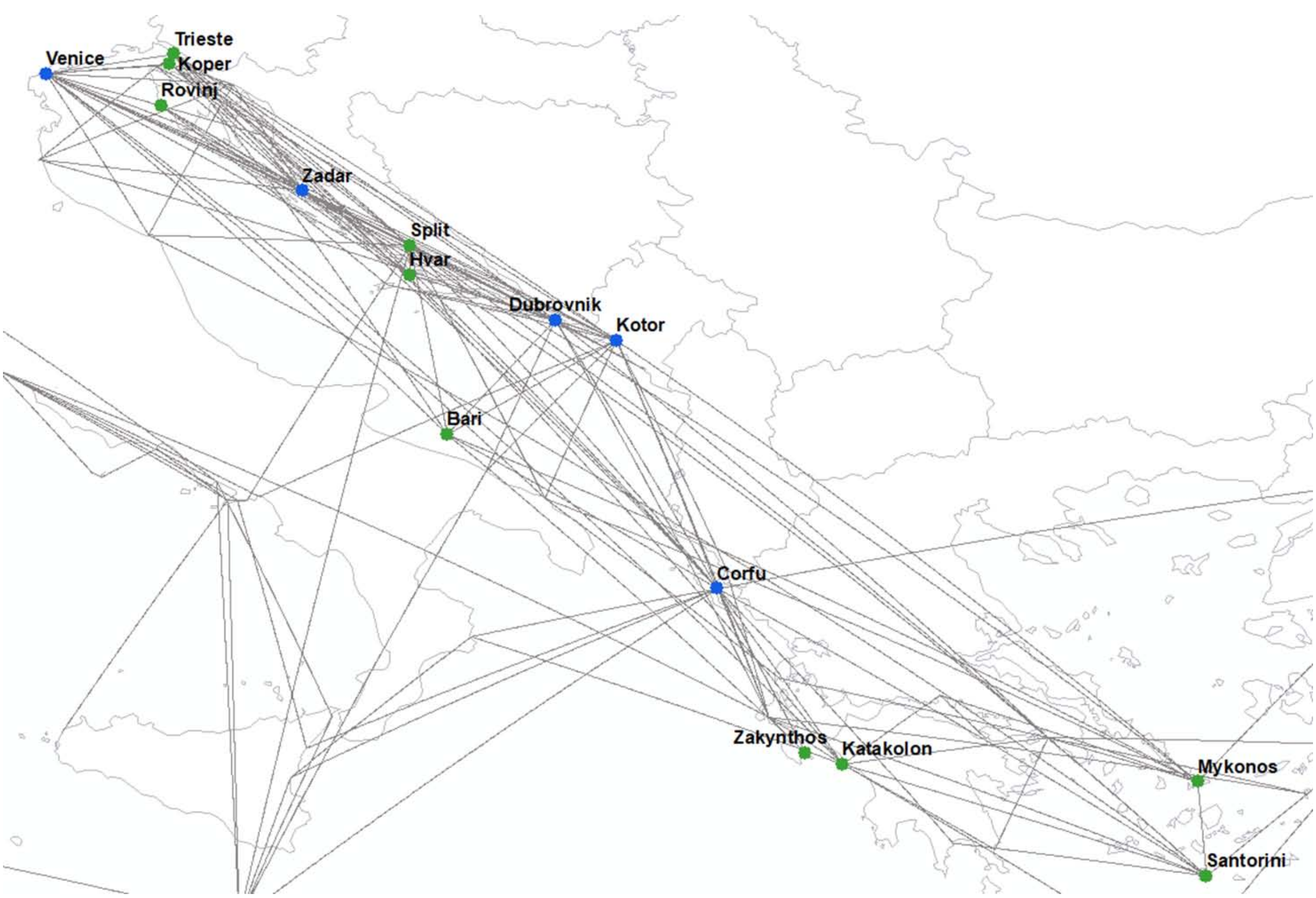

Figure 8 Spatial distribution of top 15 ranked ports based on the eigenvector centrality C^E

Source: author using ArcMap GIS

port of Split, and the third most efficient port is Dubrovnik. This means that a cruise port with a high closeness centrality can reach all other ports more quickly, making it an effective cruise port.

Regarding betweenness centrality, the most important transit port is Corfu, the second is Split, and the third is Civitavecchia. Corfu's high betweenness centrality shows that it is a key transit hub, frequently appearing on the shortest paths between other ports, making it crucial for the flow of cruise traffic across the Mediterranean and Adriatic Sea. The high betweenness centrality quantifies how often a port appears on the shortest paths between other ports. These ports are critical for connecting different parts of the network. Thus, they are also crucial for maintaining the flow of cruise ships in the Adriatic Sea.

Figure 6 shows the top 15 cruise ports ranked by betweenness centrality C^B, with three different classes of ports according to their connections to the NA system. The first class consists of the first five ports ranked by betweenness centrality C^B (marked with orange colour), followed by 10 ports ranked 6-15 (marked with green colour), and the third class includes all other ports ranked above 15. The first five ports ranked by C^B are the most important cruise ports for NA cruise ports, as they are important transit ports that often appear on the shortest routes between other Adriatic cruise ports.

Figure 7 shows the top 15 cruise ports ranked by C^C, with three different classes of ports according to their connections to the NA system. The first class consists of the first five ports ranked by closeness centrality C^C (marked with purple colour), followed by 10 ports ranked 6-15 (marked with green colour), and the third class includes all other ports ranked above 15. The first five ports ranked by C^C are the most important cruise ports for NA cruise ports as they represent the most efficient cruise ports in terms of well-connected and accessible from other parts of the cruise network.

Table 6 demonstrates a port's eigenvector centrality (C^E), indicating that connections to high-scoring ports contribute more to a node's score than to low-scoring ones. In terms of the number and quality of connections, Kotor is the most important cruise port in the network, followed by Dubrovnik and Corfu. Kotor plays a critical role not just in NA port system but also in the overall Mediterranean cruise network. It is connected to highly influential ports, making it a significant hub. The strong efficiency of ports like Kotor and Dubrovnik highlights the relevance of the Adriatic cruise market and its integration into larger Mediterranean itineraries. The Adriatic ports (Kotor, Dubrovnik, Zadar, Venice, Split, Trieste, Koper) rank relatively high, indicating the importance of the Adriatic within the wider Mediterranean cruise network. This region serves as a critical sub-network connecting some of the most important cruise destinations in Europe.

Figure 8 shows the top 15 cruise ports ranked by C^E, with three different classes of ports according to their connections to the NA system. The first class consists of the first five ports ranked by weighted eigenvector centrality C^E (marked with blue colour), followed by 10 ports ranked 6-15 (marked with green colour), and the third class includes all other ports ranked above 15. The first five ports ranked by C^E are the most important cruise ports for NA cruise ports as they are the best-connected ports and have the most connections to most other influential ports.

Centrality measures are not directly comparable, as each provides a different perspective on centrality, as discussed in Section 2.1. Each of the centrality measures presented in this article provides a different view of a port's importance in the network to provide an overall picture of the structure and dynamics of the cruise network. However, they are useful for comparing different ports because they highlight different aspects of a port's competitive position. It is important to evaluate each port using centrality measures and then compare ports using each centrality measure by ranking them. To get a holistic view of a port's role in the network, it is often useful to analyse several centrality measures together and understand what each one reveals about the port's influence, position or connectivity. Figures 9 and 10 illustrate closeness centrality, eigenvector centrality, betweenness centrality, and degree centrality, respectively, to illustrate the different centrality measures in the NA cruise ports network.

Figure 9 shows that the ports of Venice and Trieste are the most central on both measures, demonstrating their importance and connectivity to other key cruise ports. This means that Venice is an important port connected to other important cruise ports and has short paths to other ports. Trieste has characteristics similar to Venice but with slightly lower eigenvector centrality and closeness centrality. Nevertheless, it is still a rather important cruise port. Zadar and Koper are important but have different characteristics in terms of connectivity and accessibility. The port of Zadar has a rather high eigenvector centrality but a lower closeness centrality. This means that Zadar is connected to many other important ports, but the paths to other ports are slightly longer. Koper has a medium eigenvector centrality and a slightly higher closeness centrality than Zadar. Koper is an important port of call and has relatively short distances to other ports. The port of Rijeka has the shortest distances to other ports but is not as well connected to other important ports. The conclusion is that ports with a higher centrality score also have more passengers, and vice versa. Both centrality measures—weighted eigenvector centrality and unweighted closeness centrality—are positively correlated with the number of passengers at the cruise ports. However, weighted eigenvector centrality shows a slightly stronger correlation (higher R^2 value), suggesting that the quality of

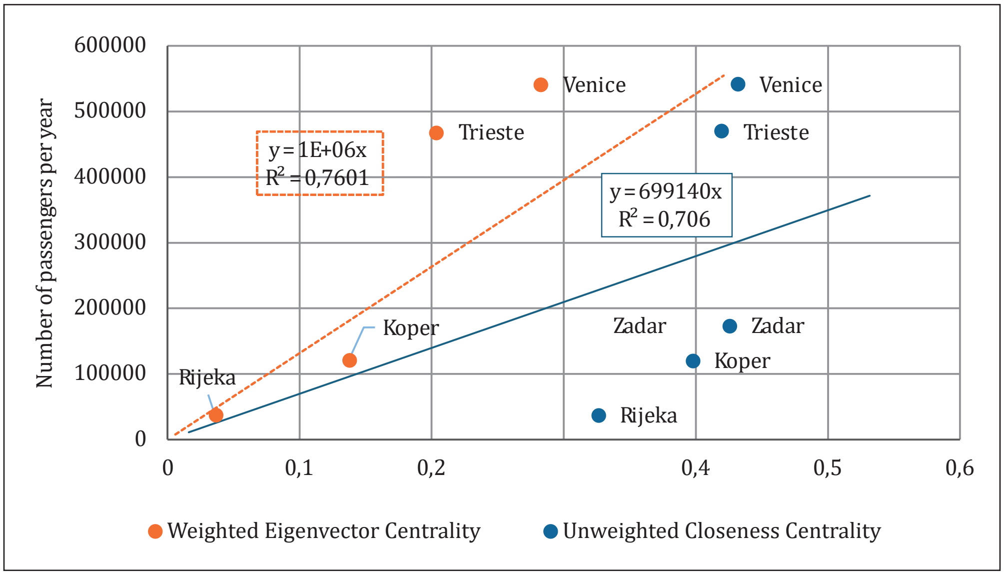

Figure 9 Cruise port positioning based on closeness centrality C^C and eigenvector centrality C^E

connections to other influential ports plays a more significant role in attracting cruise passengers than simply being centrally located within the network.

Figure 10 shows that the ports of Venice and Trieste are the most important in terms of both centrality measures, indicating their importance as ports with many connections and as key transit hubs in the cruise network. The port of Venice has a high betweenness centrality and a very high degree centrality. This means that Venice is a node that is often located on the shortest paths between other nodes and has many direct links to other nodes, making it very important in the network. The port of Trieste has a high betweenness centrality and a medium degree centrality. Trieste is an important transit hub and has many direct connections. The port of Zadar has a high degree of centrality, meaning that it is a well-connected hub and plays an important role as a transit hub. Koper and Rijeka have a smaller role in the network, with fewer direct connections and a less frequent role as hub points. Ports with high eigenvector centrality are connected to other highly influential ports, which tends to correlate with higher

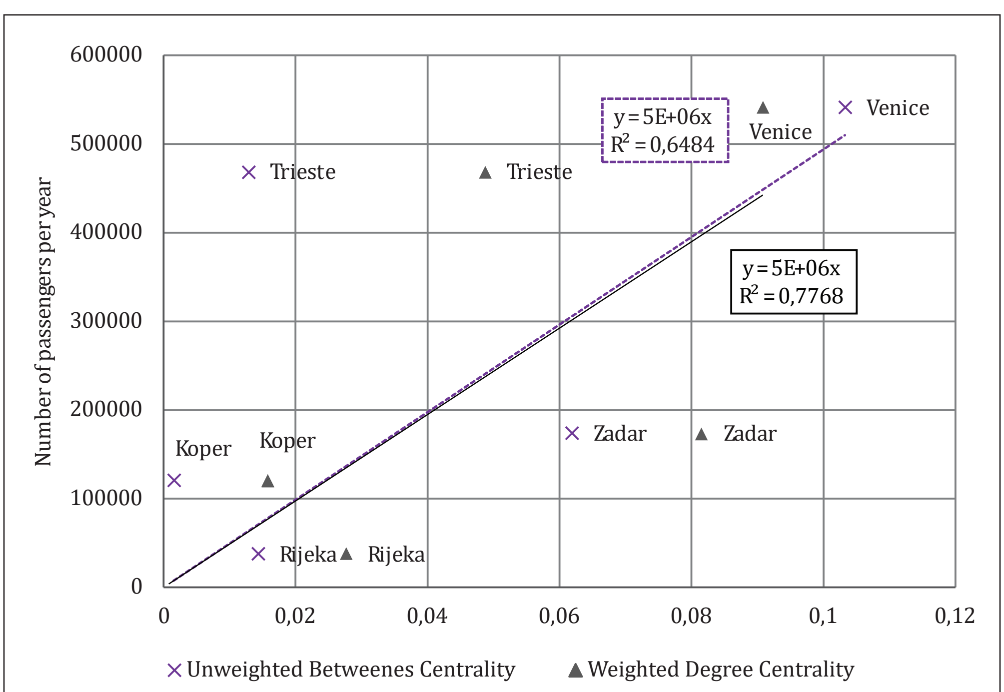

Figure 10 Cruise port positioning based on betweenness centrality C^B and degree centrality C^D

traffic. Venice is clearly the most central and busiest port in the NA port system. The R^2 for Weighted Degree Centrality (0.7768) is higher than that for Unweighted Betweenness Centrality (0.6484), suggesting that the number of connections (Weighted Degree Centrality) is a better predictor of passenger traffic than the port's position in connecting routes (Betweenness Centrality).

4 Discussion

This study uses network analysis to understand the Adriatic Sea's port connectivity and competitive positioning. It classifies ports based on their connections within the cruise network, focusing on calculating the degree, betweenness, closeness, and eigenvector centralities. This analysis provides insights into operational and competitive dynamics within the North Adriatic cruise ports network, helping cruise lines optimize routes and improve network efficiency in this area.

The Port of Zadar has the highest in-degree centrality among the North Adriatic ports system, with the most direct incoming connections. Venice ranks highest in outgoing connections among NA ports. In 2023, Venice led in number of passengers with 541,341, followed by Trieste with 469,000 and Zadar with 173,938. Despite this, Venice and Zadar remain pivotal in connectivity influence, with Zadar also leading in eigenvector centrality (eigenvector unweighted) due to its connections to other high-scoring ports in the NA port system. The Mediterranean port system ranks Kotor with the most direct incoming connections, followed by Dubrovnik and Venice.

Betweenness centrality highlights Corfu as a major transit port in the Mediterranean system, followed by Split and Civitavecchia. Closeness centrality reveals Corfu as the most efficient port, capable of quickly reaching all other ports, followed by Split and Dubrovnik.

This research identifies "predator" ports like Venice, which serve as major departure points, from popular destination ports like Piraeus and Barcelona. For instance, Piraeus, with 22 in-degree weighted connections and 13 out-degree weighted connections, is a popular destination acting as an important stop, i.e. a port of call rather than an origin, i.e. home port.

Venice and Trieste are the NA network's most central hubs by all measures of centrality, meaning that they are key points of connection and passenger flow in the network. The port of Zadar is an important hub with good connections, but it is not as important a hub as Venice or Trieste. Koper and Rijeka's ports are less important than other ports and play a lesser role in network connectivity. These conclusions allow us to understand how individual ports are positioned in the NA network and their role in connecting and moving passengers between other ports. This comprehensive understanding of port connectivity and influence helps to optimize cruise itineraries and improve the competitive positioning of ports within the NA cruise network.

It should be noted, however, that we have included in this research five NA cruise ports and their ship arrivals for one month, i.e., August 2024. Therefore, the network analysis is limited to these specifics. However, the broader application of this methodology could include all itineraries of all cruise lines and all Mediterranean cruise ports for a longer period of time i.e. year or two at least. This could provide a deeper insight into the competitiveness of the cruise port system regarding its operational and geographical dynamics, especially for capture seasonality to reflect year-round trends rather than peak-season dynamics alone.

In order to evaluate the approach presented in this article, we have compared the method and the results with a state-of-the-art paper, namely [27]. The article employs Social Network Analysis (SNA) as the primary method to assess the centrality of cruise ship navigation networks in Southern Europe. SNA is used to analyze the relationships between 20 selected ports based on cruise ship calls from 2015 to 2019. The analysis includes calculating various metrics such as outgoing and incoming centrality degree, betweenness centrality, and hub index to understand the dynamics of the cruise port network. Like in the article [27], we used degree centrality to measure the number of connections for each cruise port. Moreover, we also used the betweenness centrality metric to measure the extent to which a node lies on the shortest paths between other cruise ports. In contrast to our research, [27] used another metrics hub and authority centrality. These measures of a particular cruise port increase as they relate to relevant nodes in the network and vice versa. We also used eigenvector centrality to obtain a node's influence based on its neighbours' importance. Another metric that has not been used to obtain cruise port advantage in a competitive market is closeness centrality, where we measure how quickly (efficient) a cruise ship can reach other cruise ports in the network. This gives important information for cruise ports in the competitive cruise market network. The results of the research [28] are difficult to compare with our research because they analyzed the Southern European cruise network, and we, in our research, analyzed the North Adriatic region with extensive connections to all Mediterranean regions. Both studies confirm that ports with higher centrality scores play a dominant role in cruise itineraries. Esteve-Pérez and Río-González [27] identified Barcelona, Civitavecchia, and Piraeus as major hubs, reinforcing their strategic importance in Southern Europe. Our research similarly finds that Venice and Trieste serve as key departure hubs in the North Adriatic, mirroring the role of larger Mediterranean hubs. Furthermore, c emphasized that ports with high betweenness centrality act as key transit points. Our study supports that finding by showing that Corfu and Split have high betweenness scores, indicating their importance in linking cruise routes between different Mediterranean sub-regions. While [27] analyzed Southern Europe's cruise network, our study provides a more region-specific focus on the North Adriatic Sea, which has been less studied in cruise network literature. By examining the interactions between North Adriatic and Mediterranean ports, this research contributes new insights into the competitiveness of a sub-regional cruise market. Additionally, this study introduces a new classification system for cruise ports based on centrality measures, distinguishing between departure hubs (Venice, Trieste), transit ports (Corfu, Split), and well-connected secondary ports (Zadar). Moreover, while [27] examined cruise ship calls pre-COVID (2015-2019), this study includes recent data for 2024, providing a more updated view of the cruise industry's recovery and evolving network dynamics. However, both studies provide interesting insights into port connectivity and offer a new way to compare competing ports. In addition, our research presented a ranking of ports based on the connectivity measures.

The results of our research can be valuable to itinerary planners in identifying the role of different ports in the North Adriatic region. Furthermore, the relationships and connections between cruise ports uncovered in this study can inform the development of new itineraries, giving cruise lines a competitive edge and attracting new cruise destinations. In addition, comparing cruise ports based on these measures provides new insights into their operations, helping cruise lines to position themselves and enhance their market presence strategically. By using this data, cruise lines can optimize their itineraries, improve operational efficiency, and increase passenger satisfaction, thereby solidifying their dominance in the competitive cruise market.

5 Conclusions

The experimental results on the connectivity and competitiveness of the NA cruise port network show that the proposed measures perform relatively well compared to individual traditional measures, such as ranking ports by total number of cruise passengers per year and cruise ship calls per year; and also ranking ports differently. Centrality measures, including closeness, eigenvector, betweenness, and degree centrality, offer unique insights into a port's competitive position within the cruise network. These measures, collectively, provide a comprehensive view of the port network, enabling detailed competitive analysis. The centrality analysis of the North Adriatic Sea cruise ports system provides crucial insights into their connectivity and competitive positioning. These measures are essential for understanding the dynamics of the cruise industry, particularly in the Mediterranean and North Adriatic regions, which aids in optimizing itineraries, enhancing passenger experiences, and improving operational performance. High-ranked ports attract cruise lines and passengers, boosting economic benefits. Recognizing their competitive position allows for targeted strategies to enhance attractiveness and efficiency. Integrating competitive and centrality measures is crucial for sustainable growth and resilience in the cruise industry. The analysis used four centrality measures: degree centrality, betweenness centrality, closeness centrality, and eigenvector centrality. Zadar was found to be the most important port in terms of degree centrality, with 13 direct incoming connections, making it an attractive destination in the National Airport System. Venice ranked highest in unweighted outdegree centrality. Venice ranked highest in unweighted outdegree centrality with 14 out-going connections, indicating its significant departure point role in NA system. Zadar also led in unweighted eigenvector centrality with 0.364, while Venice followed closely with 0.297, indicating its importance in the network. Overall, the results illustrate that while Zadar has the highest incoming connections, Venice remains a pivotal hub with significant outgoing connections and high passenger traffic. Regarding betweenness centrality, the analysis identified critical transit ports, with Corfu being highlighted as a major transit port in the Mediterranean system, indicating its role in connecting different parts of the network. Closeness centrality results indicated that ports with higher scores can reach all other ports more quickly. Corfu was identified as the most efficient port, followed by Split and Dubrovnik. The study underscores that well-connected ports are likely to attract more cruise traffic, enhancing local economies. Ports with high centrality scores tend to have higher passenger numbers, suggesting a direct correlation between connectivity and economic benefits. The findings emphasize the need for cruise lines to optimize itineraries based on the connectivity and centrality of ports. By leveraging insights from centrality measures, cruise lines can enhance operational performance, improve passenger experiences, and strategically position themselves within the competitive cruise market. As noted, cruise ports and lines continually seek innovative methods to assess their competition and enhance their efficiency. These centrality measures offer a novel approach to evaluating the competitive positioning of cruise ports in the cruise market. The analysis underscores the importance of these centrality measures in understanding the operational dynamics and competitive positioning of cruise ports in the North Adriatic Sea.

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Appendix A

Table 1 Network analysis of cruise ships arrivals in August 2024

Port	Indegree unweighted	Outdegree unweighted	Indegree weighted	outdegree weighted	C^E unweighted	C^E weighted	C^C	C^B	C^E unweighted Rank	C^E weighted Rank	Indegree weighted Rank	Outdegree weighted Rank	C^C Rank	C^B Rank	out-in
Kotor	12	11	75	75	0.348	0.481	0.465	0.118	3	1	1	2	4	7	0
Dubrovnik	15	12	69	70	0.380	0.440	0.469	0.119	1	2	2	3	3	6	1
Venice	11	14	69	76	0.298	0.283	0.432	0.103	5	5	2	1	6	9	7
Zadar	13	11	62	62	0.365	0.321	0.426	0.062	2	4	4	4	9	13	0
Corfu	11	12	55	55	0.183	0.395	0.496	0.183	10	3	5	5	1	1	0
Split	12	14	45	44	0.329	0.231	0.492	0.175	4	6	6	6	2	2	-1
Trieste	8	7	37	40	0.279	0.205	0.420	0.013	6	7	7	7	10	26	3
Bari	6	7	28	28	0.212	0.197	0.408	0.010	8	8	8	8	12	28	0
Hvar	6	6	26	26	0.221	0.142	0.382	0.005	7	9	9	9	16	33	0
Santorini	5	8	26	26	0.069	0.094	0.420	0.042	23	13	9	9	10	15	0
Mykonos	6	4	23	23	0.117	0.096	0.392	0.034	14	12	11	11	15	17	0
Piraeus	7	5	22	13	0.094	0.040	0.395	0.056	18	20	12	15	14	14	-9
Koper	5	6	21	21	0.198	0.138	0.397	0.014	9	10	13	12	13	25	0
Rovinj	3	4	21	21	0.103	0.111	0.328	0.002	15	11	13	12	40	40	0
Katakolon	5	7	20	20	0.075	0.092	0.432	0.105	22	14	15	14	6	8	0
Rijeka	4	3	12	12	0.088	0.037	0.326	0.002	19	22	16	16	42	43	0
Kefalonia	5	5	11	11	0.042	0.028	0.462	0.160	29	24	17	17	5	4	0
Ancona	3	3	10	10	0.066	0.023	0.368	0.004	24	25	18	18	21	36	0
Sibenik	5	4	9	9	0.150	0.037	0.357	0.007	11	23	19	19	28	30	0
Brindisi	3	3	8	8	0.132	0.057	0.382	0.015	12	17	20	20	16	24	0
Valletta	4	4	8	8	0.076	0.037	0.429	0.150	21	21	20	20	8	5	0
Chivitavecchia	4	3	8	5	0.011	0.001	0.380	0.174	40	44	20	26	18	3	-3
Zakynthos	1	2	7	7	0.025	0.061	0.361	0.001	34	15	23	22	26	46	0
Piran	2	1	6	6	0.097	0.057	0.349	0.000	17	16	24	23	31	50	0
Korcula	3	3	6	6	0.117	0.040	0.364	0.001	13	19	24	23	25	44	0
Vis	2	1	5	5	0.099	0.052	0.339	0.002	16	18	26	26	37	41	0
Kusadasi	3	2	5	5	0.024	0.004	0.324	0.004	35	37	26	26	43	34	0
Sorrento	4	2	5	5	0.020	0.002	0.347	0.082	36	42	26	26	34	11	0
Ravenna	2	3	4	6	0.087	0.021	0.345	0.001	20	28	29	23	35	45	2
Monemvasia	1	1	4	4	0.010	0.008	0.324	0.000	44	32	29	31	43	50	0
Catania	1	2	4	4	0.010	0.003	0.361	0.002	42	38	29	31	26	42	0
Istanbul	1	2	4	5	0.003	0.000	0.353	0.004	49	48	29	26	30	35	1
Opatija	1	1	3	3	0.040	0.019	0.349	0.000	30	29	33	33	31	50	0
Naples	2	2	3	3	0.011	0.001	0.337	0.036	41	45	33	33	38	16	0
Crotone	2	2	3	3	0.005	0.000	0.366	0.007	48	49	33	33	24	31	0
Livorno	1	2	3	3	0.001	0.000	0.296	0.097	52	50	33	33	52	10	0
Monopoli	1	2	2	2	0.047	0.021	0.377	0.006	25	26	37	37	19	32	0
Salerno	1	1	2	2	0.047	0.021	0.368	0.018	25	26	37	37	21	22	0
Rab	1	1	2	2	0.040	0.013	0.306	0.000	30	30	37	37	48	50	0

Port	Indegree unweighted	Outdegree unweighted	Indegree weighted	outdegree weighted	C^E unweighted	C^E weighted	C^C	C^B	C^E unweighted Rank	C^E weighted Rank	Indegree weighted Rank	Outdegree weighted Rank	C^C Rank	C^B Rank	out-in
Giardini Naxos-Taormina	2	2	2	2	0.025	0.009	0.370	0.034	33	31	37	37	20	18	0
Heraklion	1	1	2	2	0.010	0.004	0.308	0.001	44	36	37	37	47	47	0
Lefkada	1	1	2	2	0.018	0.003	0.300	0.001	37	39	37	37	50	48	0
Itea	2	2	2	2	0.016	0.002	0.328	0.034	38	40	37	37	40	19	0
Patmos Island	1	1	2	2	0.013	0.002	0.335	0.002	39	43	37	37	39	39	0
Messina	1	1	2	2	0.001	0.000	0.316	0.000	54	53	37	37	46	50	0
Pula	1	1	1	1	0.040	0.006	0.319	0.000	30	33	46	46	45	50	0
Amalfi	1	1	1	1	0.045	0.005	0.368	0.018	27	34	46	46	21	23	0
Bar	1	1	1	1	0.045	0.005	0.349	0.000	27	34	46	46	31	50	0
Gythion	1	1	1	1	0.009	0.002	0.345	0.000	46	41	46	46	35	50	0
La Goulette-Tunis	1	1	1	1	0.010	0.001	0.305	0.008	42	46	46	46	49	29	0
Sarande	1	1	1	1	0.006	0.001	0.357	0.000	47	47	46	46	28	50	0
Corinth Canal	1	1	1	1	0.002	0.000	0.248	0.000	51	51	46	46	56	50	0
Gaeta	1	1	1	1	0.003	0.000	0.262	0.012	50	52	46	46	54	27	0
Positano	1	1	1	1	0.001	0.000	0.300	0.003	52	54	46	46	50	37	0
Trapani	1	1	1	1	0.001	0.000	0.261	0.002	55	55	46	46	55	38	0
Cannes	1	1	1	1	0.000	0.000	0.233	0.066	57	56	46	46	57	12	0
Ponza Island	1	1	1	1	0.000	0.000	0.231	0.001	56	57	46	46	58	49	0
Palma de Mallorca	1	1	1	1	0.000	0.000	0.190	0.033	59	58	46	46	59	20	0
Palmarola	1	1	1	1	0.000	0.000	0.280	0.021	58	59	46	46	53	21	0
Barcelona	1	0	1	0	0.000	0.000	0.160	0.000	60	60	46	60	60	50	0