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Port selection by container ships: A big AIS data analytics approach

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A R T I C L E I N F O

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A B S T R A C T

Port selection is of vital importance for both port operators and shipping lines. In this contribution, an Automatic Identification System (AIS) big data approach is developed. This approach allows identifying container ships using only AIS data without the need for supplementary information from commercial databases. This approach is applied to investigate the port selection statistics of container ships between Shanghai and Ningbo Zhoushan Port, two of the largest ports in the world in terms of calling frequency, to generate practical insights. Results show that: i) the ratios among large ships, medium ships and small ships of these two ports are both approximately 1: 4: 5; ii) these two ports both have an exclusive (i.e., more feeder ports covered in geographical coverage) and intensive (i.e., more feeder ships deployed in shipping service frequency) collection and distribution network mainly consisting of small ships, but that of Shanghai is more intensive; iii) in terms of ultra-large ships over 380 m, Shanghai has accommodated an extra 18.5% compared to that of Ningbo Zhoushan, this indicates Shanghai's attraction for such vessels in global fleet deployment; iv) the feeder network between Shanghai and Ningbo Zhoushan is weak, and their relationship is actually in competition; v) Ningbo Zhoushan could offer more choices for ultra-large container ships (over 380 m), which implies its greater potential in future port competition; vi) when the depth of channels and berths is sufficient, the distance to hinterland and the convenience of a collection and distribution network begin to get more important in port selection. The empirical findings unveil the decision-making of container lines, competition between ports and implications for shipping policy.

1. Introduction

Port selection is of vital importance for both port operators and shipping lines (Yang, Wu, & Wang, 2021). Usually, port operators aim to attract more ships, accommodate larger ships and handle ships more efficiently. Being selected by more shipping lines means stronger competitiveness in the context of port competition (Wang, Meng, & Zhang, 2014). For container shipping lines, port selection is related to the structure of the hub and spoke and relay networks, as well as their operation strategies (Munim, Duru, & Ng, 2022). Consequently, ports and shipping lines choose and collaborate with each other, and the pattern of container ship deployment and port calls in the current shipping industry takes shape in the end (Asgari, Farahani, & Goh, 2013).

The port selection problem is a hot research topic and has been discussed from different perspectives. Based on an analysis of 55 related papers researched from the Web of Science in the period 1998–2022 with the keyword 'port selection/ port choice', 31 research use Multi-Attribute Decision-Making (MADM) as the method. In this sense, MADM methods have been adopted as the most common approaches to analyse the problem of port selection which is complex and influenced by various factors. Guy and Urli (2006) selected 8 factors affecting port selection and explained the selection behaviour observed in the North-east of North America using the multi-criteria approach. Yuen, Zhang, and Cheung (2012) constructed 19 port choice factors and applied an Analytical Hierarchy Process (AHP) approach to evaluate the competitiveness of Chinese ports and other Asian ports. Lam and Dai (2012) concluded the 5 most common criteria for port selection and proposed a

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web-based decision support system to determine the port selection problem using the AHP methodology. Yeo, Ng, Lee, and Yang (2014) presented a fuzzy Multiple-Criterion Decision-Making (MCDM) model to assess 18 port choice factors in an uncertain environment from the shipping line perspective. Yang and Chen (2016) explored a global hub port assessment criteria including 20 items with a hybrid MCDM approach combining the AHP and Grey Relational Analysis (GRA). Hsu, Lian, and Huang (2020) investigated 14 factors impacting port choice and studied the port choice problem with a hybrid MCDM approach. Chowdhury and Haque Munim (2023) presented a fuzzy AHP-BWM-PROMETHEE approach for identifying the best location for a new dry port.

Besides the MADM approaches used to investigate factors in the port selection problem, other multidisciplinary efforts could also be witnessed for discussing a single factor. Lorena and Joaquin (2010) proposed a methodology based on non-parametric statistical techniques to analyse the impact of increasing inter-port competition on port preferences. Ferrari, Parola, and Gattorna (2011) revealed the role of a port's distance to the hinterland in port selection with the gravity model. Yeo, Pak, and Yang (2013) analysed the effect of port security levels on port choice by adopting the system dynamics approach. Wang, Meng, and Miao (2016) conducted data mining on global satellite ship data and analysed hub port choice in Southeast Asia. Zhu, Fu, and Bell (2021) investigated the effects of shipping line-port integration on port call choices of shipping lines with probit models and found that shipping lines preferred ports with adequate infrastructure. Felipe Souza, de Jong, and Yang (2023) investigated the port choice process from the perspective of exporters and importers. Pu, Bai, Hou, and Yang (2023) proposed an RDD-based model introducing firm-level characteristics to reveal heterogenous liners' potential port choice mechanisms.

The previous research suggested what factors should be taken into account in the early stage of port selection at the strategic level. However, the literature did not address the actual actions of shipping lines in their port call selection. This inadvertently raises questions regarding the evaluation of port performance that reflects reality. To measure port performance, Data Envelopment Analysis (DEA) (Cullinane & Wang, 2006; Cullinane, Wang, Song, & Ji, 2006; Jose, 2001) and stochastic frontier models (Cullinane, Song, & Gray, 2002; Cullinane & Wang, 2006; Jose & Wu, 2005) were employed as the Port Performance Indicators (PPIs). Wang and Cullinane (2016) proposed the Port Centrality Assessment (PCA) as a decision support tool for liner operators in the port selection or route choice at the conceptual phase. Wang, Zeng, Li, and Yang (2016) used the annualized slot capacity as an indicator to evaluate the port connectivity of the Bohai Bay Rim (China) logistic network. Ha, Yang, Notteboom, Ng, and Heo (2017) developed a new framework based on the combination of the Decision-Making Trial and Evaluation Laboratory (DEMATEL) tool and Analytical Network Process (ANP) together with Fuzzy Evidential Reasoning (FER) to measure port performance. Despite port performance being studied in the literature, a major gap and opportunity remains for investigating shipping line behaviour in their port selection using Automatic Identification System (AIS) big data. Jiang et al. (2023) explored how information integration afforded by the recent development of Port Centric ICT systems (PCIS) impacted port performance. Gningue, Bedoui, and Venkatesh (2023) proposed a port performance measurement approach using a sustainability balanced scorecard based on stakeholders' expectations. Yap, Hsieh, and Lee (2023) performed data analytics of liner shipping services to investigate shipping connectivity and container port performance.

According to IMO (2002), ships of 300 GT or over, and on international voyages are mandatorily required to install the AIS. The AIS equipment automatically exchanges information between ships and between ships and coastal stations. In this way, ships' information is recorded and stored in the coastal stations. Therefore, the historical AIS data provides an excellent approach to investigating the information related to ships and ports. Applications can be seen for areas pertaining to research concerning ship collision risk evaluation (Feng, Grifoll, Yang, & Zheng, 2022; Hörteborn & Ringsberg, 2021), shipping route detection (Wang, Li, Han, Osen, & Zhang, 2022), threat assessment (Serra-Sogas, O'Hara, Pearce, Smallshaw, & Canessa, 2021), traffic pressure monitoring (Lensu & Goerlandt, 2019; Madon et al., 2022), abnormal ship behaviours identification (Duan, Ma, Miao, & Zhang, 2022), ship motion pattern extraction (Rong, Teixeira, & Soares, 2022) and shipping policies mining (Bai, Hou, & Yang, 2021; Prochazka, Adland, & Wolff, 2019). Yap and Yang (2022) analysed the impact of COVID-19 pandemic on hub port choice and shipping connectivity using the case of major container ports in Southeast Asia with global satellite ship data. Basing on AIS, Zhang, Yang, Bai, and Lai (2023) presented a data-driven framework to investigate the schedule disruption recovery behaviour of vessels. However, identifying container ships from AIS data alone and further generating insights on port selection by container ships do not exist to our knowledge. This gives rise to our research topic.

The paper's original contributions are two folds. First, we present a big data approach to investigate the port selection of container ships from pure historic AIS data in the absence of commercial databases. Second, we generate new results of container ships visiting Shanghai Port and Ningbo Zhoushan Port. Findings and managerial implications are discussed by comparing the calling statistics between these two major container shipping hubs in the world.

The remainder of this paper is structured as follows: Section 2 provides a big data approach to identify container ships from pure AIS data. Section 3 reports the application of this approach as the empirical study of Shanghai Port and Ningbo Zhoushan Port. Finally, Section 4 concludes the most important findings and managerial recommendations.

2. Research methodology

We evaluate whether a ship calls at a specific port according to its AIS trajectories. However, in the AIS data, different types of ships include container ships, general cargo ships, tankers and bulk carriers which are all displayed as 'cargo ship'. This means that pure AIS data does not indicate the specific type of ship. Hence, we cannot judge whether a ship is a container ship or otherwise based on vessel trajectory obtained from AIS data. Usually, this problem (i.e., determination of ship type) is solved by obtaining ship characteristics from commercial sources such as databases from Lloyd's or the China Classification Society (CCS). Nonetheless, it can be noted that container ships usually visit specific container terminals which makes it possible to identify these vessels through regional screening in the absence of commercial databases. The details about AIS datasets, regional screening and identification of container ships are described in the following sections.

2.1. Logic framework

Fig. 1 provides the logic framework of the proposed big AIS data analytics approach to identify container ships from pure AIS data. Firstly, we use the point-in-polygon algorithm (Galetzka & Glauner, 2017; Hormann & Agathos, 2001) to filter the dynamic AIS data outside of the container terminal area. Next, specific ship type codes in the static AIS data are used to eliminate non-container ships (e.g. tugs, pilot boats, ships engaged in dredging or underwater operations, etc.) inside of the container terminal area. Finally, container ships in the container terminal area are captured. The proposed method is described in detail in the following subsections.

2.2. AIS datasets

According to IMO (2002), AIS is required to be fitted aboard all ships of 300 GT and upwards that are engaged on international voyages, cargo ships of 500 GT and upwards not engaged on international voyages and all passenger ships irrespective of size. The AIS equipment broadcasts two types of information. These are known as static information and

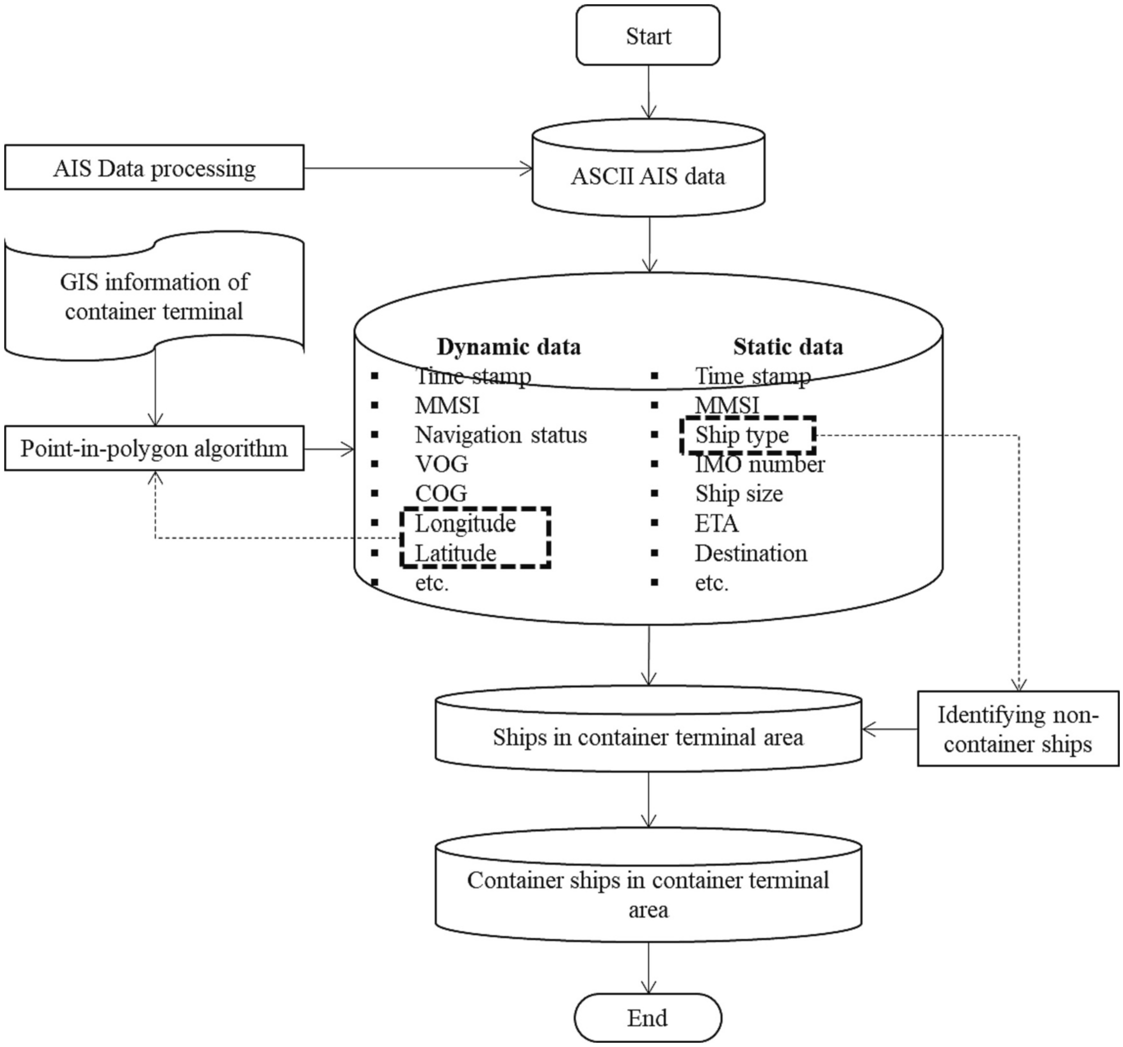

Fig. 1. The framework of the proposed method for identifying container ships.

dynamic information. The information is recorded and stored by coastal stations. The information can be extracted from stored AIS records.

Dynamic information contains data including transmitted time and received time (in UTC), MMSI (Maritime Mobile Service Identity), navigation status, rate of turn (ROT), speed over ground (SOG), ship position (latitude and longitude), course over ground (COG) and true heading (HDG). Static information containers data including MMSI, IMO number, call sign, ship type, ship size (i.e. dimension to bow, dimension to stern, length, dimension to port, dimension to starboard, beam), ETA (estimated time of arrival) and destination. It should be emphasized that Code 70–79 in ship type represents 'cargo ship' (see Table 1). Therefore, we cannot identify whether a vessel is a container ship, bulk carrier or general cargo ship.

2.3. Regional screening

The type of terminal can be used to set the threshold for visiting ships. For instance, LNG terminals are likely to receive LNG ships while container terminals are likely to receive container ships. Therefore, if we set a filter in the container terminal area, ships outside the area would be filtered out. This means container ships that have visited a container terminal will fall in the filtering area. Hereby, we call this approach '*regional screening*'. As shown in Fig. 2 (a) and Table 2, 161 ships visited the Yangshan port area of Shanghai Port from 00:00 to 24:00 on June 1, 2020. After the regional screening, 30 ships were found to have ever berthed at Yangshan Container Terminal Phase IV (see Fig. 2 (b) and Table 2).

The method for regional screening follows the point-in-polygon algorithm presented by Hormann and Agathos (2001). Firstly, let the terminals in the study area be described as a set

Table 1
AIS Ship Types of the cargo ships (MarineTraffic, 2022).

Type Code	Description	Type Code	Description
70	Cargo, all ships of this type	75	Cargo, Reserved for future use
71	Cargo, Hazardous category A	76	Cargo, Reserved for future use
72	Cargo, Hazardous category B	77	Cargo, Reserved for future use
73	Cargo, Hazardous category C	78	Cargo, Reserved for future use
74	Cargo, Hazardous category D	79	Cargo, No additional information

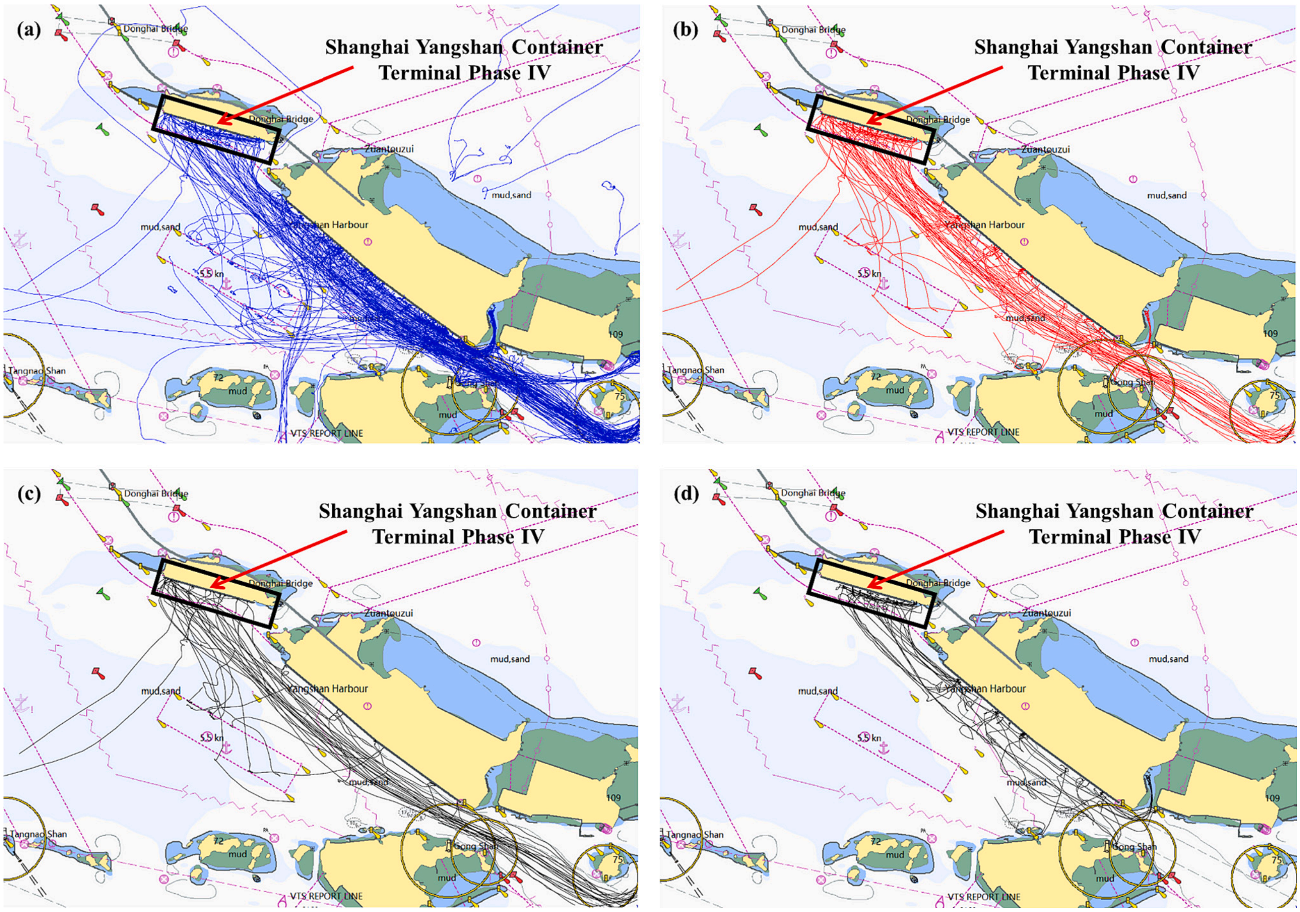

Fig. 2. (a) Trajectories of all ships (blue lines), (b) trajectories of ships in the screened region (red lines), (c) trajectories of all container ships (black lines) and (d) non-container ships (e.g. tugs, etc., black lines) of the screened region in the study area during 2020/06/01 00:00:00–23:59:59. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
Descriptive statistics of the experimental data scale.

Operation	Action	Captured ship quantity	Descriptions
Research data selection		161	Ships ever visited the Yangshan port area (see Fig. 2 (a))
Regional screening	Algorithm 1	30	ever berthed at Yangshan Container Terminal Phase IV (see Fig. 2 (b))
Container ships identifying	Algorithm 2	23	Container ships ever stopped at Yangshan Container Terminal Phase IV (see Fig. 2 (c))
		7	Non-container ships ever stopped atYangshan Container Terminal Phase IV (see Fig. 2 (d))

$$T = \{T_i | T_i, i = 1, 2, \ldots, n-1, n\} \tag{1}$$

where T_i is the ith container terminal and n is the number of the container terminal in the study area.

The shape and location of the container terminal T_i is defined as

$$T_i = \{A_i | A_i = [(x_1, y_1), (x_2, y_2), \ldots, (x_{i-1}, y_{i-1}), (x_i, y_i)], i = 1, 2, \ldots, k-1, k\} \tag{2}$$

where A_i is the location and shape of the container terminal T_i, this terminal is a polygon formed by connecting k vertices in turn; x_i and y_i are the longitude and latitude of the ith vertex.

Next, let the dynamic AIS records of ships be described by a set

$$DR = \{DR_j | DR_j, j = 1, 2, \ldots, m-1, m\} \tag{3}$$

where DR_j is the jth record and m is the total number of the dynamic AIS records. The jth AIS record is defined as

$$DR_j = \{DS_j | DS_j = (t_j, I_j, \ldots, V_j, N_j, x_j, y_j), j = 1, 2, \ldots, m-1, m\} \tag{4}$$

where S_j is the state vector of the jth AIS record. For instance, t_j is the time stamp, I_j is the MMSI, V_j is the speed, N_j is the navigation state, x_j and y_j are the longitude and latitude of the ship's position.

The point-in-polygon algorithm defines a dynamic coordinate system with $(0|0) = (x_i, y_i)$ by moving the container terminal A_i. Then this algorithm takes $(0|0)$ as the starting point and (xmax|0) as the ending point to draw a directed line segment, here, x_{max} is the maximum x_i value of the vertexes of the container terminal A_i. Next, calculate the intersections of the directed line segment with the edges of the container terminal A_i. The steps of the algorithm are followed as Algorithm 1.

Algorithm 1. Point-in-polygon algorithm for regional screening, with reference from (Galetzka & Glauner, 2017).

Input: AIS data; GIS information of container terminal.
Output: AIS data of ships in the container terminal area.
Step 1: Check if any AIS position (x_j, y_j) equal to any vertex (x_i, y_i) or locates on any edge of the container terminal A_i. If so, it is inside.
Step 2: Search the vertex (x_i, y_i) which is not on the X-axis in the vertex set of the container terminal A_i. If none is found, position (x_j, y_j) is outside of the container terminal.
Step 3: Set j to 1. Starting from vertex (x_i, y_i), repeat Step (4)-(9) till to all vertexes in the set A_i are visited:
Step 4: Set i to $j + i$ until to find the next vertex (x_i, y_i) which does not lie on the X-axis. If $j + i > n$, set j to $-i$ and continue searching.
Step 5: As per the results of step (4), step (6)-(8) is followed accordingly:
Step 6: If no vertex is skipped in Step (4), then check whether the directed line segment from (x_i, y_i) to (x_{i+j}, y_{i+j}) intersects with the positive X-axis. If yes, the number of intersections adds 1.
Step 7: If at least one vertex with a positive x-value has been skipped in Step (4), then check whether the directed line segment from (x_i, y_i) to (x_{i+j}, y_{i+j}) intersects with the complete X-axis. If yes, the number of intersections adds 1.
Step 8: If at least one vertex with a negative x-value has been skipped, do nothing and continue.
Step 9: Set (x_{i+j}, y_{i+j}) as the starting vertex for the next iteration.
Step 10: Count the number of intersections. If it is even, the AIS position (x_j, y_j) is outside of the container terminal A_i, otherwise inside.

2.4. Identification of container ships

During calling at a specific port for container ships, tugs are usually employed to assist in berthing and unberthing. This makes tugs also fall into the selected area when using the regional screening approach. In addition, dredging ships engaging in maintaining the depth, bunker barges refuelling vessels, supply ships providing provisions and pilot boats embarking and disembarking pilots would fall into the same container terminal area of operation. Nonetheless, these vessels are given specific codes in the AIS ship type. For instance, the code for a tug is 52, and for a pilot boat is 50. These codes differ from cargo ships (i.e. 70–79). According to the ship type code, 23 container ships (see Fig. 2 (c) and Table 2) and 7 non-container ships (e.g. tugs, etc. see Fig. 2 (d) and Table 2) were captured to have ever stopped at Shanghai Yangshan Container Terminal Phase IV.

Algorithm 2 shows the procedure to identify container ships from the AIS records inside the container terminal area. Let the static AIS records of ships be described by a set

$$SR = \{SR_j | SR_j, j = 1, 2, \dots, m-1, m\} \quad (5)$$

where SR_j is the jth record and m is the total number of the static AIS records. The jth static AIS record is defined as

$$SR_j = \{SS_j | SS_j = (t_j, I_j, \dots, C_j, D_j, P_j), j = 1, 2, \dots, m-1, m\} \quad (6)$$

where SS_j is the state vector of the jth static AIS record. For instance, t_j is the time stamp, I_j is the MMSI, C_j is the code of ship type, D_j is the ship dimensions, and P_j is the destination.

Algorithm 2. Algorithm for identifying container ships in the container terminal area.

Input: AIS data; code set C for the non-container ships; MMSI set *I*.
Output: AIS dynamic set *DR* and static set *SR* of Container ships in container terminal area.
Step 1: Build the code set *C* for the non-container ships.
Step 2: Delete the AIS records in which the code for the ship type falls into the code set *C*.

```
for j ← 1 to m
  if ship type code C_j ∈ C then
    I_j ← C_j; SR_j = []; DR(I_j) = [];
  end
end
```

Step 3: Extract the unrepeated MMSI in the remaindered AIS records and make the MMSI set *I*.

```
length_new_DR = length(DR) ;
for j ← 1 to length_new_DR
   I_j=DR_j(:, inde_column = MMSI);
end
I = unique(I_j) ;
```

Step 4: Extract all AIS dynamic set *DR* and static set *SR* records according to the MMSI set *I*.

```
for j ← 1 to m
  if  Ship type code I_j ∈ I then
    SR_j = SR_j; DR_j = DR_j;
  else
    SR_j = []; DR_j = [];
  end
end
```

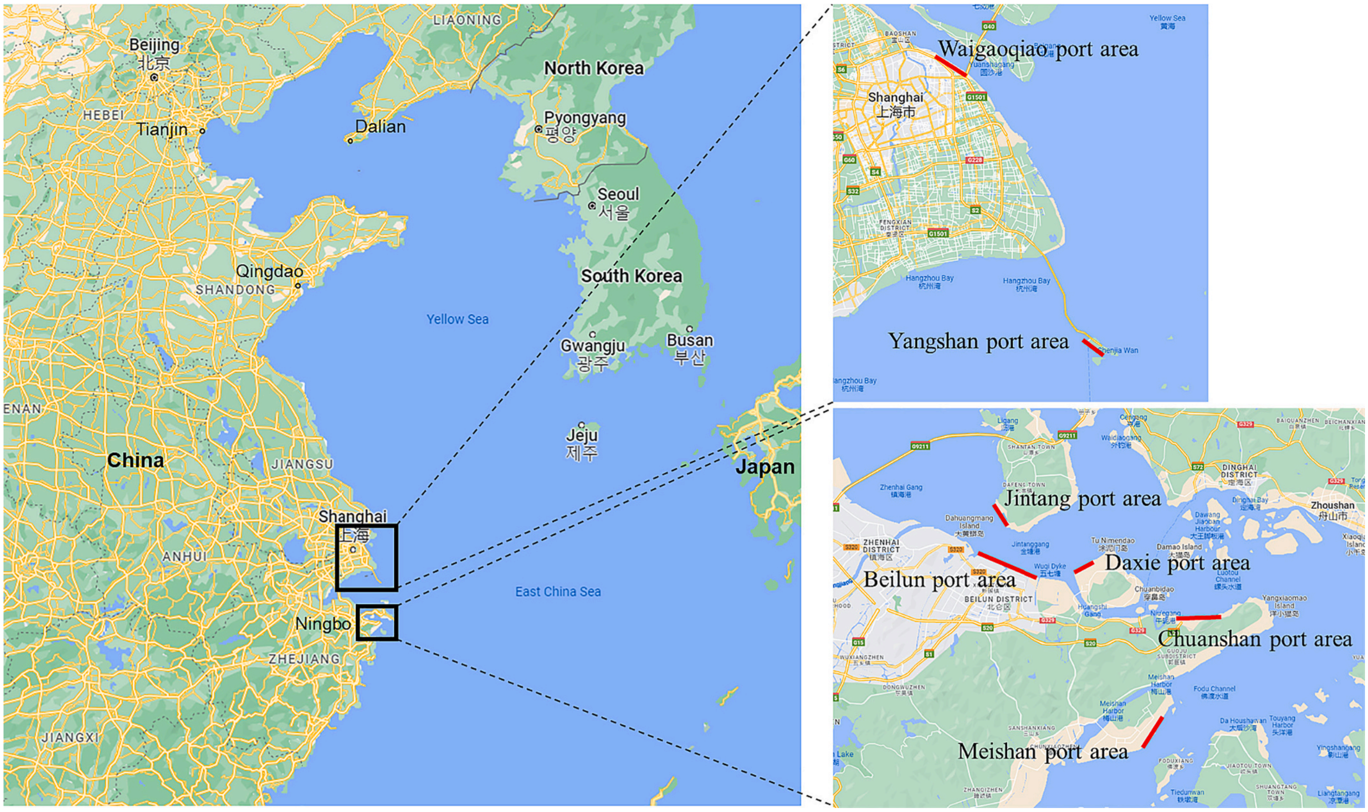

Fig. 3. Locations and international container terminal distributions in Shanghai and Ningbo Zhoushan Port.

Within the container terminal area A_i, there may exist other types of ships, for instance, tugs assisting with berthing and unberthing, dredge ships engaging in maintaining the depth, oil barges filling the fuel, supply ships providing the provisions and pilot boats embarking and disembarking pilots, etc. Therefore, C_j varies with ship type, for instance, the code for tug is 52, and that for pilot-boat is 50. Noting that the codes of cargo ships fall into 70–79, so we could research the code set C of ship types in the static AIS data which are out of 70–79, where

$$C = \{C|C_j = 0, \ldots, 99, C_j \neq 70, 71, \ldots, 79, j = 1, 2, \ldots, m-1, m\} \quad (7)$$

Then filter these no-cargo ships according to the researched codes. Consequently, the remaining ships in A_i are the container ships that we try to find. In turn, with the MMSI set I, we could extract all dynamic AIS record DR and static set SR of container ships for further analysis, where

$$I = \{I|I_j(C_j), C_j \in C, j = 1, 2, \ldots, m-1, m\} \quad (8)$$

$$DR = \{DR|DR_j(I_j), I_j \in I, j = 1, 2, \ldots, m-1, m\} \quad (9)$$

$$SR = \{SR|SR_j(I_j), I_j \in I, j = 1, 2, \ldots, m-1, m\} \quad (10)$$

3. Empirical study

In this section, we use Shanghai Port and Ningbo Zhoushan Port as the case of empirical study. Using the proposed approach in Section 2, container ships which ever called Shanghai and Ningbo Zhoushan from Jan. 1st – Dec. 31st, 2020 are identified and their statistics characteristics are recognized. Managerial insights for underlying calling behaviour in port selection by container ships are provided.

3.1. Brief description of Shanghai Port and Ningbo Zhoushan Port

In terms of container throughput, Shanghai and Ningbo Zhoushan were respectively ranked as the busiest and third-busiest ports in the world in 2021 (Chen, Meng, & Jia, 2022). And according to UNCTAD (2022), Shanghai and Ningbo respectively ranked as the world's first and second best-connected ports in 2022. As shown in the top right-hand panel in Fig. 3, the international container terminals of Shanghai Port are distributed over the Waigaoqiao port area and Yangshan port area (offshore container port). The international container terminals that can accommodate mega container ships in Ningbo Zhoushan Port are located at Beilun, Jintang, Daxie, Chuanshan and Meishan port areas (refer to the bottom right-hand panel of Fig. 3). Geographically, Ningbo Zhoushan Port is located 50 nautical miles from Yangshan and 150 nautical miles from Waigaoqiao of Shanghai Port (see left panel of Fig. 3). Therefore, these two ports have overlapping hinterlands and compete with each other (Feng, Grifoll, Yang, Zheng, & Martin-Mallofre, 2020).

3.2. AIS data

The coastal AIS network in China is divided into three subareas (i.e. North, East and South China Sea separately). Each subarea is managed by a Navigation Guarantee Center. Our data is obtained from the Navigation Guarantee Center of the East China Sea. To eliminate the influence of seasonality, data from 2020/1/1–2020/12/31 is collected for analysis. In the AIS data set, a daily file contains more than 10 million records. Each record for AIS Class A includes either dynamic or static information, but that of Class B contains both dynamic and static information.

3.3. Results

Using the presented algorithm in Section 3, container ships that called at Shanghai or Ningbo Zhoushan during the period Jan. 1st – Dec. 31st, 2020 were identified. As reported in Fig. 4, a total of 23,818 and 16,331 container ships above 75 m in length visited Shanghai and Ningbo Zhoushan respectively. Shanghai Port received 145.8% more

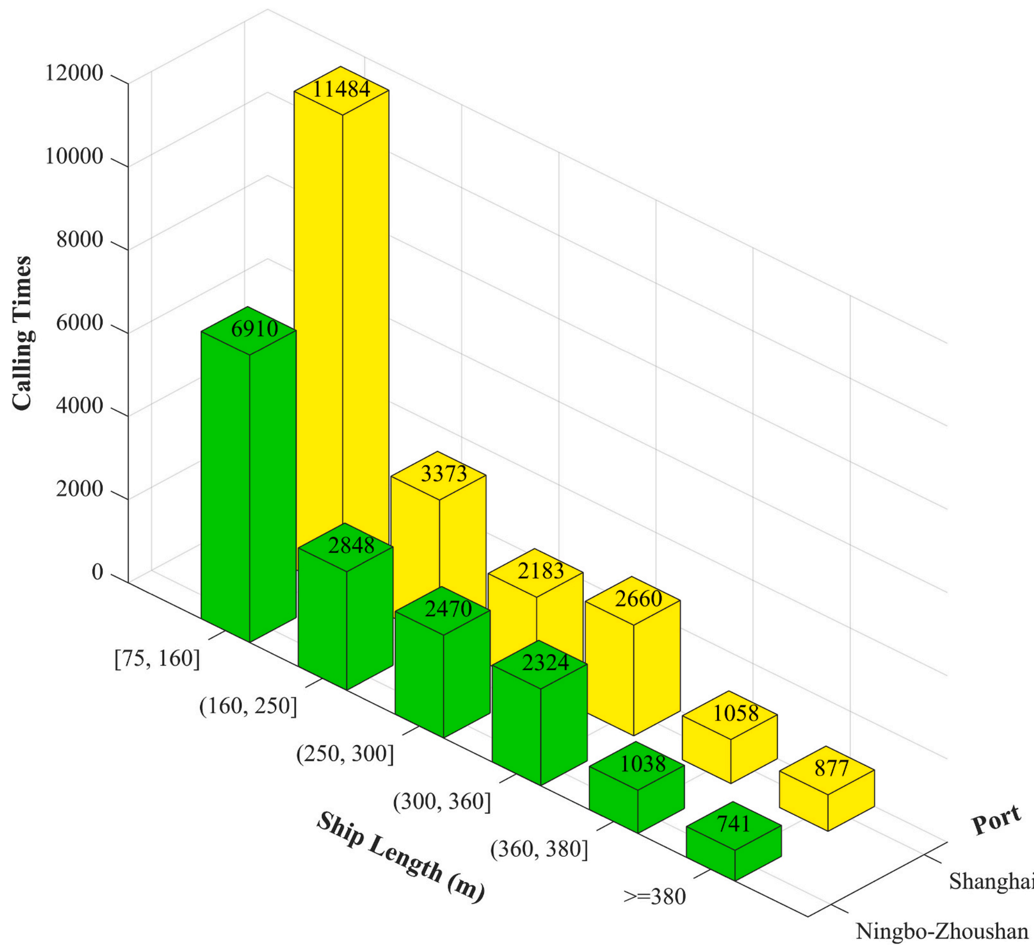

Fig. 4. Frequency statistics of container ships in different lengths calling Shanghai Port and Ningbo Zhoushan Port during the period Jan. 1st – Dec. 31st, 2020.
1. Ship length over 380 m or capacity is more than 16000TEU;
2. Ship length between 360 m and 380 m or capacity between 11000TEU and 16000TEU;
3. Ship length between 300 m and 360 m or capacity between 6000TEU and 13000TEU;
4. Ship length between 250 m and 300 m or capacity between 1000TEU and 7000TEU;
5. Ship length between 160 m and 250 m or capacity between 500TEU and 5500TEU;
6. Ship length between 75 m and 160 m or capacity less than 2000TEU.

container ship calls than Ningbo Zhoushan Port. According to the approximate relationship between the length and capacity of built container ships (Garrido Salsas, Saurí Marchan, Marreno, Gül, & Rúa Costa, 2021; Garrido, Saurí, Marrero, Gül, & Rúa, 2020), we classify these container ships into 6 categories as per the ship length (see Fig. 4):

Among these container ships, stops of vessels over 380 m, 360–380 m, 300–360 m, 250 - 300 m, 160–250 m and 75–160 m at Shanghai counts 877, 1058, 2660, 2183, 3373 and 11,484; and those of Ningbo Zhoushan record 740, 1038, 2324, 2470, 2848 and 6910 separately. The ratios between Shanghai and Ningbo Zhoushan are 1.185, 1.019, 1.145, 0.884, 1.184 and 1.662 respectively.

In the context of increasing competition, larger and larger container ships are built by the shipping lines to obtain the scale effect (Lian, Jin, & Yang, 2019). However, due to technical and physical restrictions, not all ports are allowed to accommodate the latest generation mega container ships. This challenge of handling the latest ultra-large container ships in turn becomes a critical indicator of port performance (Kurt, Aymelek, Boulougouris, & Turan, 2021). Additionally, from a geographic standpoint, the feeder-hub relationship is an important indicator to assess port connectivity in terms of shipping service frequency and market coverage (Wang & Cullinane, 2016). Therefore, we group the caught ships into three categories by the ship length, i.e., large ships over 360 m, medium ships between 160 m and 360 m, and small ships less than 160 m for further analysis.

It could be found that, in terms of the large ships over 360 m, Shanghai received 8.1% more ship calls than Ningbo Zhoushan. For the segment of medium ships of 160–360 m, Shanghai was 7.0% higher than Ningbo Zhoushan; however, counting for those small ships which are less than 160 m, Shanghai received 66.2% more vessel calls than Ningbo Zhoushan. Nonetheless, in the segment of 360–380 m, Ningbo Zhoushan was almost equal to Shanghai, and for the ships of 250–300 m, Ningbo Zhoushan attracted conversely 11.6% more visits than Shanghai. AIS trajectories for ships of different lengths visiting Shanghai Port and Ningbo Zhoushan Port are plotted in Fig. 5. The visual judgment shows that these two ports are busy, and some statistical characteristics could also be found. These are discussed in Section 3.4.

3.4. Discussion

The hinterland of ports differs in size, resulting in varying port scales and their positions in regional and global shipping networks. Therefore, ports are divided into hub ports and feeder ports in port functions. Hub ports, including international and regional hub ports, mostly service international ocean routes or near ocean routes, such as Hong Kong, Shanghai, and Singapore; however, feeder ports accommodate coastal routes. This means hub ports would be visited by large ships, medium

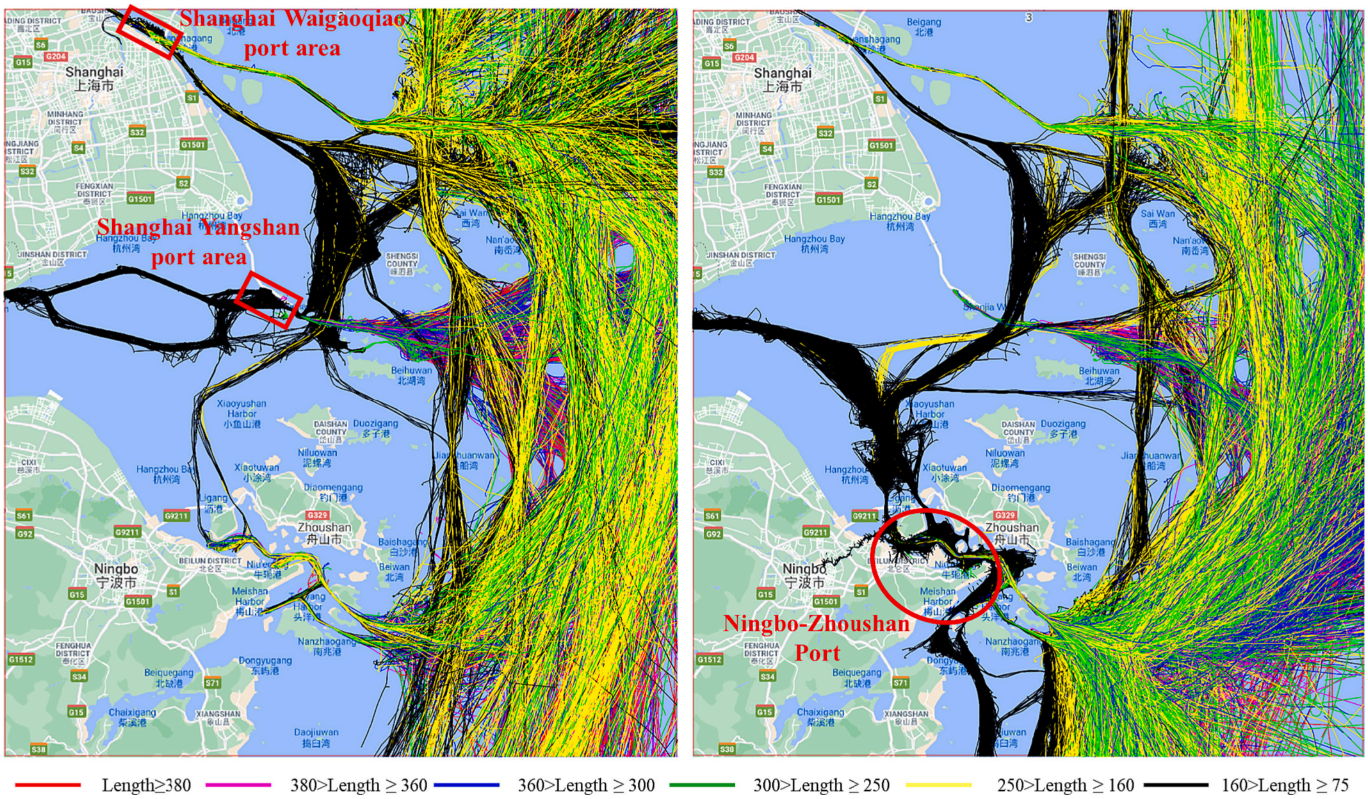

Fig. 5. AIS trajectories of ships in different lengths visiting Shanghai Port (left) and Ningbo Zhoushan Port (right) from Jan. 1st – Dec. 31st, 2020.

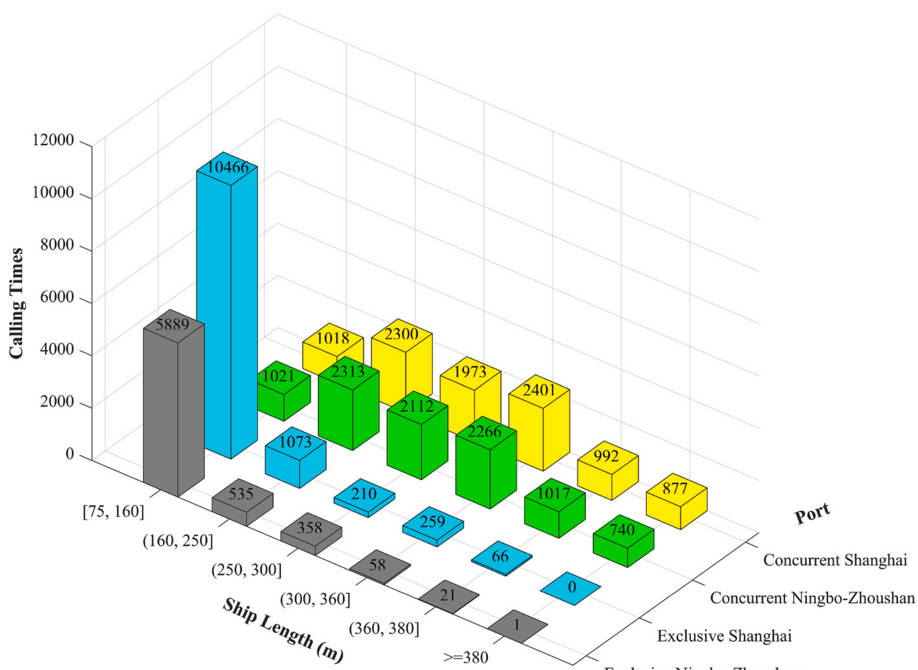

Fig. 6. Frequency statistics of container ships of different lengths calling only Shanghai Port, only Ningbo Zhoushan Port, both Shanghai and Ningbo Zhoushan during the period Jan. 1st – Dec. 31st, 2020.

ships and small ships, however, feeder ports mainly by small ships. In this sense, the ship size ratios of different ports will be different. For the hub ports, the ship size ratios of large ships, medium ships and small ships have rarely been investigated according to the existing literature. As reported in Fig. 4, 23,818 and 16,331 container ships visited Shanghai and Ningbo Zhoushan respectively in 2020. The proportion of large ships, medium ships and small ships calling for Shanghai Port is 8.9%, 38.0% and 53.1%, and those for Ningbo Zhoushan Port are 10.9%, 46.8% and 42.3%. The ratios among large ships, medium ships and small ships of these two world-class ports are both approximately 1: 4: 5, which indicates the fleet structure of Shanghai Port and Ningbo Zhoushan Port is multilevel and the collection and distribution network is extensive (i.e., connecting numerous feeder ports in the geographical coverage). This result supports the opinions of Lian et al. (2019), i.e., upsizing of ships induces a significant increase in the scale of feeder services. However, this shipping ecology also helps container lines to formulate the spoke networks and relay networks, and in turn, offers the ports more opportunities to attract more liner shipping services by providing a wider set of onward linkages (Liu, Wang, & Yip, 2013).

We can also categorise visiting ships into two types which are exclusive calls (i.e., at either Shanghai or Ningbo Zhoushan) or concurrent calls (i.e., both Shanghai and Ningbo Zhoushan).

From Fig. 6 it could be found that exclusive ship calls in Shanghai and Ningbo Zhoushan are 12,074 and 6862 respectively with the shares being 42.0% and 55.8%. For exclusive calling ships, the proportions of small ships of less than 160 m are nearly 90% (i.e., 86.7% and 85.8% respectively for Shanghai and Ningbo Zhoushan Port). The numbers indicate that each hub port has a strong and exclusive collection and distribution network comprising smaller feeder ships. The numbers also suggest that the collection and distribution network of Shanghai was covering more feeder ports and deploying more feeder ships and deploying more feeder ships in shipping service frequency than Ningbo Zhoushan. The stronger collection and distribution network points to Shanghai's stronger competitiveness in terms of port selection vis-a-vis Ningbo-Zhoushan. This observation is consistent with the findings of Luo, Chen, and Zhang (2022), Huang, Grifoll, Feng, Ortego, and Zheng (2022) and Wan, Zhang, Wang, and Chen (2014).

It could be also be witnessed in Fig. 6 that the exclusive calls of ships over 300 m in Ningbo Zhoushan and Shanghai are 80 and 325, respectively, the former is only about 25% of the latter, which further supports Shanghai's stronger competitiveness in port selection vis-a-vis Ningbo Zhoushan. However, in terms of ships between 250 m and 300 m, the figures are 358 and 210 separately, indicating Ningbo Zhoushan attracted 70.5% more calls than Shanghai. This depicts the unique position of Ningbo Zhoushan Port in terms of deep-sea direct-call, which supports Cullinane, Teng, and Wang (2005) and Lam and Yap (2011).

Fig. 6 also reports the individual concurrent visiting of container ships to Shanghai Port and Ningbo Zhoushan Port. In 2020, the frequencies of concurrent visiting to Shanghai Port and Ningbo Zhoushan Port were 9561 and 9469, the total numbers almost equalled, and Shanghai was only 1% higher than Ningbo-Zhoushan. However, in terms of large ships over 380 m, Shanghai accommodated an extra 18.5% compared to that of Ningbo Zhoushan Port, this implies Shanghai's attraction for such vessels in global fleet deployment despite the depth endowment in channel and berth of Ningbo Zhoushan to welcome large ships (Feng, Grifoll, & Zheng, 2019).

In the meantime, Fig. 6 reported that the exclusive calls made by the small ships less than 160 m at Shanghai and Ningbo Zhoushan were 10,466 and 5889, respectively. However, the total frequencies of concurrent calls were 1018 and 1021, only counting for 10.6% and 10.8% of

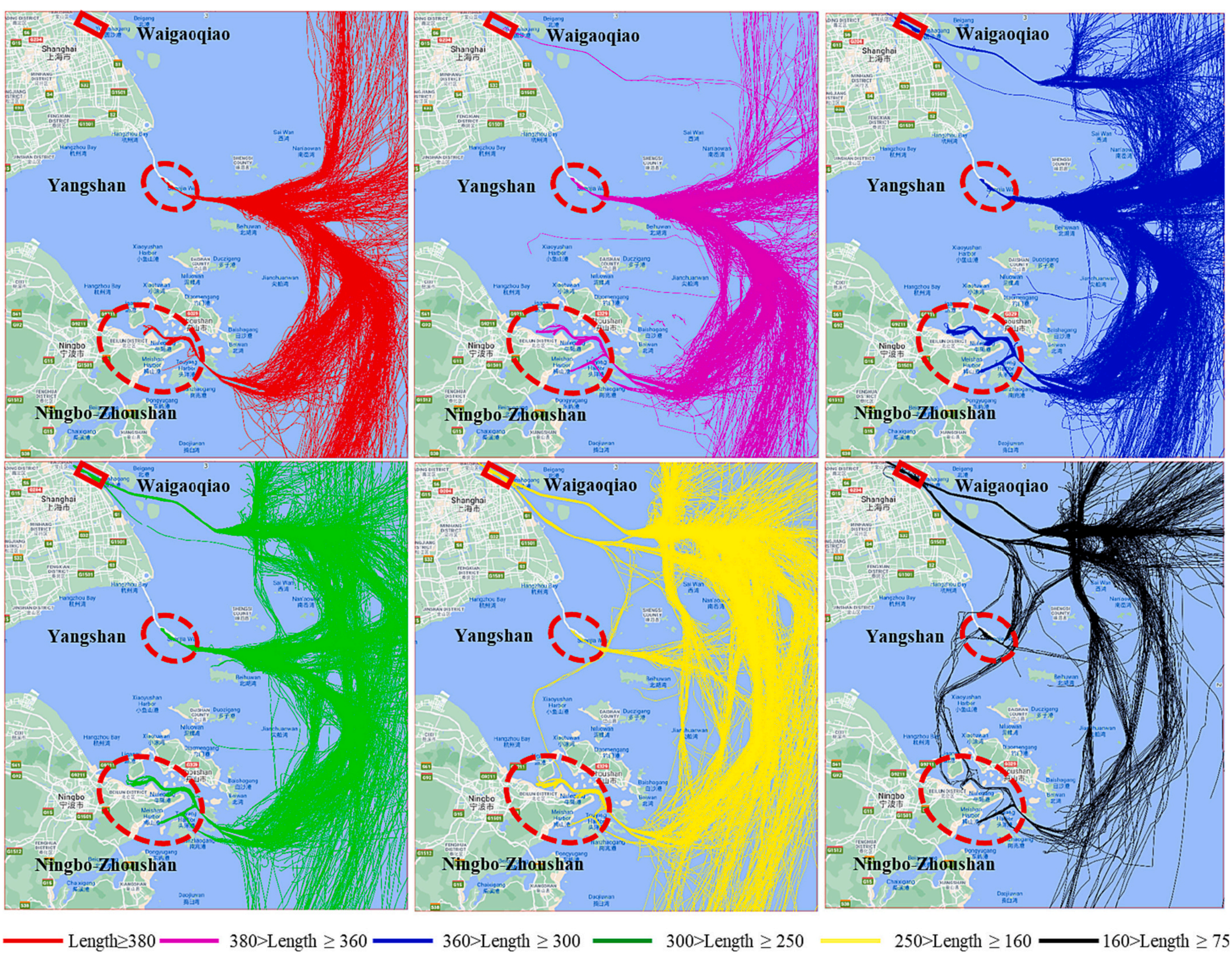

Fig. 7. AIS trajectories of one day before and after visiting Shanghai of ships which call both Shanghai and Ningbo-Zhoushan.

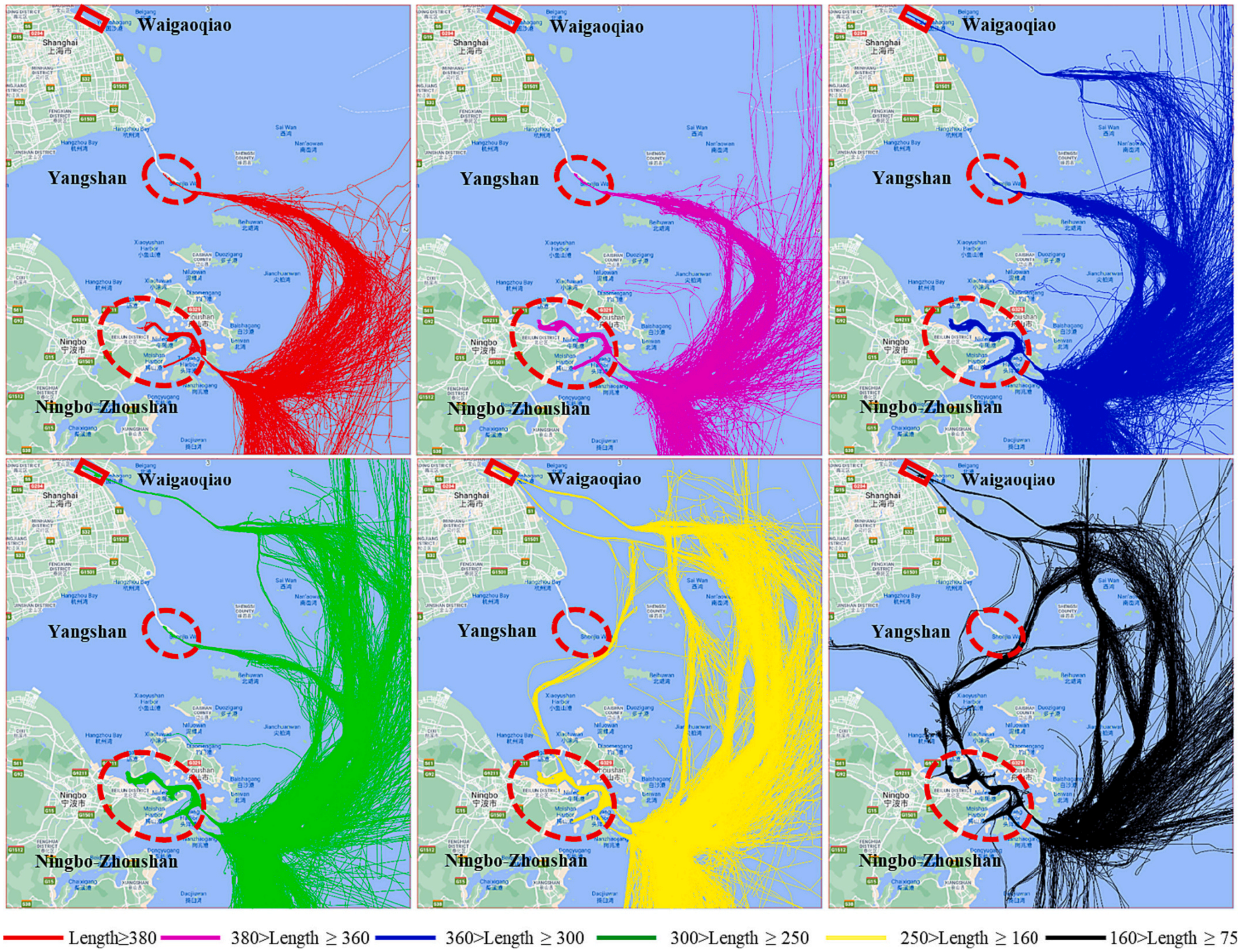

Fig. 8. AIS trajectories of one day before and after visiting Ningbo Zhoushan of ships which call both Shanghai and Ningbo-Zhoushan.

the total frequencies. This meant that almost 90% small ships must make a choice between Shanghai Port and Ningbo Port, that is, either to call at Shanghai or Ningbo. As a comparison, the medium ships between 160 m and 360 were 6674 and 6691, the shares are 69.8% and 70.7% of all ships concurrently visiting Shanghai Port and Ningbo Zhoushan Port. This denoted the feeder network between these two ports was weak, and the relationships between Shanghai and Ningbo Zhoushan were actually in competition, which supported Dong, Zheng, and Lee (2018) and Wang, Lau, Su, Zhu, and Kanrak (2022).

As described in Fig. 3, the international container terminals of Shanghai Port are located at Waigaoqiao and Yangshan. Whereas those of Ningbo Zhoushan Port are located in Beilun, Jintang, Daxie, Chuanshan and Meishan port areas. We plot the AIS trajectories of ship calls at Shanghai (see Fig. 7) and Ningbo Zhoushan (see Fig. 8) of ships which call both Shanghai and Ningbo-Zhoushan. As such, new findings are generated:

I. For Shanghai Port, all ships over 380 m and the vast majority of ships between 380 m and 360 m only visit Yangshan instead of Waigaoqiao, however, Daixe, Chuanshan and Meishan in Ningbo Zhoushan Port have ever accommodated those ships. In this sense, this means that Ningbo Zhoushan could offer more choices for super large container ships (over 11000TEU), which also implies a greater potential for Ningbo Zhoushan in future port selection.

II. For Shanghai Port, with the decrease in ship draughts, more ships would call Waigaoqiao and fewer ships berth at Yangshan. The reasons are two folds: First, the deep-water channel at the Yangtze Estuary is restricted in depth, therefore, ships with draught more than 12.5 m are usually blocked from the Waigaoqiao port area; Second, Yangshan is an offshore port area, which is about 50 nautical miles farther from the hinterland than Waigaoqiao. In this sense, the draught in channels and berths is essentially important for ships, but when the depth of channels and berths is sufficient, the distance to the hinterland and the convenience of the collection and distribution network may begin to get more important in port selection.

III. Ships of all different lengths which visited Yangshan were possible to call Ningbo, but small ships less than 250 m, especially ships less than 160 m, would not call Yangshan after visiting Ningbo. This does not necessarily mean that Yangshan is the feeder port of Ningbo-Zhoushan, but it is certain that, in the port rotation of ships less than 250 m, the port order of Yangshan is prior to Ningbo, that is, ships less than 250 m always visit Yangshan first, and then Ningbo. This is also an interesting topic for further research.

4. Conclusions

Port selection is essentially important for both port operators and shipping lines. Despite the potential importance, detailed statistics for investigating port selection of container ships called at individual ports are not available until now. In this study, we propose a composite method combining the point-in-polygon algorithm and historic AIS information. This method allows identifying container ships from pure historic AIS data in the absence of commercial databases. In the empirical study, the approach is applied to investigate the port selection behaviours of ships between Shanghai and Ningbo Zhoushan which are geographically close and overlap in the hinterland. The main conclusions which potentially provide managerial insights to stakeholders are concluded as below:

I. The ratios among large ships, medium ships and small ships of Shanghai Port and Ningbo Zhoushan Port are both approximately 1: 4: 5, which indicates that the fleet structure of a world-class port is multilevel and the collection and distribution network is extensive (i.e., connecting numerous feeder ports). The upsizing of ships induces a significant increase in the scale of feeder services. However, this shipping ecology also helps container lines to formulate the spoke networks and relay networks, and in turn, offers the ports more opportunities to attract more liner shipping services by providing a wider set of onward linkages.

II. Each hub port has a strong and exclusive collection and distribution network, and the collection and distribution networks mainly consist of small ships. The collection and distribution network of Shanghai is covering more feeder ports and is deploying more feeder ships than Ningbo-Zhoushan. The stronger collection and distribution network points to Shanghai's stronger competitiveness in port selection vis-a-vis Ningbo Zhoushan.

III. In terms of large ships over 380 m, Shanghai accommodated an extra 18.5% compared to that of Ningbo Zhoushan Port, and this implies a more prominent position of Shanghai in global fleet deployment despite the depth endowment in channel and berth of Ningbo Zhoushan to welcome large ships.

IV. The feeder network between Shanghai Port and Ningbo Zhoushan is weak, and the relationship between Shanghai and Ningbo Zhoushan is actually in competition.

V. For Shanghai Port, all ships over 380 m and the vast majority of ships between 380 m and 360 m only visit Yangshan instead of Waigaoqiao, however, Daixe, Chuanshan and Meishan in Ningbo Zhoushan Port have ever accommodated those ships. In this sense, this means that Ningbo Zhoushan could offer more choices for super large container ships (over 11000TEU), which also implies a greater potential for Ningbo Zhoushan in future port selection.

VI. For Shanghai Port, with the decrease in ship length and ship draughts, more ships would call Waigaoqiao and fewer ships berth at Yangshan. This shows that the draught in channels and berths is essentially important for ships, but when the depth of channels and berths is sufficient, the distance to the hinterland and the convenience of the collection and distribution network begin to get more important in port selection.

This study can be extended or practically applied in the shipping industry in the following ways. First, this composite method combining the point-in-polygon algorithm and historical AIS information allows identifying container ships from pure historic AIS data without the need for supplementary information from commercial databases. By the same token, it could be used to investigate other specific ships, for instance, LNG ships, VLCC ships, etc. Also, this approach could be applied to explore port selection statistics in other ports.

There are still some limitations for this big data approach to investigate the port selection of container ships from pure historic AIS data in the absence of commercial databases. For instance, the shipping route types will impact the gap between the two ports' exclusive ship sizes. However, in the pure AIS data, the information of the shipping routes involved is absent. Therefore, this concern cannot be addressed only depending on the pure AIS data technically. Also, the COVID-19 pandemic impacted potentially the calling of container ships. Technically, the pure AIS data does not include social events such as the COVID-19 pandemic. Therefore, additional information involving COVID-19, port traffic scheduling, and voyage schedules, and so on is required to discuss this issue. This topic will be included in our future works.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

Asgari, N., Farahani, R. Z., & Goh, M. (2013). Network design approach for hub ports-shipping companies competition and cooperation. *Transportation Research Part A: Policy and Practice, 48*, 1–18.

Bai, X., Hou, Y., & Yang, D. (2021). Choose clean energy or green technology? Empirical evidence from global ships. *Transportation Research Part E: Logistics and Transportation Review, 151*, Article 102364.

Chen, R., Meng, Q., & Jia, P. (2022). Container port drayage operations and management: Past and future. *Transportation Research Part E: Logistics and Transportation Review, 159*, Article 102633.

Chowdhury, M. M. H., & Haque Munim, Z. (2023). Dry port location selection using a fuzzy AHP-BWM-PROMETHEE approach. *Maritime Economics & Logistics, 25*(2), 301–329.

Cullinane, K., Song, D., & Gray, R. (2002). A stochastic frontier model of the efficiency of major container terminals in Asia: Assessing the influence of administrative and ownership structures. *Transportation Research Part A: Policy and Practice, 36*(8), 743–762.

Cullinane, K., Teng, Y., & Wang, T. (2005). Port competition between Shanghai and Ningbo. *Maritime Policy & Management, 32*(4), 331–346.

Cullinane, K., & Wang, T. (2006). Data envelopment analysis (DEA) and improving container port efficiency. *Research in Transportation Economics, 17*, 517–566.

Cullinane, K., Wang, T., Song, D., & Ji, P. (2006). The technical efficiency of container ports: Comparing data envelopment analysis and stochastic frontier analysis. *Transportation Research Part A: Policy and Practice, 40*(4), 354–374.

Dong, G., Zheng, S., & Lee, P. T. (2018). The effects of regional port integration: The case of Ningbo-Zhoushan port. *Transportation Research Part E: Logistics and Transportation Review, 120*, 1–15.

Duan, H., Ma, F., Miao, L., & Zhang, C. (2022). A semi-supervised deep learning approach for vessel trajectory classification based on AIS data. *Ocean and Coastal Management, 218*, Article 106015.

Felipe Souza, C. S. P., de Jong, G., & Yang, D. (2023). Port choice in Rio de Janeiro, Brazil: An analysis of the perspectives of exporters and importers in the container market. *International Journal of Shipping and Transport Logistics, 17*(1–2), 232–256.

Feng, H., Grifoll, M., Yang, Z., & Zheng, P. (2022). Collision risk assessment for ships' routeing waters: An information entropy approach with automatic identification system (AIS) data. *Ocean and Coastal Management, 224*, Article 106184.

Feng, H., Grifoll, M., Yang, Z., Zheng, P., & Martin-Mallofre, A. (2020). Visualization of container throughput evolution of the Yangtze River Delta multi-port system: The ternary diagram method. *Transportation Research Part E: Logistics and Transportation Review, 142*, Article 102039.

Feng, H., Grifoll, M., & Zheng, P. (2019). From a feeder port to a hub port: The evolution pathways, dynamics and perspectives of Ningbo-Zhoushan port (China). *Transport Policy, 76*, 21–35.

Ferrari, C., Parola, F., & Gattorna, E. (2011). Measuring the quality of port hinterland accessibility: The Ligurian case. *Transport Policy, 18*(2), 382–391.

Galetzka, M., & Glauner, P. (2017). A Simple and Correct Even-Odd Algorithm for the Point-in-Polygon Problem for Complex Polygons. In *Proceedings of the 12th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications - GRAPP, (VISIGRAPP 2017)* (pp. 175–178). SciTePress.

Garrido, J., Saurí, S., Marrero, Á., Gül, Ü., & Rúa, C. (2020). Predicting the future capacity and dimensions of container ships. *Transportation Research Record, 2674*(9), 177–190.

Garrido Salsas, J., Saurí Marchan, S., Marreno, Á., Gül, Ü., & Rúa Costa, C. (2021). Container ship size: Which dimensions can be expected? *R-Evolucionando el transporte*, 2695–2717.
Gningue, M., Bedoui, W., & Venkatesh, V. G. (2023). A port performance measurement approach using a sustainability balanced scorecard based on stakeholders' expectations. *Maritime Policy & Management*. https://doi.org/10.1080/03088839.03082023.02236101
Guy, E., & Urli, B. (2006). Port selection and multicriteria analysis: An application to the Montreal-New York alternative. *Maritime Economics & Logistics, 8*(2), 169–186.
Ha, M., Yang, Z., Notteboom, T., Ng, A. K., & Heo, M. (2017). Revisiting port performance measurement: A hybrid multi-stakeholder framework for the modelling of port performance indicators. *Transportation Research Part E: Logistics and Transportation Review, 103*, 1–16.
Hormann, K., & Agathos, A. (2001). The point in polygon problem for arbitrary polygons. *Computational Geometry, 20*(3), 131–144.
Hörteborn, A., & Ringsberg, J. W. (2021). A method for risk analysis of ship collisions with stationary infrastructure using AIS data and a ship manoeuvring simulator. *Ocean Engineering, 235*, Article 109396.
Hsu, W. K., Lian, S., & Huang, S. S. (2020). An assessment model based on a hybrid MCDM approach for the port choice of liner carriers. *Research in Transportation Business & Management, 34*, Article 100426.
Huang, D., Grifoll, M., Feng, H., Ortego, M. I., & Zheng, P. (2022). Characterizing the evolution of the Yangtze River Delta multi-port system using compositional data techniques. *Maritime Policy & Management, 49*(5), 667–684.
IMO. (2002). Guidelines for the installation of a shipborne automatic identification system (AIS). In *International maritime organization (IMO) London*.
Jiang, B., Haider, J., Li, J., Wang, Y., Yip, T. L., & Wang, Y. (2023). Exploring the impact of port-centric information integration on port performance: The case of Qingdao port. *Maritime Policy & Management, 50*(4), 466–491.
Jose, T. (2001). Efficiency measurement of selected Australian and other international ports using data envelopment analysis. *Transportation Research Part A: Policy and Practice, 35*(2), 107–122.
Jose, T., & Wu, H. (2005). Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals). *Transportation Research Part A: Policy and Practice, 39*(5), 405–424.
Kurt, I., Aymelek, M., Boulougouris, E., & Turan, O. (2021). Operational cost analysis for a container shipping network integrated with offshore container port system: A case study on the west coast of North America. *Marine Policy, 126*, Article 104400.
Lam, J. S. L., & Dai, J. (2012). A decision support system for port selection. *Transportation Planning and Technology, 35*(4), 509–524.
Lam, J. S. L., & Yap, W. Y. (2011). Dynamics of liner shipping network and port connectivity in supply chain systems: Analysis on East Asia. *Journal of Transport Geography, 19*(6), 1272–1281.
Lensu, M., & Goerlandt, F. (2019). Big maritime data for the Baltic Sea with a focus on the winter navigation system. *Marine Policy, 104*, 53–65.
Lian, F., Jin, J., & Yang, Z. (2019). Optimal container ship size: A global cost minimization approach. *Maritime Policy & Management, 46*(7), 802–817.
Liu, L., Wang, K. Y., & Yip, T. L. (2013). Development of a container port system in Pearl River Delta: Path to multi-gateway ports. *Journal of Transport Geography, 28*, 30–38.
Lorena, G. A., & Joaquin, S. S. (2010). Analysis of the evolution of the inland traffic distribution and provincial hinterland share of the Spanish port system. *Transport Reviews, 30*(3), 275–297.
Luo, M., Chen, F., & Zhang, J. (2022). Relationships among port competition, cooperation and competitiveness: A literature review. *Transport Policy, 118*, 1–9.
Madon, B., Le Guyader, D., Jung, J.-L., De Montgolfier, B., Lopez, P. J., Foulquier, E., Bouveret, L., & Le Berre, I. (2022). Pairing AIS data and underwater topography to assess maritime traffic pressures on cetaceans: Case study in the Guadeloupean waters of the Agoa sanctuary. *Marine Policy, 143*, Article 105160.
MarineTraffic. (2022). What is the significance of the AIS Shiptype number?. https://help.marinetraffic.com/hc/en-us/articles/205579997-What-is-the-significance-of-the-AIS-SHIPTYPE-number.
Munim, Z. H., Duru, O., & Ng, A. K. Y. (2022). Transhipment port's competitiveness forecasting using analytic network process modelling. *Transport Policy, 124*, 70–82.
Prochazka, V., Adland, R., & Wolff, F. C. (2019). Contracting decisions in the crude oil transportation market: Evidence from fixtures matched with AIS data. *Transportation Research Part A: Policy and Practice, 130*, 37–53.
Pu, X., Bai, X., Hou, Y., & Yang, D. (2023). An examination of liner Companies' port choices under external shocks considering firm heterogeneity. *Journal of Transport Economics and Policy (JTEP), 57*(3), 225–246.
Rong, H., Teixeira, A., & Soares, C. G. (2022). Maritime traffic probabilistic prediction based on ship motion pattern extraction. *Reliability Engineering & System Safety, 217*, Article 108061.
Serra-Sogas, N., O'Hara, P. D., Pearce, K., Smallshaw, L., & Canessa, R. (2021). Using aerial surveys to fill gaps in AIS vessel traffic data to inform threat assessments, vessel management and planning. *Marine Policy, 133*, Article 104765.
UNCTAD. (2022). Port liner shipping connectivity index, quarterly. https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=170026.
Wan, Z., Zhang, Y., Wang, X., & Chen, J. (2014). Policy and politics behind Shanghai's free trade zone program. *Journal of Transport Geography, 34*, 1–6.
Wang, C., Li, G., Han, P., Osen, O., & Zhang, H. (2022). Impacts of COVID-19 on ship Behaviours in port area: An AIS data-based pattern recognition approach. *IEEE Transactions on Intelligent Transportation Systems, 23*(12), 25127–25138.
Wang, G. W. Y., Zeng, Q., Li, K., & Yang, J. (2016). Port connectivity in a logistic network: The case of Bohai Bay, China. *Transportation Research Part E: Logistics and Transportation Review, 95*, 341–354.
Wang, H., Meng, Q., & Zhang, X. (2014). Game-theoretical models for competition analysis in a new emerging liner container shipping market. *Transportation Research Part B: Methodological, 70*, 201–227.
Wang, L., Lau, Y., Su, H., Zhu, Y., & Kanrak, M. (2022). Dynamics of the Asian shipping network in adjacent ports: Comparative case studies of Shanghai-Ningbo and Hong Kong-Shenzhen. *Ocean and Coastal Management, 221*, Article 106127.
Wang, X., Meng, Q., & Miao, L. (2016). Delimiting port hinterlands based on intermodal network flows: Model and algorithm. *Transportation Research Part E: Logistics and Transportation Review, 88*, 32–51.
Wang, Y., & Cullinane, K. (2016). Determinants of port centrality in maritime container transportation. *Transportation Research Part E: Logistics and Transportation Review, 95*, 326–340.
Yang, D., Wu, L., & Wang, S. (2021). Can we trust the AIS destination port information for bulk ships?–implications for shipping policy and practice. *Transportation Research Part E: Logistics and Transportation Review, 149*, Article 102308.
Yang, Y., & Chen, S. (2016). Determinants of global logistics hub ports: Comparison of the port development policies of Taiwan, Korea, and Japan. *Transport Policy, 45*, 179–189.
Yap, W. Y., Hsieh, C. H., & Lee, P. T. W. (2023). Shipping connectivity data analytics: Implications for maritime policy. *Transport Policy, 132*, 112–127.
Yap, W. Y., & Yang, D. (2022). Hub port choice and shipping connectivity in Southeast Asia during COVID-19 pandemic: Implications for post-pandemic competition landscape. *Maritime Policy & Management*. https://doi.org/10.1080/03088839.2022.2135179
Yeo, G., Ng, A. K. Y., Lee, P. T., & Yang, Z. (2014). Modelling port choice in an uncertain environment. *Maritime Policy & Management, 41*(3), 251–267.
Yeo, G., Pak, J., & Yang, Z. (2013). Analysis of dynamic effects on seaports adopting port security policy. *Transportation Research Part A: Policy and Practice, 49*, 285–301.
Yuen, C. A., Zhang, A., & Cheung, W. (2012). Port competitiveness from the users' perspective: An analysis of major container ports in China and its neighboring countries. *Research in Transportation Economics, 35*(1), 34–40.
Zhang, L., Yang, D., Bai, X., & Lai, K.-H. (2023). How liner shipping heals schedule disruption: A data-driven framework to uncover the strategic behavior of port-skipping. *Transportation Research Part E: Logistics and Transportation Review, 176*, Article 103229.
Zhu, S., Fu, X., & Bell, M. G. (2021). Container shipping line port choice patterns in East Asia the effects of port affiliation and spatial dependence. *Transportation Research Part E: Logistics and Transportation Review, 156*, Article 102527.