Identification and Differentiation of the Hierarchical Structure of the Caribbean Cruise Shipping Network Based on Route Organization

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Abstract: In recent years, with the continuous expansion of the global cruise tourism market, global and regional cruise shipping networks have gradually formed and improved. Among them, the Caribbean cruise shipping network is particularly mature and complex, with a typical regional spatial organization. This paper takes cruise routes as the starting point to analyze the basic characteristics of the Caribbean cruise shipping network, investigate their hierarchical structure and spatial differentiation characteristics, and summarize the general spatial laws of a regional cruise shipping network. The results show that Caribbean cruise routes are mostly circular, and some of them have multi-circular sections. Medium and short cruise routes are common, and most cruise routes usually include sailings that last for a week. The cruise network forms an inverted V shape with the Florida Peninsula as the core connecting the eastern and western Caribbean Seas. There are differences in the number of sailings and centrality of different ports, thus forming the functional differentiation of core hub ports, functional hub ports, and general ports. The Caribbean cruise shipping network is divided into different hierarchies; with the increasing complexity of hierarchies, the numbers of ports and shipping groups have increased, the number of sailings and the centrality show rising trends, and the structure of the cruise shipping network tends to be complicated and the coverage tends to be broad. The three hierarchies basically reflect the core, skeleton, and overall pattern of the Caribbean regional cruise shipping network, and the core hierarchy includes most of the core hub ports.

Keywords: cruise ship; caribbean; cruise route; port; network hierarchy; shipping group; differentiation

1. Introduction

In recent years, the global cruise tourism market has continued to expand, and high-density cruise routes (CRs) (in the sense of the trajectories of cruise passenger flows) and high-frequency sailing organization are leading to more cruise ports and expanded cruise shipping networks [1]. Globally, the distribution of CRs is unbalanced, showing obvious regional concentration, and the regional difference of cruise shipping networks is obvious. CRs are concentrated mainly in North America and Europe, especially in the Caribbean, the Mediterranean, and other regional tourism-market areas; of these, the Caribbean is the world’s most developed cruise tourism market [2]. As the core content of cruise tourism activities [3], cruise shipping networks are important research objects in transport geography, and, in cruise research, the concept of “flow” is especially important and plays a role in reshaping the economy, society, and culture of ports [4]. A CR reflects the sailing direction and starting and ending ports of a cruise ship, and unlike traditional freight lines, CRs have both shipping and leisure functions. Apart from their traditional transportation functions, cruises also involve the development of scenic spots on shore and cruise tourism services [5,6]. CRs are often characterized by many ports of call, short time cycles, and complex port connections, thereby leading to rules that differ from those of traditional...
freight lines regarding route organization and spatial layout. Cruise tourism is closely related to regional development and plays an important role in driving regional economic growth, improving city image, and shaping port functions [7–10].

In research into cruise shipping networks, the cruise port is an important entry point and analysis object [11]. Ports are the basic component units of CRs: planning a CR requires a reasonable choice of ports, and the expansion of the cruise market requires connecting new ports as new carriers of the market [12]. The location conditions of cruise ports and surrounding leisure tourism resources determine the spatial organization pattern of CRs, and the choice of new ports of call is closely related to their locations [9]. In the regional cruise tourism market, certain preconditions, such as safety environment and high accessibility, must be met for a port to become a new node of the shipping network [12]. CRs connect many ports and different tourist destinations and so are the basis of cruise shipping network organization and form a “point–line” integration situation [6]. Some scholars have focused on the research perspective of ports and CRs, analyzed the spatial organization mode of cruise ports and CRs from the perspective of nodes and channels, and discussed the formation mechanism and interaction relationship of cruise shipping networks from the perspective of ports, terminals, and enterprise organizations [13–16]. Some scholars have attached importance to analysis from a network perspective: they analyzed the spatial structure, spatial connection laws, and complexity of shipping networks from an overall perspective and studied the basic characteristics of regional or global shipping networks [17–20]. In addition, some scholars have focused on the planning and design of CRs and have established mathematical models for quantitative evaluation and simulation analysis of node design, route operation, and ship scheduling [21–24]. In terms of research methods, scholars have in recent years mostly used different methods—such as statistical analysis [3], principal component analysis [25], complex network analysis [18,20,26,27], and econometric modeling [19]—to conduct quantitative research on important port nodes and organizational relations between port nodes of shipping networks. However, they have tended to concentrate on container shipping networks, and there has been limited quantitative analysis of cruise shipping networks because of a lack of data. Recently, cruise tourism has been facing great challenges, such as the COVID-19 epidemic [28], the increasing frequency of accidents [29] and the new environmental effects [30]. With the rising public concerns of health and safety, some scholars have expanded the studies in health crisis management and safety management of cruise [29,31]. In addition, some scholars concentrate on the emissions of cruise ships, studying environmental effects of CRs [30,32,33].

In general, previous studies were mostly focused on the global CR network, with few studies of regional CR networks and regional spatial organization modes. Regarding cruise shipping networks, the Caribbean is the most mature region and is representative of a regional cruise shipping network. To date, research on cruise shipping networks has mostly used the analysis methods for container shipping networks but has failed to consider the particularities of cruise tourism activities and how they affect the sailing organization and shipping network. There has been much research on cruise ports and especially individual cruise home ports, but there has been little research on the spatial organization, shipping groups, and shipping networks of cruise ports and CRs. When analyzing shipping groups and hierarchies, scholars mostly use the concepts of social network components and factions for abstract analysis [26], but that approach lacks scientific judgment and accurate condensing suitable for the characteristics of shipping networks. As a special shipping network, the particularity of a cruise shipping network lies in its dual properties of transportation and tourism. Shipping groups, formed by a series of ports connected, reflects the key shipping organization links in the cruise shipping network. Against this background, the present paper is focused on the regional spatial organization of CR shipping, taking the Caribbean as the research area. Herein, we (i) construct a shipping-group identification model based on CR features, (ii) analyze the basic spatial features, organization rules, and distribution pattern of the CRs, (iii) depict the importance and functional differentiation of cruise ports, (iv) analyze accurately the structure of the cruise shipping network, (v) summarize the
spatial scope and characteristics of different hierarchies of the network, and (vi) reveal the spatial organization rules of regional cruise shipping networks.

2. Data and Methods

2.1. Data Sources

The analysis area for the present study is the Caribbean Sea, and the analysis data include those for CRs, cruise ports, and other basic data. We make the following comments regarding the data sources. (1) The Caribbean is a relatively independent geographical area. Based on the regional integrity of the cruise network and the consistency of the CRs, the present research scope is expanded reasonably to cover the Caribbean Sea, the Gulf of Mexico, and some areas along the Pacific coast of North America and the northern coast of South America, forming a pan-Caribbean research area. (2) The important research data herein are those for CRs, obtained mainly from the Cruise Critic website (https://www.cruisecritic.com/) from 1 December 2021 to 31 December 2021 that hosts Caribbean CR data and involves 366 routes in total. The CR data include the following main information: the name of the CR, its sailing days and number of ports of call, the names of its ports of origin, call, and destination, and the information about cruise ports and their countries. These data contain adequate information about ports and CRs, and is normally used in cruise study [17]. (3) The cruise port is also an important research object herein and is the basic analysis unit; in total, 127 cruise ports or destinations are selected, all located in the pan-Caribbean region. (4) The data were collected in December 2021, with a total of 31 days of CR data. (5) The pan-Caribbean region is divided into the regions of the Florida Peninsula, the Gulf of Mexico, and the eastern, western, and southern Caribbean according to the naming traditions of land and sea patterns and geography. The Florida Peninsula region includes the Florida Peninsula located in the mainland of the United States and the Bahamas to its east; the Gulf region is mainly the northern Gulf of Mexico; the eastern Caribbean includes mainly eastern Mexico, southern Cuba, and Jamaica; the southern Caribbean includes mainly eastern Mexico, southern Cuba, and Jamaica; the southern Caribbean includes the southern coast of the Caribbean Sea and northern South America.

2.2. Methods

The ongoing research goal of port geography is how to describe the internal differentiation of a shipping network. Herein, we seek to describe and evaluate a cruise shipping network from the perspective of shipping groups combined with port centrality and numbers of ship sailings. The latter two are evaluated from a “point” perspective, with the number of ship sailings reflecting the scale of a port and the port centrality reflecting its pivotability. Shipping groups depict the internal differentiation and hierarchies of the cruise ship network.

The number of sailings $T$ at a cruise port reflects the connection intensity between it and other cruise ports and represents its scale. If the number of sailings in line $i$ is $m_i$, then $T$ is calculated as

$$ T = \sum_i m_i. $$

Jeon et al. pointed out that centrality is an important indicator for evaluating the pivotability of ports [34], and commonly used centrality indices are degree centrality, betweenness centrality, and closeness centrality. In the shipping network, the total number of cruise ports is $n$. The degree centrality reflects the connection between a cruise port and other ports and is calculated as

$$ C_{RDi} = \frac{d(i)}{n - 1} $$
where \( d \) is the degree of a cruise port, i.e., the number of cruise ports directly connected to it. The betweenness centrality reflects the transit capacity of a cruise port as an intermediate node and is calculated as

\[
C_{RBi} = \frac{2 \sum_{j<k} g_{jk}(i)}{(n-1)(n-2)}
\]

where \( g_{jk} \) is the number of paths connecting cruise ports \( j \) and \( k \), and \( g_{jk}(i) \) is the number of paths passing through cruise port \( i \). Finally, similar to transport accessibility, the closeness centrality reflects the proximity of a cruise port to other cruise ports and is calculated as

\[
C_{RPi}^{-1} = \frac{\sum_{i<j} d_{ij}}{n-1}
\]

In the organization of CRs, there is the common phenomenon that a series of cruise ports is connected and forms a port–line section that is called the shipping group. Some groups of ports are closely linked, often as a common part of different CRs. Meanwhile, repeated shipping groups also reflect the common part of different CRs; these show core ports, key channels, and main tourist markets in the CR organization and reflect its spatial laws. Therefore, analyzing shipping groups is an important way to identify the spatial organization pattern of a CR network. Shipping group \( L \) is defined as

\[
L(k) = \bigcap_{i \in [1,n]} H_i
\]

where \( n \) is the number of CRs, \( H_i \) represents CR \( i \), and \( k \) is the number of CRs intersecting, which reflects the number of repeated shipping groups in different CRs. In addition, the length of a shipping group is denoted as \( l \), indicating that there are \( l \) ports from the start to the end; in general, \( l \) is not less than 3.

3. Cruise-Line and Port Features of Caribbean

3.1. Distribution Pattern of Cruise Routes

Under the comprehensive influence of landform, sea shape, and land and sea patterns, the spatial organization of Caribbean CRs shows certain spatial rules (Table 1). There are 366 CRs in the Caribbean, forming an organizational differentiation between circular and non-circular routes. The general characteristic of cruise tourism activities is “where there is a go, there must be a return”. Many cruise ships form circular sailings, and such routes have the same ports of departure and destination. In the Caribbean, the majority of the routes are circular, amounting to 327 in total and accounting for 89.3% of the total. This shows that the circular route is a general pattern of cruise-travel route organization. However, there are only 39 non-circular CRs with different departure and destination ports, accounting for 10.7% of the total; this has become a special pattern of CR layout and cruise tourism organization. Note that some routes form small circles, forming the spatial organization mode of “small loop inside big loop”. In this spatial model, the ports connecting different ring routes in the same CR are usually large integrated home ports or important destination ports, such as Miami, Port Everglades, Port Canaveral, Guadeloupe, and Martinique. There are only 15 non-closed routes without a circular navigation track, accounting for 4.1% of the total, which is a very low number; this has become a special phenomenon of CR organization. There are 266 routes with a circular navigation track, accounting for 72.7% of the total, with high number and proportion. There are 85 routes with two or more loops, accounting for 23.2% of the total; “small loop inside big loop” has become an important feature of CRs. Most of the non-circular routes involve private islands in the eastern Caribbean, such as Barbados, St. Martin, and San Juan. These have airports near their ports, which can route the flow of tourists back to their departure points. In addition, although some routes have different ports of departure and destination, both are located in mainland United States, and travelers can be returned by land transportation, such as from Miami.
to New York. Cruise tourism activities form two types of travel patterns, i.e., “sea to sea and back” and “sea to land and back”, but the former is the main one, which reflects the general law of cruise tourism activities.

| Shape                        | Explanation                                      | Count | Proportion |
|------------------------------|--------------------------------------------------|-------|------------|
| End to end                   | The route has the same ports of departure and destination. | 327   | 89.3%      |
| Different beginning from end | The route has different ports of departure and destination. | 39    | 10.7%      |
| Small loop inside big loop   | There are multiple loops in the route.            | 85    | 23.2%      |
| Single loop                  | There is only one loop in the route.              | 266   | 72.7%      |
| Not closed                   | There is no loop in the route.                    | 15    | 4.1%       |

CRs are routes that provide tourism services, and their durations are often closely related to the travel periods of tourists. The different durations of travel demand cause CRs to have different duration–structure characteristics. Caribbean cruises range from a minimum of two nights to a maximum of 32, and in the sailing-duration distribution, most sailings are for fewer than 14 nights. Among them, 7-night sailings account for 29.2% of the total, followed by 5-night and 14-night sailings, accounting for 9.6% and 8.2% of the total, respectively. Seven-night and 14-night cruises predominate, reflecting the week-long nature of cruise travel. Because people’s work and rest are usually on a one-week cycle, a trip of moderate duration can not only ensure leisure quality but also avoid excessive fatigue. In addition, many social and economic activities are arranged on a one-week cycle, which leads to a high demand for one-week travel. In addition, the Caribbean Sea is a relatively closed area, and it is difficult to form long routes because of the influence of geographical scope and the spatial patterns of sea, land, and islands. Therefore, the one-week route is a relatively ideal CR organization mode.

The duration rule of CR determines its spatial distribution rule (Table 2). Because most Caribbean routes depart from the Florida Peninsula, the duration of a cruise determines how far it can go. The majority of short CRs are for fewer than seven nights, accounting for 53.8% of the total and mainly connecting the Florida Peninsula region and surrounding areas in the Bahamas (east of the Florida Peninsula) and the western Caribbean. Medium-duration CRs of more than eight nights and fewer than 14 nights account for 36.9% of the total and are distributed mainly in the eastern, western, and southern Caribbean. The number of long-duration CRs of over 14 nights is relatively small, accounting for only 9.3% of the total and mainly on southern Caribbean routes and some trans-regional routes.

As Figure 1 shows, Caribbean CRs cover areas including the Gulf of Mexico, the Caribbean coast, the Florida Peninsula, and the East Coast of the United States, forming a spatial structure approximating one core with two secondary cores; the one core is the Florida Peninsula, while the two secondary cores refer to the Antilles in the east and the Caribbean coast of Mexico’s Yucatan Peninsula in the west, where the connection of the CRs is very dense. This spatial structure forms an inverted V shape. In the southern Caribbean, the Atlantic Ocean, and the Sargasso Sea, CRs are sparse, especially along the west bank of
the Gulf of Mexico, where there are barely any cruise ports. The regionalization caused by spatial closure is a general characteristic of Caribbean cruise-network organization. The uneven spatial distribution of CRs forms a multi-core, multi-cluster, and multi-radial network spatial pattern. The CRs form several cores such as the Florida Peninsula, the Lesser Antilles, Cozumel Island, and Aruba Island and thus form multiple radiative networks connecting the surrounding areas, forming multiple clusters that are densely populated spatially with Florida–eastern Caribbean and Florida–western Caribbean routes. Located at the center of the regional geometry, the Florida Peninsula is the organizational core of a network of CRs that radiates north to the east coast of the United States, west to the Gulf coast, southwest to the Bahamas and the Antilles, and south to the coast of South America. The western islands of Cozumel and the Mayan coast of the Yucatan Peninsula form a localized radial network connecting the Florida Peninsula, the northern coast of Mexico, and Panama in the southern Caribbean. The eastern Antilles islands form a localized radiative network that connects the Florida Peninsula to Panama and the South American coastal islands of Aruba and Curaco.

![Figure 1. Cruise ports in the Caribbean Sea.](image)

**3.2. Numbers of Sailings at Ports**

The number of CRs associated with a port reflects its importance in the shipping network, while the associated frequency of cruise ships reinforces this, further promoting the depth of differentiation in the cruise shipping network. The calculated number of sailings at each cruise port in December 2021 is indicated in Table 3. The capacity of different ports to receive cruise ships, the source market of cruise passengers, and the local tourism resources are different, which leads to the different number of sailings at each port. The total number of sailings at a Caribbean port is between one and 49, the latter being for Miami, which has the most calls. The number of sailings basically presents a pyramid-like quantitative structure: with more sailings, there are fewer ports. There are six ports with 40–50 sailings, accounting for only 4.7% of the total, i.e., Miami, Port Everglades, St. Thomas, San Juan, St. Martin, and Nassau; these ports are located in the Florida Peninsula, the Antilles islands, and the Sargasso Sea—the former two are important tourist sources, and the latter four are the main tourist destinations in the Caribbean. There are seven ports with 30–40 sailings, accounting for only 5.5% of the total, i.e., Cozumel, St. Barts, Antigua, St. Lucia, Port Canaveral, Barbados, and St. Kitts; these are distributed mainly in the Antilles and are all tourist destinations. There are 14 ports with 20–30 sailings, accounting for 11.0% of the total, and there are 23 ports with 10–20 sailings, accounting for 18.1% of the total. Most ports have a small number of sailings, fewer than 10, involving 77 ports in total and accounting for 60.6% of the total.
Table 3. Amounts and proportions of sailings at ports in Caribbean Sea.

| Number of Sailings | Port Name                                                                 | Count | Proportion |
|--------------------|---------------------------------------------------------------------------|-------|------------|
| 40–50              | Miami, Port Everglades, St. Thomas, San Juan, St. Martin, Nassau           | 6     | 4.7%       |
| 30–40              | Cozumel, St. Barts, Antigua, St. Lucia, Port Canaveral, Barbados, St. Kitts | 7     | 5.5%       |
| 20–30              | Key West, Grenada, Grand Cayman, Aruba, Martinique, Dominica, Maya Coast, St. Vicente, Tortula, Grand Turk, Roatan, Ocean Cay MSC Marine Reserve, Puerto Plata, Jost Van Dyke | 14    | 11.0%      |
| 10–20              | Curacao, CocoCay, Quepos, Bonaire, Half Moon Cay, Amber Cove, Freeport, Galveston, Guadeloupe, Labadee, Great Stirrup Cay, Terre-de-Haut, Princess Cay, Cartagena, St. Kitts, Castaway Cays, Puntarenas, Illes des Saintes, Virgin Gorda, Colon, Charleston, Falmouth, Belize City | 23    | 18.1%      |
| 1–10               | New Orleans, Mayreau, Tampa, Ocho Rios, St. Croix, Puerto Jimenez, La Romana, etc. | 77    | 60.6%      |

3.3. Centrality of Ports

The origin, attachment, and termination of CRs, the interweave and overlap of CRs, and the sailing frequency make the positions and functions of ports different, which profoundly affects the development potential of ports. We calculated the centrality of each port, and the results are shown in Figures 2 and 3. The degree centrality of the cruise ports is between zero and 0.4, which varies greatly because of geographical factors and the route network structure. Nearly half of the cruise ports have a degree centrality of less than 0.05, and fewer than 10% have a degree centrality of more than 0.3, which indicates that only a few ports in the cruise shipping network are connected with most of the other ports in the network and have high shipping connectivity. These ports are mainly tourist source ports or major tourist destination ports. However, most ports are only connected with a few ports, and these ports are mainly tourist destinations with fewer tourism resources but outstanding characteristics. The betweenness centrality of the cruise ports is between zero and 0.2; 60% of the ports have a media centrality of less than 0.01, while only 5% of the ports have a media centrality of higher than 0.1. This reflects the fact that there are no ports obviously located in the middle channel in the cruise shipping network as a whole, and only a few ports show certain channel intermediation and serve as important port nodes through which many CRs pass. The closeness centrality of the cruise ports is between zero and 0.4, and the overall distribution is relatively uniform, showing the structural characteristics of low at both ends and high in the middle. This indicates that the closeness centrality of the cruise ports presents a relatively balanced spatial distribution, and there is no core port in the cruise network whose transport accessibility is significantly higher than that of other ports.

Figure 2. Spatial pattern of cruise shipping lines in Caribbean Sea.
According to their centrality, the cruise ports are divided into three categories by the K-means clustering method (Table 4). The first category is the core hub ports, including 14 cruise ports and accounting for 11.0% of the total. The degree centrality, betweenness centrality, and closeness centrality of the core hub ports are all at high levels: these ports are closely connected with other ports and are the core nodes of the CR network. The centrality of the functional hub ports is lower than that of the core hub ports, but there is usually a higher level of one type of centrality, which is the hub ports with specific functions or serving specific regions. Generally, the degree centrality, betweenness centrality, and closeness centrality of ports of call are low, and the hub function is low; they are the basic nodes in the cruise shipping network, with a large number and wide distribution.

The layout of such ports is relatively concentrated, mainly in the Florida Peninsula and the Antilles Islands, showing a trend of spatial agglomeration and distribution, with only two ports located in Mexico and Panama. From the perspective of tourist sources and destinations, there are two types of core hub ports: (i) home ports as

**Table 4.** Classification and amount structure of cruise ports in Caribbean Sea.

| Type                  | Port Name                                                                 | Count | Proportion |
|-----------------------|--------------------------------------------------------------------------|-------|------------|
| Core hub ports        | Miami, Nassau, Port Everglades, Cozumel, Puntarenas, St. Barts, St. Martin, St. Lucia, San Juan, St. Thomas, Antigua, Barbados, Grenada, St. Kitts (Port Sant) | 14    | 11.0%      |
| Functional hub ports  | Castaway Cay, Port Canaveral, Ocean Cay MSC Marine Reserve, Grand Cayman, Key West, Colon, Charleston, St. Kitts, St. island, Grand Turk, Guadeloupe, Jost Van Dyke, Dominica, Martinique, Terre-de-Haut, CocoCay, Maya, Roatan, Puerto Plata, Labadee, Half Moon Cay, Freeport, Amber Cove, Curacao, Aruba, Galveston, Belize City, Bonaire, St.Croix, Princess Cays, Great Stirrup Cay, Bequia, Tortola, St. Vicente, Cartagena (Colombia), Puerto Limon | 36    | 20.5%      |
| General ports         | Falmouth, Panama Canal, Isla Parida, Puerto Jimenez, Balboa, Quepos, etc. | 77    | 60.6%      |

| Count       | Proportion |
|-------------|------------|
| 0-0.05      | 10.0%      |
| 0.05-0.1    | 23.0%      |
| 0.1-0.15    | 16.0%      |
| 0.15-0.2    | 13.0%      |
| 0.2-0.25    | 13.0%      |
| 0.25-0.3    | 10.0%      |
| 0.3-0.35    | 0.4%       |
| 0.35-0.4    | 0.0%       |

**Figure 3.** Structure of centrality of cruise ports in Caribbean Sea.
tourist sources, such as Port Everglades in Miami in the United States, and (ii) scenic or tourist-destination ports visited frequently by tourists or CRs, such as Cozumel in Mexico and San Juan in the Antilles islands. The number of functional hub ports is 36, accounting for 20.5% of the total number of functional hub ports, which are distributed evenly along the Caribbean coast and form a ring of ports around the Caribbean. In addition, there are more functional hub ports in the Florida Peninsula and the Gulf coast; functional hub ports are mainly tourist-destination ports with rich tourism resources and high tourism quality. The number of general ports is the largest, up to 77, with a proportion of 60.6%. Their spatial distribution is more extensive and scattered, including the Caribbean Sea, the Gulf of Mexico, northeastern United States, and the Pacific coast of North America. These are mainly small tourist-destination ports or low-frequency tourist-source ports connecting the Caribbean Sea. On the whole, cruise ports form a specific spatial distribution pattern: core hub ports in a cluster distribution, functional hub ports in a ring-belt distribution, and general ports in a dispersed distribution.

4. Cruise Shipping Groups and Shipping Network Hierarchies of the Caribbean

4.1. Identification of Cruise Shipping Groups

The interweaving and overlapping of different CRs have led to differentiations in port status, port functions, and port linkages, prompting ports to form different groups and hierarchies (Table 5). These groups and hierarchies reflect the key areas of the CR shipping network, which in turn reflect the key cruise tourism markets. The $K$ value of the preceding model has a characterization effect on the hierarchical structure of the shipping groups. When $K = 1$, there are 161 shipping groups in total, involving 93 ports and accounting for 73.2% of the total. When $K = 2$, the numbers of ports and groups are the same as those when $K = 1$, indicating that all shipping groups involved in the previous model have been identified. With increasing $K$, the numbers of ports and groups decrease gradually, and the hierarchical structure of the shipping network continuously shrinks and condenses. When $K = 5$, the proportion of groups drops below 20% for the first time, and the proportion of ports drops below 30% for the first time. When $K = 8$, the proportion of groups drops below 10% for the first time, and the proportion of ports drops below 20% for the first time. When $K = 5$, the proportion of clusters falls below 5% for the first time, and the proportion of ports falls to ~10%. When $K = 15$, there is only one shipping group. With decreasing $K$, the number of shipping groups gradually increases, and the hierarchical structure of the shipping network keeps expanding and enriching.

Table 5. Indices corresponding to different $K$ values.

| $K$ Value | Number of Groups | Proportion | Number of Ports | Proportion | Number of Sailings | Degree Centrality | Betweenness Centrality | Closeness Centrality |
|-----------|------------------|------------|----------------|------------|-------------------|-------------------|-----------------------|----------------------|
| 15        | 1                | 0.6%       | 3              | 2.4%       | 26.3              | 0.209             | 0.053                 | 0.349                |
| 14        | 3                | 1.9%       | 9              | 7.1%       | 28.3              | 0.225             | 0.052                 | 0.346                |
| 13        | 4                | 2.5%       | 10             | 7.9%       | 27.3              | 0.217             | 0.048                 | 0.346                |
| 12        | 4                | 2.5%       | 10             | 7.9%       | 27.3              | 0.217             | 0.048                 | 0.346                |
| 11        | 5                | 3.1%       | 12             | 9.4%       | 25.9              | 0.206             | 0.042                 | 0.346                |
| 10        | 7                | 4.3%       | 15             | 11.8%      | 26.5              | 0.210             | 0.043                 | 0.346                |
| 9         | 9                | 5.6%       | 19             | 15.0%      | 27.5              | 0.218             | 0.052                 | 0.349                |
| 8         | 13               | 8.1%       | 25             | 19.7%      | 25.6              | 0.203             | 0.047                 | 0.344                |
| 7         | 23               | 14.3%      | 31             | 24.4%      | 25.6              | 0.203             | 0.045                 | 0.341                |
| 6         | 24               | 14.9%      | 32             | 25.2%      | 25.4              | 0.202             | 0.044                 | 0.342                |
| 5         | 32               | 19.9%      | 38             | 29.9%      | 23.8              | 0.189             | 0.044                 | 0.336                |
| 4         | 53               | 32.9%      | 45             | 35.4%      | 22.9              | 0.182             | 0.039                 | 0.330                |
| 3         | 76               | 47.2%      | 65             | 51.2%      | 18.1              | 0.143             | 0.030                 | 0.310                |
| 2         | 161              | 100%       | 93             | 73.2%      | 14.5              | 0.115             | 0.024                 | 0.294                |
| 1         | 161              | 100%       | 93             | 73.2%      | 14.5              | 0.115             | 0.024                 | 0.294                |
4.2. Structure of Shipping Network Hierarchies

According to the expansion characteristics of the shipping network with different $K$ values, this paper analyzes shipping groups with $K = 10, 8, \text{and } 5$ and describes the structural differentiation of the Caribbean port shipping network (Table 6).

Table 6. Structure of CR groups in Caribbean Sea.

| Hierarchy | $K$ | Ports | Ports Added |
|-----------|-----|-------|-------------|
| Level I   | 10  | Grand Turk, Port Everglades, Guadeloupe, Half Moon Cay, St. Thomas, Martinique, San Juan, Tortola, Amber Cove, St. Martin, Cozumel, Grand Cayman, Ocho Rios, Princess Cays, St. Vicente | - |
| Level II  | 8   | St. Martin, St. Kitts, Half Moon Cay, Port Everglades, Antigua, Tortola, St. Thomas, San Juan, Grand Turk, Guadeloupe, Dominica, Martinique, Aruba, Curacao, Barbados, St. Lucia, Amber Cove, Port of Spain, St. Vicente, Labadee, Cozumel, Princess Cays, Grenada, Grand Cayman, Ocho Rios | St. Kitts, Antigua, Dominica, Aruba, Curacao, Barbados, St. Lucia, Port of Spain, Labadee, Grenada |
| Level III | 5   | Martinique, Guadeloupe, Antigua, St. Martin, St. Kitts (Sant Port), St. Lucia, Dominica, Tortola, Barbados, St. Thomas, San Juan, Port Everglades, Half Moon Cay, St. Vicente, Grenada, Port of Spain, Miami, Puerto Plata, Aruba, Grand Turk, Curacao, Ocean Cay MSC Marine Reserve, Grand Cayman, Ocho Rios, Cozumel, Maya Coast, Labadee, Princess Cays, Amber Cove, Belize City, Bonaire, Port Canaveral, Cartagena (Colombia), Colon, Puerto Limon, Roatan, Saba, St. Barts | Belize City, Bonaire, Cartagena (Colombia), Colon, Costa Maya, Miami, Ocean Cay MSC Marine Reserve, Port Canaveral, Puerto Limon, Puerto Plata, Roatan, Saba, St. Barts |

Level I. The number of shipping groups at this level ($K = 10$) is small: there are seven groups in total, and each group covers a small number of cruise ports. Among them, three shipping groups involve four ports each, and the remaining four shipping groups involve three ports each. There are 15 ports involved in this level, accounting for 11.8% of the total: these are Port Everglades, Grand Turk, Guadeloupe, Half Moon Cay, St. Thomas, Martinique, San Juan, Tortola, Amber Cove, St. Martin, Cozumel, Grand Cayman, Ocho Rios, Princess Cays, and St. Vicente. These ports are mainly tourist-destination ports, distributed mainly in the Greater Antilles islands, which contain 10 ports. The rest are in the western Caribbean or the Bahamas, with two each. Only one is located in the tourist-source market of the Florida Peninsula. The frequency of occurrence of a port in different shipping groups can reflect its core position in the cruise shipping network. In this level, the ports with the most frequent group affiliations are Port Everglades and St. Thomas, with four and three groups, respectively, which are the converging ports of most shipping groups. Port Everglades is an important home port of the Florida Peninsula, with important functions of tourist distribution and airline organization, and St. Thomas is the destination and home port of the eastern Caribbean.

Level II. At this level ($K = 8$), the number of shipping groups increases to 13, and the number of ports involved increases to 25, accounting for 19.7% of the total. These ports are still mainly distributed in the Antilles islands and are mainly important tourist-destination ports. Among them, the largest shipping group involves even ports. The most frequent group-attached port is still Port Everglades, with five shipping groups. The second are St. Martin and Guadeloupe, located in the Lesser Antilles, which are connected to four shipping groups. Half Moon Cay, Barbados, and Martinique are all linked to three shipping groups. Among them, St. Maarten, Guadeloupe island, Martinique, and Barbados are
located in the Lesser Antilles islands in the eastern Caribbean; the surrounding area has many private islands and tourist attractions, and the CR organization is mixed, forming a dense cruise shipping area. Half Moon Cay is adjacent to the Florida peninsula, located at the meeting point from the United States to the south and east Caribbean; it is located in the Bahamas and is rich in tourism resources.

Level III. This level ($K = 5$) has the largest number of shipping groups, i.e., 32, involving 38 ports and accounting for 29.9% of the total. Note that these ports include many island ones and are distributed mainly in the Lesser Antilles and the Bahamas; islands, ports, and ships develop together. Among them, the number of ports involved in a shipping group is up to 10. In this hierarchy, the ports with the most frequent group attachments are Port Everglades and Martinique, with nine shipping groups. Guadeloupe is next, which is linked to eight groups. Martinique is an island in the eastern Caribbean, just south of the Lesser Antilles. With the extension of the cruise shipping network, in addition to its internal contact with the Antilles islands, Martinique’s connection also extends to the southern Caribbean and the coast of South America, thereby increasing the port shipping group.

4.3. Spatial Patterns of Shipping Network Hierarchies

The shipping groups at different levels are shown in Figure 4, and each level has its own characteristics and spatial rules.

In level I, the ports of Port Everglades and St. Thomas are the core. The ports in the Florida Peninsula, the Bahamas, and the Lesser Antilles are connected, forming a northwest-to-southeast shipping group that forms the market relationship between tourist sources and tourist destinations. This shows that Florida–eastern Caribbean is the backbone of the Caribbean cruise network. In addition, the three ports of Cozumel, Grand Cayman, and Ocho Rios in the western Caribbean form a relatively independent shipping group and become the core of the CR network in the western Caribbean, but they are connected mainly with island ports and have the market relationship of tourist destinations. Port Everglades is the core hub port of the shipping group, connected to Grand Turk via Half Moon Cay and extending to San Juan and St. Thomas. There are both direct and indirect connections among ports, forming a complex cruise shipping network. For example, Port Everglades is connected to Grand Turk both directly and through Half Moon Cay, forming a partially closed loop route. The structure of the level-I group is relatively simple, but it has certain rules of route organization. It is the core part and skeleton of the Caribbean shipping network.

Figure 4. Spatial patterns and types of cruise ports in Caribbean Sea.
Level II expands and extends on the basis of level I. Level II has Port Everglades, St. Martin, and other ports as its core and connects the Florida Peninsula, the Bahamas, and the Lesser Antilles from northwest to southeast. In this hierarchy, the Lesser Antilles islands form a relatively dense group of routes, reflecting the region as a rich source of tourism resources and an important tourist destination formed by the rich routes. As a whole, this level of shipping cluster extends farther south, to Port of Spain on the northern coast of South America. In addition, Port Everglades and Half Moon Cay connect Aruba and Curacao directly to the south, establishing a shipping link between Florida and the Bahamas to the northern coast of South America. The shipping-group structure of this level is relatively complex, covering mainly the eastern Caribbean Sea route while also involving the western and southern ones, which reflects roughly the overall pattern of the Caribbean Sea shipping network.

Level III is a further extension of level II. The hierarchical cluster shows a complex network pattern of multi-core and multi-cluster. With the core hub ports of Miami, Port Everglades, and Port Canaveral in the Florida Peninsula, level III connects the ports of call in the eastern, western, and southern Caribbean, forming a group of shipping routes radiating southward. The western Caribbean Sea, with Cozumel as its core, connects the home port of Florida and the coastal ports of Coastal Maya, Belize City, and other western coastal ports, and connects Grand Cayman and Ocho Rios to the east, forming a local shipping network in the western Caribbean Sea. The eastern Caribbean Sea connects the Antilles Islands with ports such as San Juan, Antigua, and Martinique as the core and extends to the Bahamas and the Florida Peninsula to the north and to the northern coast of South America to the south. In addition, there are independent cruise shipping links between some South American ports; Puerto Limon, Colon, and Cartagena form a relatively independent shipping group in Panama. The shipping groups at this level are interlaced with each other and have complex structures, which basically cover the whole Caribbean region and reflect the overall pattern and core architecture of the Caribbean shipping network (Figure 5).

![figure 5](image_url)

**Figure 5.** Structure of CR groups in Caribbean Sea.

4.4. Features and Rules of Shipping Network Hierarchies

By comprehensive analysis of the hierarchical pattern and structure of the shipping network, the following characteristics can be summarized.

(1) The main areas connected by shipping groups at different levels are different, but some common key areas are formed. The shipping cluster of level I is concentrated in the area from the Florida Peninsula to the Lesser Antilles via the Bahamas, forming the cruise shipping corridor from southwest to northeast, which is the core skeleton of the Caribbean cruise shipping network and concentrates most CRs and sailings. In addition, it
also includes the Cozumel–Grand Cayman–Ocho Rios shipping cluster, which is the main line to the western-Caribbean tourist destinations and forms the second cruise shipping corridor. On the basis of level I, level II extends to the southern Caribbean Sea and connects the northern coast of South America, forming the north–south structure of the Florida Peninsula, the Bahamas, the Lesser Antilles, Aruba, and Curacao. Level III is a further extension of the cruise network, connecting more extensively to ports in the western Caribbean, the Florida Peninsula, the southern Caribbean, and the Greater and Lesser Antilles islands. The cruise network structure is more complex than level II.

(2) The number of ports involved in shipping groups at different levels is relatively small, but there are many sailings involved. Although the number of cruise ships attached to each port shows a decreasing phenomenon, the decrease is small. The number of ports involved in level I is 15, accounting for 11.8% of the total number of ports; the number of sailings is 397, accounting for 26.9% of the total number of the sailings, and the average number of sailings is 26.5. Level II covers 25 ports, accounting for 19.7% of the total number of ports; the number of sailings is 640, accounting for 43.3% of the total number of sailings, and the average number of sailings at ports is 25.6, a slight decrease. There are 38 ports involved in level III, accounting for 29.9% of the total number of ports; the number of sailings is 906, accounting for 61.3% of the total number of sailings, and the average number of sailings in each port is 23.8, showing an obvious trend of decline. The network formed by level III already reflects more than 60% of the shipping links in the Caribbean.

(3) The identification based on shipping groups is applicable mainly to the identification of important tourist destinations located in the middle of the route, but the identification results are not completely consistent with those of hub ports based on centrality. Level I is the core of the shipping network, including most of the core hub ports, such as Port Everglades, Cozumel, St. Martin, St. Lucia, San Juan, St. Thomas, Antigua, Barbados, Grenada, and St. Kitts. These ports are located mostly in the Antilles Islands, and the CRs are densely organized and the ports are closely connected with cruise ships. Some ports, such as Port Everglades, serve as tourist hubs for the region. The ports of Miami and St. Barts were added to levels II and III. Among the core hub ports, Nassau and Puntarenas are not included in level III. Nassau is located in the Bahamas, and with most of its routes to and from the United States, the organization is relatively simple. Puntarenas, on the other hand, is located in the southwest Caribbean and has a relatively simple route organization with few shipping groups. At the same time, the ports in level I include functional hub ports such as Grand Turk, Half Moon Cay, and Princess Cays, which are important travel destinations. Although the number of sailings and centrality are only in the middle level, they still play an important role in the cruise travel organization.

5. Discussion and Conclusions

CRs are shipping lines with both shipping and leisure functions. As one of the world’s most popular cruise tourism destinations, the Caribbean has the most mature and complex cruise shipping network. The geographical phenomenon of regional spatial organization is typical, but the interior presents relatively significant spatial differentiation. It is found that Caribbean CRs are mainly circular, with most of them having a circular structure while some have a multi-ringed structure. Most of the cruise routes are of short or medium duration, especially seven-day routes; cruise tourism takes one week as the travel cycle. The route distribution pattern forms the spatial pattern of a multi-core, multi-cluster, and multi-radial network. The hierarchy and structure of the shipping network are closely related to the distribution of its geographical elements. The core skeleton of the Caribbean network is split between the Florida Peninsula, a major destination for cruise tourists, and the Lesser Antilles, a tourist hotspot. The spatial separation of tourist sources and tourism resources determines the direction of tourism flow from north to south and promotes the formation of an inverted-V-shaped southward radiation structure of the cruise network. In addition, relatively independent local geographical areas form a certain internal structure and hierarchy. There are significant differences in the centrality of Caribbean
cruise ports, and there are obvious differences in port hub functions, forming the functional differentiation structure of 14 core hub ports, 36 functional hub ports, and 77 general ports. The core hub ports are distributed mainly in the Florida Peninsula and the Lesser Antilles islands, the functional hub ports are distributed mainly around the Caribbean Sea, and the distribution of general ports is relatively scattered. The Caribbean shipping network is divided into different hierarchies according to route group identification. The structure of level I is relatively simple, which is the core skeleton of the shipping network. Level II covers mainly the eastern Caribbean Sea routes and involves the western and southern Caribbean Sea. Level III is more complex, which basically reflects the overall structure and spatial pattern of the Caribbean cruise network. The port hierarchy has a good coupling with the number of dependent sailings and the centrality. With increasing shipping hierarchy (III → II → I), the number of sailings and the centrality of ports show an increasing trend. However, note that the core level has a good coupling relationship with most core hub ports but does not include some core hub ports with a simple shipping organization. This study breaks through the traditional methods of social-network and complex-network analysis and helps to identify the core port–line organizations in the high-density agglomeration areas of CRs, which has important guiding significance for cruise tourism planning and management.

Different geographical space and location factors have complex influence mechanisms on the formation and evolution of the shipping network. Regionalization is the basic concept of the organization of the cruise shipping network, but the regionalization of different regions still forms general and special differentiation. This paper reflects the general rules of the spatial organization of regional cruise shipping networks, but it also reflects the strong particularity of the Caribbean Sea. In general, this study provides insights into case studies of regional cruise shipping networks. Future research can draw lessons from the analysis method of route structure, port function differentiation, and shipping network hierarchy in this study and apply it to other regions. However, relevant research conclusions must be combined with regional characteristics to strengthen the particularity analysis when referring to other regions or scales. The particularity of the spatial structure, patterns, and laws of cruise shipping networks in different development stages and regions still requires further research.

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