Analysis of Southeast Asian Potential Ports in the Container Shipping Network Between China and Southeast Asian Nations

Siheng Chang[1], Jinhai Chen[1,*], Peng Peng[2]

[*]Corresponding author: jhchen@jmu.edu.cn

Navigation College of Jimei University, Xiamen 361021, Fujian, China[1]
State Key Laboratory of Resources and Environmental Information System, Institute of Geographic Sciences and Natural Resources Research, Beijing 100101, China[2]

Abstract: China and the Association of Southeast Asia Nations (ASEAN) are geographically nearby with a high degree of economic interdependence. Most of the Southeast Asian countries are emerging economies with a large demand for maritime infrastructures. Therefore, improving ports infrastructure in this region could substantially increase the growth of transportation and economic activities between China and ASEAN. This paper adopts the centrality index parameters using the characteristics of the port of the China-ASEAN shipping network and a reasonable calculation method of system centrality is put forward using actual ports throughput data. The 92 container ports in the China-ASEAN shipping network are graded based on the comprehensive evaluation and potential container ports that have been identified in Southeast Asia. The main findings are as follows:(1) Singapore Port and Kaohsiung Port are the hub ports of the China- ASEAN container shipping network, which control the development of the maritime trade between China and ASEAN;(2) Cai Mep Port in Vietnam owns the largest potential, as compared with other considered potential ports connected Chinese ports in Southeast Asia;(3) The 12 potential container ports in Southeast Asia mainly located in Vietnam and Philippines. For the Chinese government and enterprises, investing in port construction in Vietnam and the Philippines could be a smart choice.

Keywords: China-ASEAN Shipping Network, Ports, Maritime Big Data.

1 INTRODUCTION

With an initiative like the '21st-Century Maritime Silk Road (MSR) and the Regional Comprehensive Economic Partnership (RCEP) [1], China and ASEAN have built a solid and robust partnership with booming trade and economic cooperation, which has sped up infrastructure construction and improved interconnectivity over the last two decades. China and ASEAN are the world's main economies, and they are also among the world's fastest-growing. In August 2020, ASEAN Secretariat notes its concatenated gross domestic product (GDP) of US $3.166 million in 2019 grew by 28.2% from the 2015 figure that stood at the US $2.469 million. It means the Southeast Asian region has huge development potential.

Maritime transportation is the major conduit of international trade, and ports play a key part in international cargo transportation [2]. Southeast Asia is a vital region of the global maritime

BDEDM 2023, January 06-08, Changsha, People's Republic of China

DOI 10.4108/eai.6-1-2023.2330241

industry, particularly for cargo shipments between Asia and Europe. The Coronavirus disease (COVID-19) triggered a global health and economic disaster with far-reaching implications for international trade. However,2020 is a banner year for China-ASEAN trade. ASEAN replaced the European Union as China's top merchandise trading partner in 2020, according to statistics from the General Administration of Customs of China. Imports and exports between China and ASEAN will amount to 4.74 trillion yuan in 2020, increasing 7% year on year. Therefore, the Chinese government and businesses may greatly boost the growth of economic activities between China and ASEAN by increasing port investments in the Southeast Asian area. However, ASEAN has its internal issues, such as uneven economic progress among its members. Most Southeast Asian countries are developing countries, and port infrastructure construction is facing various challenges notably a shortage of funds. This raises a significant and pressing problem of identifying Southeast Asia's potential ports connected with Chinese ports. It is critical to increasing investments and infrastructure construction in these ports to maintain the economic viability of China's connections with Southeast Asian countries.

The application of the centrality concept in maritime container transportation, in particular to the port sector, has already been addressed in the literature. Fleming and Hayuth first introduced port centrality and intermediacy as locational attributes indicative of the strategic role of each port within a transportation system [3] Centrality was defined as the locational advantage within the market area the port serves. In other words, if the port is located in the midst, rather than being on the periphery, of a large hinterland, then the more central port has an advantage in attracting extra traffic generated from that hinterland. Intermediacy represents the natural geographical 'in betweenness' of a port in connecting more than one foreland market. Intermediate ports can attract extra traffic if they are favored by carriers as connecting hubs or relay points in the system. Typical examples are the ports of Hong Kong or Singapore, which are strategically located in favorable intermediate positions along major sea trade routes. The concept of port centrality has greatly facilitated practical research related to port development and inter-port relationship. For example, the feature of port betweenness centrality and degree centrality have been utilized by Hu and Zhu to identify the potentially congested ports in a busy maritime network [4]. Some studies provide further evidence of the effectiveness of port centrality in determining a port hierarchy and in indicating all the attributes underpinning it. [5-8] A major shortcoming of port centrality studies is there is little comprehensive quantitative benchmarking available for assessment. This study aims to adapt a comprehensive grade method based on complex network theory and centrality index and take port throughput into account. We identify potential container ports connect with Chinese ports in Southeast Asia.

2 METHODOLOGY AND DATA

2.1 Network Construction

This study focuses on the degree of trade relations between ports; hence, we employed a directed graph, $G = (V, E,)$ that represents the overall set of between China -ASEAN shipping network trade relations constructed on an annual time scale. For the graph $G = (V, E,)$, V=$\{v_1, v_2, \cdots v_n\}$ is set of all ports in G , and is the set of all edges that link the pairs of ports in V, representing the routes between ports i and j. The elements in the adjacency matrix take the form of e_{ij}=1; if a route exists; otherwise, e_{ij}=0.

2.2 Centrality Indicators

(1) Degree Centrality

The degree of centrality is a measure of how many of the nodes in a network are connected. The connection centrality of a node refers to network connectivity. A port's degree centrality refers to the number of neighbor ports directly connected with the port. The degree centrality can be represented as the "organizational capacity" of a container port. If node i and node j are connected, $a_{ij} = 1$ can be defined; if not, $a_{ij} = 0$ can be defined as follow.

$$DC_i = \frac{1}{n-1} \sum_{j=1, j \neq i}^{n} a_{ij} \tag{1}$$

(2) Betweenness centrality

Betweenness centrality is defined as the proportion of the shortest paths between every pair of nodes that pass through the given network towards all the shortest paths. It mainly reflects the influence of nodes in the entire network, as high values often correspond to hubs or bridges.

$$BC_i = \sum_{s \neq i \neq t} \frac{\sigma_{st}(i)}{\sigma_{st}} \tag{2}$$

where $\sigma_{st}(i)$ is the sum of the shortest paths from nodes s to t that pass through node i and σ_{st} is the sum of the shortest paths from nodes s to t.

(3) Closeness centrality

Closeness centrality measures the minimum distance between a given node and other nodes, which reflects the relative accessibility of that node in the network. The closeness centrality can evaluate the role a node plays in a network. A container port is connected with other container ports by the shipping lines, so the closeness centrality not only means the shipping lines coverage of a container port but also reflects the "shipping accessibility" of a container port and its significance in the global container shipping network. The greater the closeness centrality of the port, the higher the relative reachability of the port.

$$CC_i = \frac{1}{n-1} \sum_{j=1, j \neq i}^{n} d_{ij} \tag{3}$$

where d_{ij} is the length of the topologically shortest path between ports i and j.

(4) Eigenvector Centrality

Eigenvector centrality emphasizes the importance of a network node. It measures the relative score of all the nodes in the network based on the principle that the connection to a node with a higher centrality value has a greater effect on the centrality score. High eigenvector centrality

means that, in a network, the central port not only has a large number of connecting routes, its connecting ports also have a significant impact on it.

$$EC_i = \frac{1}{\lambda}\sum_{j=1}^{N} a_{i_j} x_j \tag{4}$$

where λ is the constant, a_{i_j} is one if j is connected to i and zero otherwise. $x_j$is the centrality of node j

(5) System Centrality

Centrality is one of the most studied concepts in complex network research[9][10]. Centrality measures might be generally classified into four basic categories relating to different perspectives: degree centrality, closeness centrality, betweenness centrality, and eigenvector centrality, which analyze transportation networks to evaluate the status of nodes in the network as a whole or at the level of nodes [11][12]. However, the centrality indicators of degree, closeness, betweenness, and eigenvector represent a node's location advantage as being directly connected to others, being accessible to others, being the intermediary between others, and the importance of ports in terms of its connectivity with important ports, respectively. Any central indicator can only reflect topological features, but not comprehensive, to comprehensively reflect the hub ability of the port, this paper draws lessons from Han et al [13]. They put a method that the System Centrality (SC_i) on the study stations classification of China's high-speed network, which is the comprehensive quantitative centrality.

The SC is calculated as follows:

$$SC_i = (\omega_1 \cdot CC_i + \omega_2 BC_i) \times DC_i \tag{5}$$

where CC_i , BC_i, DC_i is closeness centrality, betweenness centrality, degree centrality, respectively. ω_1 , ω_2 is the weighted coefficient of CC_i , BC_i.

According to the characteristics of the China-ASEAN shipping network and ports' throughput, we consider eigenvector centrality indicators. The new parameters are correspondingly adapted by giving due consideration to the container port's throughput that is only involved between China and Southeast Asia.

We are making correlation analysis for degree centrality, closeness, centrality, betweenness centrality, eigenvector centrality with container port's throughput. The results are shown in Table1. There exists the highest correlation (0.884) between the betweenness centralities and container port's throughput of container ports and the lowest correlation (0.379)between the closeness centralities and container port's throughput of container ports, which indicates that the characteristics of container cargo transport, with traffic size and reachability, are not the primary objectives of maritime cargo transport, and high transshipment is quite attractive for the organizational effectiveness of ports. We also consider the polarization of betweenness centrality, which is a node with better betweenness centrality in the network that will have its system centrality enlarged (e.g. multiplier effect). So the final formula is

$$SC_i = (\omega_1 CC_i + \omega_2 DC_i + \omega_3 EC_i) \times (1 + BC_i) \quad (6)$$

Where ω_1 , ω_2, ω_3 is CC_i, DC_i, EC_iweighted coefficient. ω_1=0.1, ω_2=0.45,ω_3=0.45.

We carry out a correlation analysis between the result of SC and corresponding port throughput. The Pearson correlation coefficient is 0.750, which indicates that system centrality is not only relevant to the role of the port in the network but also has a strong correlation with the port throughput.

Table 1 Correlation between centrality and port throughput

Correlation coefficient(R)	DC	EC	BC	CC
Total Throughput	0.790	0.666	0.884	0.379

2.3 Data

This paper analyzed the China-ASEAN shipping network, involving 93 container ports and 9193 OD routes in 2019 (www.shipxy.com). We used these data to calculate the arrival and departure records of vessels at all calling container ports. This resulted in a dataset comprising all ports, routes, and journeys, which was used to define the transportation networks.

3 RESULTS

The container ports mainly located in eastern coast of China, Indonesia, Philippines, Vietnam and Thailand in the China-ASEAN shipping network (in Fig.1).

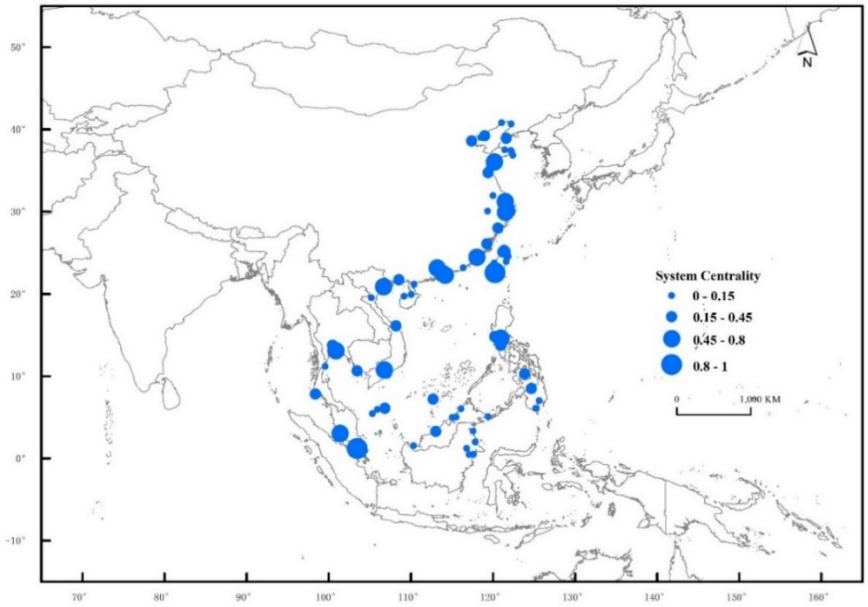

Fig.1 Distribution of ports in China-ASEAN shipping network

Table 2 The hierarchical structure of the ports system in China and Southeast Asia

Level	Scores	Number of Ports	Ports
1	[0.8,1]	2	Singapore; Kaohsiung
2	[0.45,0.8)	14	Manila; Ningbo; Shanghai; Xiamen; Tanjung Pelepas; Hong Kong; Qingdao; Cat Lai;Lame Chabang; Tanjung Priok;Port Klang; Haiphong,etc.
3	[0.15,0.45)	28	Cai Mep;Saigon;Taichung;Subic Bay; Batangas;ZhouShan;Danang;Vung Tau;Mawan;Fuzhou; Bintulu;,etc.
4	(0,0.15)	49	Quanzhou; Shantou;Shenzhen; Davao;Samarinda;Rizhao;Lanshan; Kuching;Keelung,etc

Table 2 shows all container ports in China and Southeast Asia are classified into four layers, focusing on the first to third layers. The first layers as the container ports hub ports, the second layers as regional hub ports, and the third layers as the ports with development potential in the China- ASEAN container shipping network. The result shows that Singapore and Kaohsiung are the hub ports of the China- ASEAN container shipping network and control the development of the maritime trade between China and ASEAN. Hub ports in the first layer and regional hub ports the second layer(Fig,4) are located in China (Kaohsiung Port, Ningbo Port, Shanghai Port, Xiamen Port, Hong Kong Port, Qingdao Port, Shekou Port Guangzhou Port, Singapore (Singapore Port), Philippines (Manila Port), Malaysia (Tanjung Pelepas Port, Port Klang,), Vietnam (Cat Lai Port, Haiphong Port), Thailand(Laem Chabang Port), Indonesia (Tanjung Priok Port). Port Klang, Tanjung Pelepas, Laem Chabang are emerging as new competitors to Singapore and could become new hub ports.Specifically, the Singapore Port, Port Klang and Tanjung Pelepas Port of Malaysia in the Strait of Malacca are the primary and secondary chokepoints in both core and secondary maritime shipping routes in this region. These are the top container ports in Southeast Asia, all with well-developed infrastructure, such as Port Klang and Tanjung Pelepas port upgraded their existing facilities, infrastructure and scale by building new berths and container yards to handle over 20.8 million TEU in 2018 .

In the first and second layers(in Fig.2), there is a high eigenvector centrality of each container port in the China-ASEAN shipping network. It is observed that Singapore has the highest eigenvector centrality. Specifically, the ports of eigenvector centrality in the first and second layers much higher than others. Therefore, it demonstrates that most container ports have limited ability to open up direct shipping lines to key container ports and conversely most shipping trunk lines concentrate on a few container ports in the China-ASEAN shipping network. Singapore(0.172) has the highest betweenness centrality. The container port with the second and third highest betweenness centrality is Kaohsiung(0.141), Manila(0.08) respectively. The betweenness centrality of Manila has a big gap compared to Singapore Port and Kaohsiung Port. Undoubtedly, Singapore Port and Kaohsiung Port have become the transshipment hub port for China and the Southeast Asia countries.

In the third layer(in Fig.3), we focus on 12 potential container ports connected with Chinese ports in Southeast Asia, which distribute in Vietname(Cai Mep Port, Saigon Port, Danang Port, Vung Tau Port), Philippines(Subic Bay Port, Batangas Port, Cebu Port, Cagayan de Oro Port), Thailand(Bangkok Port, Phuket Port), Malaysia(Johor Port, Bintulu Port), Indonesia(Tanjung

Perak Port). These ports with higher eigenvector centrality, as compared with fourth lawyer ports, which means that the ports not only have some connecting routes, its connecting ports also have a significant impact on it. Higher degree centrality also reflects the potential ports that can connect the direct shipping lines to the other neighbor ports. Variation of closeness centrality smoothly indicates these potential ports are mainly located near the shortest paths of many Origin-Destination pairs between China and Southeast Asia. Furthermore, one can find that Vietnam and the Philippines have the most ports with development potential. The main

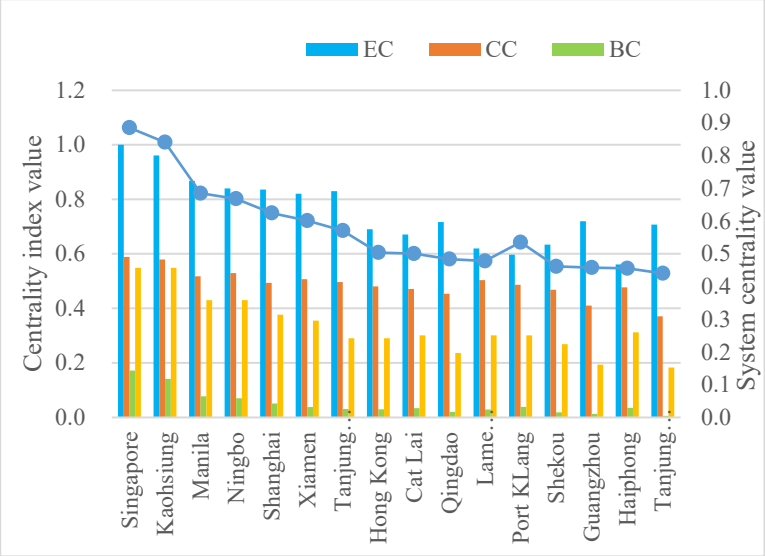

Fig.2 Ports in the first and second layers

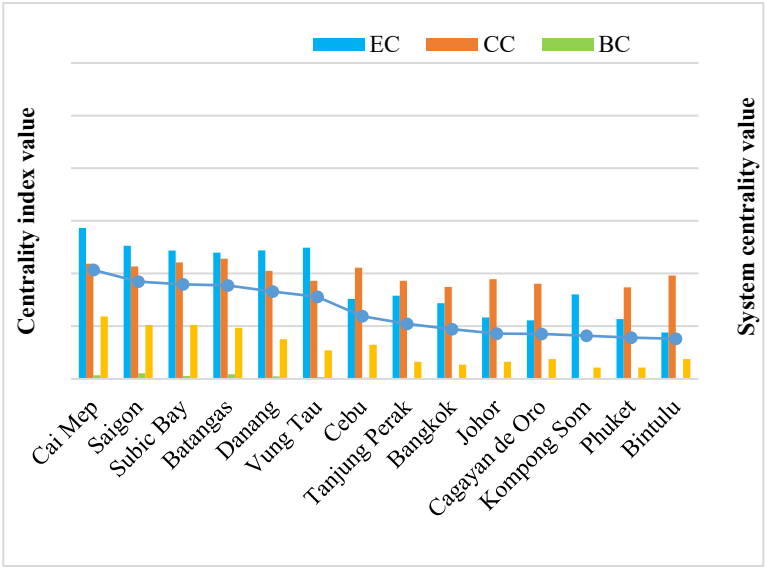

Fig.3 Ports in third layers located in Southeast Asia

reason that the digital economy spawned by the pandemic in 2020, cooperating more tightly in the electronics manufacturing industry between China and ASEAN. Especially, electrical and mechanical products are the first major product in bilateral trade between China and Vietnam. In 2020, Vietnam also serves as China's largest trading partner in the ASEAN. Vietnam is one of the most important suppliers of rice to China; China was still the Philippines' largest trading partner in the first (fourth-largest export market, largest import source) and second quarter (second-largest export market and largest import source) in 2020. Both countries have also agreed to establish a "fast track" lane and a "green channel" to guarantee the steady flow of goods and stability of industry a land supply chains between the Philippines and China impacted by COVID-19. Thus, benefited from both economic and geographic proximity.

The Cai Mep Port in Vietnam has the largest development potential, as compared with other considered potential ports. Take a closer look, the eigenvector centrality of Cai Mep Port is 0.573 and the degree centrality is 0.44. It indicates Cai Mep Port connects a certain number of hub ports and regional hub ports and relatively closes trade links in the China-ASEAN shipping network. Cai Mep Port is strategically located 50 kilometers southeast of Vietnam's commercial hub, Ho Chi Minh City. It offers direct access to and from Asia, Europe, and the Americas. These advantages prove it has large development potential and value investment.

In the fourth layer(in Fig.4), the top 10 Southeast Asia ports in the fourth layers mainly distribute in Indonesia(Samarinda Port, Makassar Port, Balikpapan Port, Cigading Port, Muara Pantai Port). Why Indonesia 's ports lack advantages compare with Vietnam and the Philippines in the China-ASEAN shipping network?

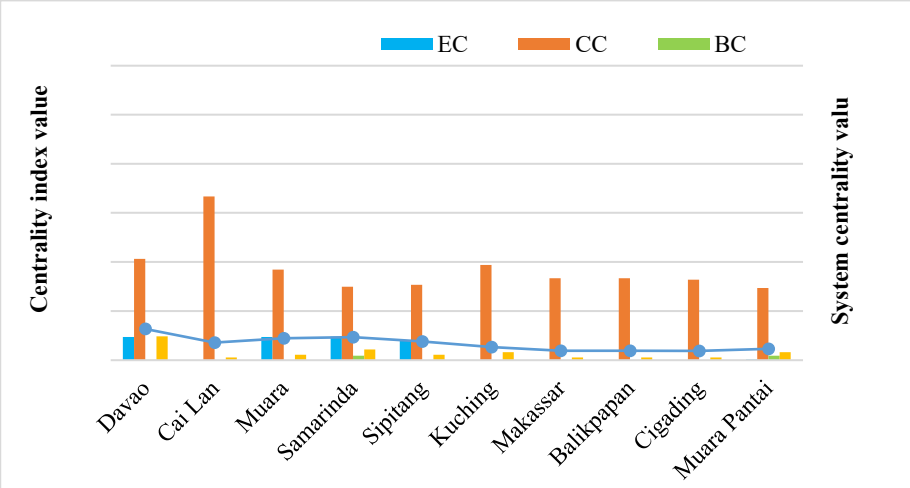

Fig.4 Top 10 ports in the fourth layers located in Southeast Asia

During the pandemic, Indonesia and China's economic relationship is seen to keep progressing despite both countries' difficulties in a domestic economic context. Fortunately, in commodities, the trade between Indonesia and China is still growing. In detail, 11 Indonesian commodities showed a significant increase in the first quarter of 2020 as shown by Table 3.As shown in Table 3, Packed fruits grow fastest, but electronics slowest. The Ministry Of Commerce People's Republic of China notes, In recent years, China and ASEAN keep progressing on different

industrial chains, particularly in the electronics manufacturing industry, which has a significant growth in the value of associated product imports and exports. As a part of the global electronics manufacturing chain, China imported 226.81 billion yuan of integrated circuits from ASEAN in the first half of 2020, increasing 23.8 percent year on year and accounting for 24.2 percent of overall ASEAN imports. The integrated circuit, energy, agricultural products contributed 3.2 %, 1.7 %, and 0.8% to China's trade growth with ASEAN, respectively. Thus, the small percentage of export growth electronics is one of the reasons for the lack of advantages of its ports

Table 3 Indonesian commodity export rise

No	Commodity	Increase percentage
1	Packed fruits	320.27
2	Processsed woods	222.44
3	Iron and steel	196.40
4	Swift's nest	189.61
5	Canned fish	92.59
6	Coal	74.42
7	Frozen fish	53.78
8	Shoes	24.59
9	Furniture	30.87
10	Tropical food	22.29
11	Electronics	14.70

One finding is that there is no great difference in the reachability of each container port which means the probability that one container port is connected with other container ports. The closeness centrality of China and ASEAN countries can be better understood if considering its geographic location, which indicates that transportation between almost all pairs of ports can be achieved directly or depending on one other intermediary ports and high reachability.

According to our results, we can further have the following suggestions:

(1) The national cooperation between Vietnam and China, the Philippines, and China have huge development potential and should be significantly improved shortly. As compared with other Southeast Asian countries,

(2) Investing in port construction in Vietnam and the Philippines can be a good choice for China to accelerate the implementation of the MSR and RCEP initiative

4 CONCLUSION

Ports that serve as a connection point between the sea and hinterland transport constitute strong support for both logistical and economic activities. With the strengthening of trade and regional integration dynamics between China and Southeast Asian countries, direct contact has increased. Southeast Asia gradually became the most important investment area for the Chinese government and enterprise. This paper pays more attention to container ports connected with Chinese ports in Southeast Asia based on centrality analysis. The conclusion demonstrates that:

(1) Singapore and Kaohsiung are the hub ports of the China- ASEAN container shipping network and control the development of the maritime trade between China and ASEAN.

(2) Regionl Hub ports are mainly located in China, the Philippines, Malaysia, Vietnam, Thailand, Indonesia Potential ports are mainly located in Vietnam and the Philippines, Cai Mep in Vietnam has the largest investment potential, as compared with other considered potential ports connected to Chinese ports in Southeast Asia.

(3) As compared with other Southeast Asian countries, the national cooperation between Vietnam and China, the Philippines, and China have huge development potential in the future for the Chinese government and enterprise, investing port construction in Vietnam and the Philippines can be a good choice for China to accelerate the implementation of the MSR and RCEP initiative.

Acknowledgements: This research was supported by the Natural Science Foundation of Fujian Province(2020J01659), National Natural Science Foundation of China (42001391).

REFERENCES

[1] K. Shimizu, “The ASEAN Economic Community and the RCEP in the world economy,” Journal of Contemporary East Asia Studies, vol. 10, no. 1, pp. 1–23, Jan. 2021,

[2] J. Zheng, L. Yang, W. Li, X. Fu, and D. Li, “Priority analysis of port investment along the 21st-Century Maritime Silk Road region: the case of Southeast Asia,” Maritime Policy & Management, pp. 1–19, Jun. 2021.

[3] D. K. Fleming and Y. Hayuth, “Spatial characteristics of transportation hubs: centrality and intermediacy,” Journal of Transport Geography, vol. 2, no. 1, pp. 3–18, Mar. 1994.

[4] Y. Hu and D. Zhu, “Empirical analysis of the worldwide maritime transportation network,” Physica A: Statistical Mechanics and its Applications, vol. 388, no. 10, pp. 2061–2071, May 2009.

[5] Z. Li, M. Xu, and Y. Shi, “Centrality in global shipping network basing on worldwide shipping areas,” GeoJournal, vol. 80, no. 1, pp. 47–60, Feb. 2015.

[6] C. Ducruet, “Multilayer dynamics of complex spatial networks: The case of global maritime flows (1977–2008),” Journal of Transport Geography, vol. 60, pp. 47–58, Apr. 2017.

[7] C. Ducruet, S.-W. Lee, and A. K. Y. Ng, “Centrality and vulnerability in liner shipping networks: revisiting the Northeast Asian port hierarchy,” Maritime Policy & Management, vol. 37, no. 1, pp. 17–36, Jan. 2010.

[8] Y. Z. Zhao, J. M. Zhou, and H. B. Kuang, “Hierarchical structures of hub ports in the global container shipping network based on centralities analysis,” vol. 3, p. 13, 2014.

[9] K.-F. Cheung, M. G. H. Bell, J.-J. Pan, and S. Perera, “An eigenvector centrality analysis of world container shipping network connectivity,” Transportation Research Part E: Logistics and Transportation Review, vol. 140, p. 101991, Aug. 2020.

[10] J.-W. Jeon, O. Duru, and G.-T. Yeo, “Cruise port centrality and spatial patterns of cruise shipping in the Asian market,” Maritime Policy & Management, vol. 46, no. 3, pp. 257–276, Apr. 2019.

[11] C. Ducruet, “Multilayer dynamics of complex spatial networks: The case of global maritime flows (1977–2008),” Journal of Transport Geography, vol. 60, pp. 47–58, Apr. 2017.

[12] Ducruet César, “Port specialization and connectivity in the global maritime network,” Maritime Policy & Management, pp. 1–17, Oct. 2020.

[13] B.Han,Y.Wang,Q.Zhang, and J.Wang,”Stations classification method based on system centrality for high-speed railway network,” vol. 42, p. 69, 2018. (in Chinese)