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Vietnam's Connectivity and Embeddedness in the Maritime Silk Road and Global Maritime Network

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ABSTRACT Vietnam is one of the sixty-five countries in the belt and road (BR) initialized by China and especially an important player along the 21st century maritime silk road (MSR). Moreover, Vietnam faces the Pacific Ocean and possesses an intrinsic advantage of maritime transport. Based on a big data system of port and shipping, the Vietnam's connectivity with the MSR and thus the global maritime system is analyzed by visualization and network analyzing methods. The mutual significances between Vietnam maritime network and the MSR (except for Vietnam) are derived from the flows between them; primary flows and key maritime trading clusters are discovered. Considering the global maritime network, the Vietnam's embeddedness in MSR and the global maritime network are portrayed by network analysis. In the context of the belt and road initiative (BRI) proposed by China, the alignment of Vietnam to the MSR and the world is examined. In conclusion, Vietnam is along the MSR while plays globally.

INDEX TERMS Marine transportation, logistics management, the belt and road initiative, big data, network theory, geographic information systems.

I. INTRODUCTION

Vietnam borders on China, Cambodia and Laos by land and Indonesia, Malaysia, the Philippines and Thailand across the sea. Vietnam is one of the 21st largest export economies in the world. In 2016, Vietnam exported $207B and imported $196B, resulting in a positive trade balance of $11B, while its GDP was $205B and average GDP per capita was $6.3k. Vietnam's top five export destinations are United States, China, Japan, South Korea and Germany, and the top import origins are China, South Korea, Japan, Singapore and Other Asia [1]. Embedded in the global commodity supply chain and logistics, Vietnam connects the world by taking trade as an important instrument.

Vietnam attended several economic alliances and assigned a bundle of free trade agreements with developed and developing economies. In 1995, Vietnam joined the Association of Southeast Asian Nations (ASEAN) and ASEAN Free Trade Area (AFTA) [2]. Enhancing ASEAN Connectivity would continue to benefit all ASEAN Member States through improved physical, institutional and people-to-people linkages. Together with the ASEAN countries, Vietnam has signed trade pacts with China, the Republic of Korea, Australia, New Zealand, India, Chile and Japan. In 2000, Vietnam and United States concluded the Bilateral Trade Agreement. In 2007, Vietnam became the 150th member of the WTO. In 2016, Vietnam signed a free trade agreement with the EU. Vietnam is currently negotiating a Free Trade Agreement with the EFTA countries (Norway, Iceland, Liechtenstein, and Switzerland). Free trade and economic integration agreements usually emphasize the importance of the physical delivery of the goods and people flows [3]. The physical connectivity, which consists of various dimensions of land, maritime, and aviation modes, is critically important to implement the complex agreements, national policies, regulatory frameworks and infrastructure financing, including the Chinese Belt and Road Initiative (BRI).

The BRI aims to promote the connectivity of Asian, European, African continents and their adjacent seas, establish and strengthen partnerships and connectivity networks among the countries along the Belt and Road (BR) [4]–[6]. In the BRI, the Silk Road Economic Belt (SREB) focuses on bringing together China, Central Asia, Russia and Europe (the Baltic); linking China with the Persian Gulf and the Mediterranean Sea through Central Asia and West Asia; and connecting China with Southeast Asia, South Asia and the Indian Ocean. The 21st century Maritime Silk Road (MSR) is designed to go from China's coast to Europe through the South China Sea and the Indian Ocean in one route, and from China's coast through the South

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FIGURE 1. Vietnam interactions and embeddedness in the context of BRI.

China Sea to the South Pacific in the other [7]. At the China-ASEAN Expo in 2013, Chinese Premier Li Keqiang emphasized the need to build the MSR oriented toward ASEAN, and to create strategic propellers for hinterland development. As presented in Figure 1, regionally, Vietnam interacts with bordered economies including China, Laos and Cambodia; geographically, Vietnam is under the SREB and along the MSR as a key member of ASEAN. Vietnam is embedded in the SREB and MSR, and interacted with Southeast Asia by both sea and land gateways.

Geographically, Vietnam is a typical maritime economy with prosperous coastal lines for maritime transportation. It developed export-oriented economy fast and emerged as an important economy in recent years. Based on the port system of seaports and river ports, Vietnam's maritime trade contributes more than 90 percent of its total export and import cargo volumes [8]. Vietnam ports are near major maritime routes, such as the Trans-Pacific and north-south Asia trade lanes, this enhances Vietnam competitiveness against other global ports such as Singapore.

Vietnam's growing GDP and international trade are coupled with diverse connectivity and embeddedness in ASEAN, BRI and the global networks. Although the issues on connectivity, globalization, various agreements, alliances and initiatives are well examined in the context of networks especially of global commodity network, Vietnam is not studied in these contexts. This study is particularly activated by the following curiosities and questions. First, how about the Vietnam's maritime connectivity? In the present maritime geography, although Vietnam has a long coastal line and numerous sea ports, its ports are less developed compared to the upper Chinese ports and below Singapore ports. Second, is the connectivity of Vietnam's maritime network to the world consistent with the connectivity to the MSR? Besides various disputes and conflicts, Vietnam occupies the throat of MSR and even important gateways between China and ASEAN.

To investigate the Vietnam's interaction and embeddedness in the global maritime network, the networks are constructed from a data system developed in our previous study. The data structures are elucidated. The interactions and embeddedness are transferred into network relations. Based on the metrics and algorithms in network science, a group of metrics are devised to assess the interaction and embeddedness of a sub network with another or the global network.

The rest of the paper is organized as follows. Section 2 reviews the studies related to connectivity, embeddedness, BRI, Vietnam's maritime connections and network analysis methods. Then, the data system, networks, observation and activation of the study are elucidated in Section 3. In Section 4, four aspects are analyzed for Vietnam based on the maritime networks coupled with trade data. In Section 5, the implication to management and policy-making are discussed. In Section 6, the strengths, shortages and future research directions are concluded.

II. RELATED STUDIES

A. CONNECTIVITY AND EMBEDDEDNESS

Various networks represent the connectivity among geographically scattered facilities, ports, cities and regions. The relations between networks are studied as embeddedness, which originally expresses the impacts of non-economic institutions on economic activity [9]–[13].

The general embeddedness between companies, cities and countries have been largely researched and brought doubts on various institutional economic theories. World city network (WCN) emerges from globalization, which is usually studied in the context of specific product and service networks [14]. In the researches on WCN, corporate networks are used for analyzing interurban hierarchies and structures to understand the geographies of globalization [15]. Combining the WCN approach and the Global Commodity Chain (GCC) analysis can contribute to conceptualize the geographical connectivity broadly and understand the globalization processes, such as export-oriented industrialization and migration from rural hinterlands into GCC [16]. Maritime network is a representative of GCC based on the international maritime cargo transportation.

Product and producer relations are organized and carried by global supply chain and logistics systems, which are driven by trade and industries in regions. For the maritime trading economies, the above connectivity measures are mainly projected to the global maritime network. In this study, the maritime networks are formulated to examine Vietnam's interactions with other economies, and Vietnam's embeddedness in regional initiative (e.g., MSR) and global maritime network.

B. VIETNAM AND REGIONAL CONNECTIONS

Vietnam has built diverse connections with other economies by regional organizations (e.g., ASEAN and the World Trade Organization (WTO)), FTAs (with most developing and developed economies) and trade partnerships. Vietnam's

labor resources and reform policies positively activated the global investments. The investors exploit Vietnam's natural resource, large, immature, and growing domestic market, and collaborate with politically well-connected Vietnamese companies to further the long-term commercial interests [17]. After implementing opening up policy, Vietnam attracted an important partner, India, to promote trade and investment together, since the impact of India Look East Policy [18].

Smoothing the cargo transportations between countries is a topic of the international trade and transport policy agendas. Comprehensive understanding and assessment of the cargo connectivity will guide and design effective policies to remove barriers in international trade flows [19]. In this study, Vietnam's connectivity with the world is analyzed based on port connectivity [20] in the global maritime network.

C. THE BELT AND ROAD INITIATIVE

A series of integration projects and initiatives are proposed across the Eurasian continent: China's BRI, the ASEAN's Regional Comprehensive Economic Partnership (RCEP), the Trans-Pacific Partnership (TTP) previously led by America, and the Eurasian Economic Union (EEU) promoted by Russia. The BRI aims to improve the cross-border infrastructure and satisfies the fundamental requirements in the geographical area of Asia, Europe and Africa. BRI will reduce the transportation costs (both railway and maritime) among Belt and Road (B&R) countries, and especially benefit the landlocked countries [5], [6], [21]. The BRI can finely coordinate the networks based on improving the infrastructures [22].

The BRI is a large connectivity project that involves a number of actors (governments, private companies and Chinese state-owned enterprises) at a large geographic scales (cities, provinces, states and continents) [23]. The BRI encompasses 65 countries, accounting for approximately 32 percent of global GDP, 39 percent of global merchandize trade, and 63 percent of the world's population. The initiative seeks to develop a wide network of connectivity and cooperation spanning the entire Eurasian land mass and parts of Africa, including Central Asia, Southeast Asia, South Asia, the Middle East, Europe, and North and East Africa [24]. The BRI proposes to improve the transportation infrastructure to give rise to closer and larger economic, social, cultural, and political ties. Although it may be significant potential to improve the social, economic and political stability and structure in Asia, Europe, and northeastern Africa, it is criticized because of extremely ambitious and far reaching [25]. The BRI's multi-dimensional features (in-country, regional, and global) are inclusive (multi-vector, the participation of all sectors of the economy) and have a strong non-economic component (''soft power'') [4], [5], [26]. BRI aims at solving the problems of the Chinese economy with the help of foreign-policy methods and consolidating China as a global economy engine.

The BRI brings new opportunities and challenges for port cooperation and development in China and the regions along the B&R [27]. Although the BRI is basically a trade and infrastructural developmental initiative that benefits Eurasia economies, its infrastructural investments and constructions are coupled with security dynamics and even sovereignty concerns especially in Central Asia [6], [28]. Maritime ports play important roles in global logistics and supply chains while the BRI may change the ports' positions and the maritime port. [4], [5]. The maritime network will be reorganized when the perspective of BRI comes as it is expected [29].

D. NETWORK ANALYZING METHODS

Ports and shipping are organized as networks. The relations among ports (including terminals and berths) are a network of cargo handling facilities; the vessels visit these facilities for berthing and cargo handling operations, and form carriers of vessel/cargo flow networks; port, shipping and logistics operations represent a network of operators; a regional or global logistics and supply chain network enable the above operations and relations.

The competition, complementation and clusters in a complex trade network can be analyzed by degree centrality, strength centrality, closeness centrality, eigenvector centrality and betweenness centrality [30]. In the context of globalizations, the trade and cargo flows make the world interconnected and more stable [31]. By examining the global material and cargo flow networks, the trade partnerships, clusters and sub active networks can be identified [32], which reversely impact the global supply chain networks. Stakeholder complexity (complex relations among stakeholders) embedded in the underlying complex networks can be examined by combining rationalistic methods (e.g., social network analysis) and empirical methods (e.g., survey and interviews) [33].

Maritime network expresses the regional and geographical relations. It is used to investigate various global issues based on the trade, economy, environment, culture and politics. The network topologies related to geography and regional science are studied by considering the spatial interaction, where the centralized and dispersed origin-destination flows propel the evolution of networks [34]. The maritime ports and shipping flows constitute maritime connectivity or flow networks with hierarchies and dynamics [35]–[37]. The multiplex network is used to formulate the dependences among networks to analyze their robustness and stability [38], [39].

III. A SYSTEMATIC SCHEME OF THE STUDY

A. OBSERVATION AND ACTIVATION

Vietnam locates in the middle of two groups: first, China, Korea and Japan; second, the ASEAN and Oceania. It is on the right edge of Eurasia continent (Vietnam is usually considered geographically or geologically as part of Southeast Asia), where consists of developed European economies on the left edge. It faces the World's largest economy, the United States of America; and it borders the second largest economy, China.

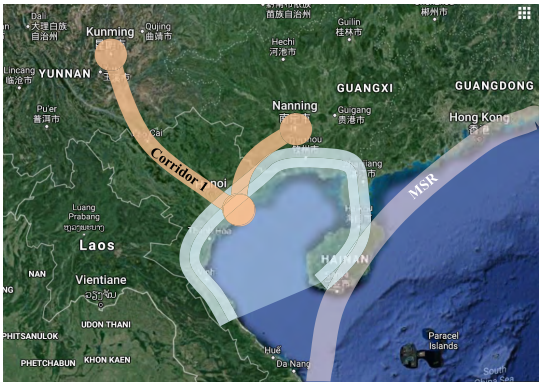

FIGURE 2. Two corridors and one economic belt initiative.

Vietnam's maritime trade contributes ninety percent of its total trade values in the recent years. Vietnam has developed more than forty maritime ports. Three distinct maritime clusters have emerged in North, Central and South Vietnam distinctly serving for three important economical deltas. Maritime transportation plays an important role in Vietnam's well-developed export-oriented economy.

Regionally, Vietnam is an active member of ASEAN, whose RCEP is an initiative of improving the ASEAN's connectivity. Vietnam is also in the geographical scope of BRI and especially of MSR. Geopolitically, Vietnam is an important "bridge" between China and ASEAN. Optimistically, the success of these two initiatives will benefit Vietnam and especially Vietnam's global connectivity.

Additionally, a China-Vietnam Initiative –"two corridors, one economic belt" (TCOB) –had been proposed between the two countries' border provinces and localities along the Tonkin Gulf in a series of areas such as trade, agriculture, industry, tourism, transport and communication [40]. As presented in Figure 2, the TCOB is around the Vietnam's Red River Delta and Tonkin Gulf, connecting the North Vietnam and three Chinese provinces (Yunnan, Guangxi and Hainan). TCOB directly links MSR while connects SREB through Yunnan Province (Figure 1).

B. A DATA-DRIVEN RESEARCH SCHEME

A methodological diagram of the paper is depicted in Figure 3. The research is an iteration process especially because it involves a data system with numerous models and algorithms. Based on the previous research [4], the geographical, economical and trade data related to Vietnam were collected. New analytical models and algorithms were developed based on the designs of this study (Sections 4-6).

The data can be classified into three groups. First, the maritime network is created from our previous studies based on five years' data, whose structure will be investigated in Figures 4-5. The data integrates various data sources. The port and vessel profiles are accumulated from searching web pages by web crawlers and developed parsers. The vessel tracks - the automated identification system (AIS) data - were bought from commercial data providers. The geographical and economical data related to Vietnam were collected from

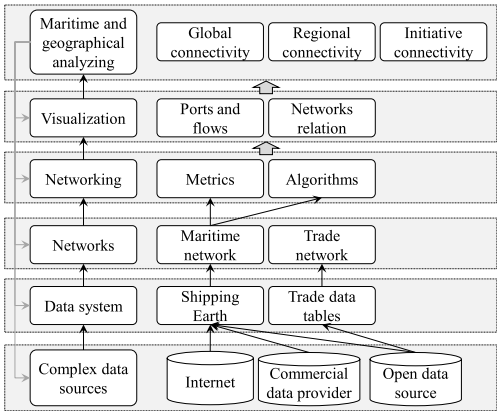

FIGURE 3. A system of the research scheme.

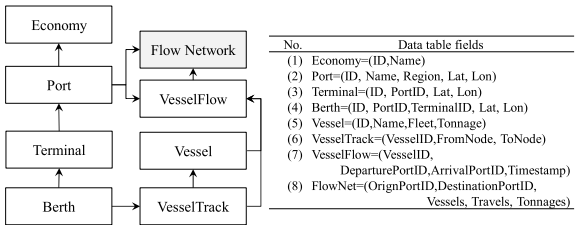

FIGURE 4. Basic data structure of the maritime data system.

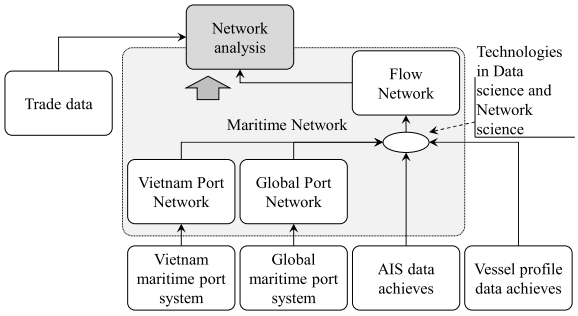

FIGURE 5. A system of maritime networks.

investigations to experts in Vietnam studies and the web pages. The Vietnam annual trade data was obtained from UN Comtrade [41].

Two data system modules are used to organize the above data: the Shipping Earth data system, and the trade data module. Correspondingly, two kinds of networks are produced: maritime networks and trade network. The maritime network integrates various scales and compositions. The trade network is coupled with the maritime networks by sharing the same set of economies.

The metrics and algorithms on general complex networks are developed based on various centrality metrics and algorithms, cluster and communities analyzing methods, general iterating/searching, routing and networking methods. Vietnam is a sub network of the global maritime network, and the BRI and MSR also can be viewed as a sub network. When the global maritime network is used as a base, all other economies, regional/geopolitical initiatives or agreements is viewed as a projection of the maritime network to the regions

of these initiatives or agreements. To examine the features and relations between networks, we develop specific metrics and algorithms (Section 4). Besides the focus of network relations in this study, the network is formed from vessel flows, which is reflected by the network visualization.

Besides examining the connectivity within a network, we develop algorithms to examine the connectivity between sub networks embedded in a global network.

In the following, the data structures of the maritime data system are described (Figure 4) and followed by a set of networks (Figure 5).

Figure 4 depicts eight entities, their relations and their compositions of data items. In the data table on the right of Figure 4, the "ID" columns are used to model the relations among data entities. Region, Port, Terminal and Berth consist of a geographical hierarchy; Vessel tracks belong to specific vessels; a vessel flow is defined by specific vessel, origin and destination ports, and a timestamp; the flow network is a network of ports, where the flow content mainly uses number of vessel travels and tonnages between the ports.

As presented in Figure 4, the network model can be represented by:

$$\text{FlowNet} = \left\{ \begin{array}{l} \text{OriginPortID, DestinationPortID,} \\ \text{Vessels, Travels, Tonnages} \end{array} \right\}.$$

The network nodes consist of the origin and destination ports; the weights of links among the nodes have four choices, number of vessels, number of travels, tonnages and connection tags that are computed from the any one of the first three values. If they are positive, the link is connected; otherwise, disconnected.

Figure 5 depicts the primary networks and their relations. Indeed, the Vietnam maritime port system is a sub system of the global maritime port system. Upon these two systems, corresponding networks are created. Coupled with the AIS vessel tracks and the vessel profiles, the flow networks are created as FlowNet. Trade data is used to present a kind of Vietnam global connectivity with the world. Figure 5 also presents the technologies used in data and network sciences.

By analyzing the flow network in Figure 4 and FlowNet, Vietnam has 44 active ports in the network. In the period of five years from 2013 to 2017, 10708 vessels in the world have visited Vietnam. These vessels involve 877 container vessels, 875 tankers, 2054 bulk vessels and 36 cruise vessels. Averagely, a valid track data record was caught per three minutes. It is also found that totally 3210 ports in the world relate to Vietnam by vessel flows. The connections between Vietnam and the world are visualized in Figure 7. In the right part of the figure, the domestic connections are depicted.

IV. ANALYZING METHODS AND RESULTS

A. GLOBAL CONNECTIVITY

Vietnam can connect with the world through maritime transport. Four dimensions are computed for Vietnam's maritime connections (Table 1). A maritime connection is defined by that a vessel visits a pair of ports and one of the ports is

TABLE 1. Annual vessel connections with vietnam maritime ports.

	Year				
	2013	2014	2015	2016	2017
Km	19128655	35617611	28884899	19683042	17193951
Active vessels	9002	9677	9715	9240	10145
-Domestic	3209	4239	3425	2623	2638
Connections	814702	1315267	1133477	763609	785769

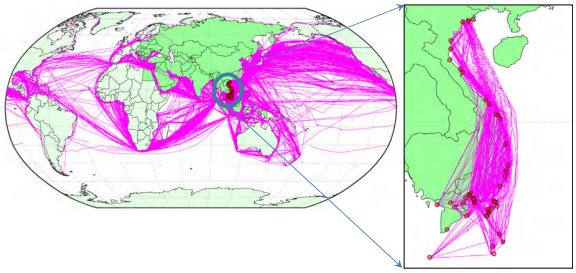

FIGURE 6. Visualizing the maritime connections between vietnam and the world.

in Vietnam. A record of the data table (7) in Figure 4 is a maritime connection. In Table 1, Vietnam's maritime system is highly active in 2014 and then the activity degree decreases. Within these five years, totally 10708 vessels visited Vietnam at least once; Vietnam connected with 3210 ports in the world through its 44 active ports. In 2017, 10,145 vessels visited the ports of Vietnam while 2,638 of them are "domestic" vessels, which only visited the ports of Vietnam. The vessel tracks connecting Vietnam with the world are visualized in Figure 6, and the domestic connections are in the right part.

It is believed that 90% trade values of Vietnam are implemented by maritime transport. However, a maritime connection does not indicate a time of maritime trade, although it may refer to a possibility of trade. To verify the consistence between maritime connection and trade, we compute the maritime connections (from FlowNet) between Vietnam and all other economies in 2017; then, the trade data between Vietnam and other economies in 2017 are obtained from comtrade.un.org; these two tables of data are merged so each economy has four data items (trade value (including import and export values), vessels, visits and tonnage). In Figure 7(a), the economies are ranked by export from Vietnam to them and then depicted; in Figure 7(b), similarly, economies are ranked by import. The ranks indicate that Vietnam mainly export cargos to USA, China, Japan, Korea and Hong Kong of China, while its top maritime partners are China, Japan, Korea, Hong Kong of China, Malaysia, Indonesia. Vietnam mainly imports cargos from China, Korea, Japan, Thailand and USA, while the maritime partners include: China, Korea, Japan, Malaysia, India, Australia and Philippines.

The above generated data also indicates the following results. First, total 142 economies trade with China; second, among them, 26 economies are possibly landlocked countries (without maritime ports), in other words, among the trade countries, 116 are maritime countries; 182 economies connected with Vietnam in maritime network; among these

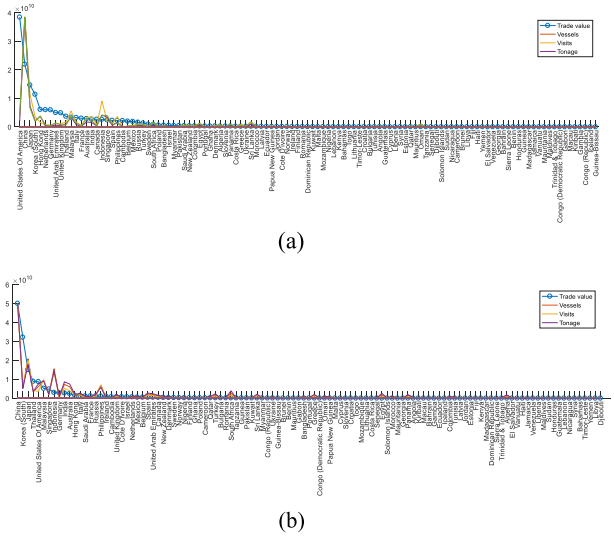

FIGURE 7. Vietnam playing with the world through value and cargo trades. (a) Trade economies ranked by export. (b) Trade economies ranked by import.

182 economies, 113 economies have trade values with Vietnam, and the other 69 economies have no trade with Vietnam.

B. GLOBAL EMBEDDEDNESS

In the context of network, embeddedness refers to routinization and stabilization of linkages among members as a result of historical exchanges and relations within a group or community [10]. In general economics and economic sociology, embeddedness refers to the degree to which economic activity is constrained by non-economic institutions [9]. In a complex network, the embeddedness can be represented by the relations among sub networks usually in the background of the global network. Here, a sub network may be a port, a port group, an economy or an economy group.

Here, the Vietnam's global embeddedness is embodied in the following aspects: significance of Vietnam's ports in the global maritime network; the situation of Vietnam's port system in the global maritime port clusters; interactions of Vietnam's ports to other global ports by maritime flows.

Using the connection data (*OrignPortID*, *DestinationPortID*, *Travels*) in FlowNet, a directed network (with edges defined by pairs of *OrignPortID* and *DestinationPortID*) with weights (*Travels*) is created. The *Pagerank* centrality [42] is used to assess the port significances in the network. In Figure 8, all ports are depicted by filled circles on the map and the circle sizes are scaled positively related to the *Pagerank* centrality. Comparing to Vietnam ports, many nearby ports in the north and south to Vietnam have greater significances.

Further, we computed the degree centrality [43] for all ports in the global maritime network. The ports' circles are scaled by the degree centrality values, as presented in Figure 9. We can identify three dominant clusters in the

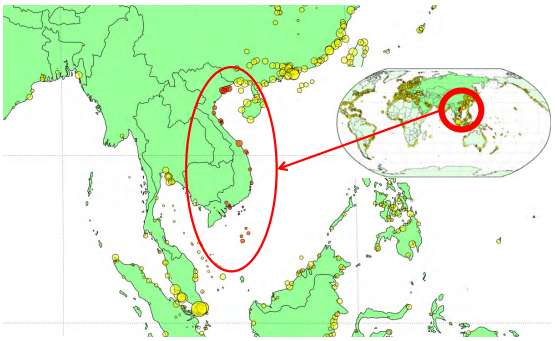

FIGURE 8. Significance of the vietnam maritime network in the context of global maritime network.

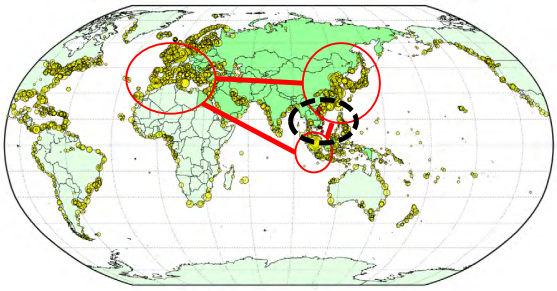

FIGURE 9. Vietnam is in the centrality triangle in global maritime network.

map: China-Korea-Japan, Strait of Malacca, and Europe. In Figure 9, three clusters form a triangle. China-Korea-Japan and the Strait of Malacca are two close clusters in the east of Eurasia while Europe locates in another end of the Eurasia continent. Vietnam is between these two close clusters, China-Korea-Japan and the Strait of Malacca, and out of the primary connections between them. Vietnam is in the "shadow" of these two clusters. As studied above, Europe will be an increasingly important trade partner of Vietnam especially when the trade agreement between them takes functions in 2018; China-Korea-Japan are most dominant import and export partners of Vietnam; Strait of Malacca is a port clusters undertaking the cargo transshipments to America (especially USA), ASEAN and Oceania economies.

Based on the data system and networks described in FlowNet and Figure 4, Table 2 is produced by the following steps. First, the ports set is divided into two groups, Vietnam ports and ports outside of Vietnam, denoted by "*Vietnam*" and "*NotVietnam*". Second, given these two port groups, two maritime networks are sliced from the global maritime network (FlowNet). A third maritime network (denoted by *Cx*) is created between these two port groups. Third, three metrics are computed by aggregations, namely Vessels, Travels and Tonnages, as denoted in FlowNet. When two ports are connected by at least one record in FlowNet, we say that a "connection" exists between these two ports. So, the fourth metric "Connections" is obtained. Forth, the percentages of third network (*Cx*) to the two networks (*Vietnam* and *NotVietnam*) are computed for these four metrics (Connections, Vessels, Travels and Tonnages). The results of the above analyses are presented in Table 2. In the table,

TABLE 2. Vietnam embeddedness in the global maritime network.

	Conn	Vessels	Travels	Tonnages
Vietnam	3267	3267	19925	4.2E+08
Cx=V&NV	2877	2877	13714	3.56E+08
NV	362136	362136	18203969	2.06E+11
Cx/V (%)	88	88	69	85
Cx/NV (%)	1	1	0	0

Note: Conn= Connections; V=Vietnam; NV=NotVietnam

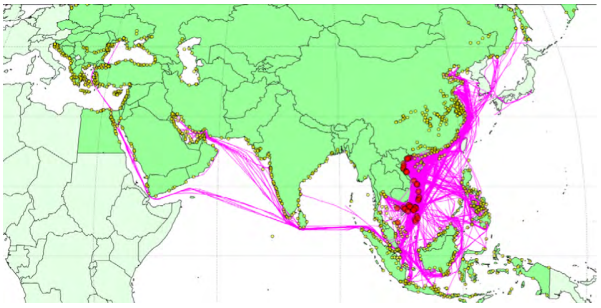

FIGURE 10. Vietnam embedded in the MSR.

Vietnam's out-connections account for 80% while the domestic connections only account for at most 20%, which indicates that Vietnam is a prominent export-oriented economy. Although Vietnam is so active in maritime transportation and global trade, its maritime connections just account for approximately 1% of the world.

C. EMBEDDEDNESS IN MSR

Among approximately 4500 active maritime ports globally, 1500 of them locate in the region of B&R and belong to about 33 economies. Vietnam is one of them and in the important throat (Figure 10). As studied in Section 4.2, the Vietnam ports are not significant in the global maritime network, while they connect two supper maritime clusters, through which Vietnam trades with the world. Due to less direct connections to America, Europe and even ASEAN economies, Vietnam connects the world through regional hubs in the two clusters, which are important players of the MSR.

The maritime tracks connecting Vietnam and the 33 MSR economies are visualized in Figure 10. From the density of tracks, the connections between Vietnam and MSR are dense in and around the South China Sea. However, the America and Europe economies are important trade partners of Vietnam. From Figure 10, we can conclude that the transshipment cargo accounts for the most of Vietnam's trade cargo flows.

As defined in Section 4.2, Vietnam ports and the MSR ports excluding Vietnam ports are taken as two sets of ports. Thus, three networks are constructed, namely Vietnam, MSR (excluding Vietnam), and the network between Vietnam and MSR. The final network is denoted by "*Vietnam&MSR*". Four metrics are then computed for these three networks following by the percentages of "*Vietnam&MSR*" to Vietnam and MSR, as presented in Table 3. Although the values of different metrics vary much, it can be asserted that Vietnam projects 80% of its maritime connections on MSR economies,

TABLE 3. Vietnam embeddedness in the MSR.

	Conn	Vessels	Travels	Tonnages
V	3,267	3,267	19,925	4.2E+08
V&MSR	2,571	2,571	18,273	3.73E+08
MSR	166,509	166,509	13,779,924	1.55E+11
(V&MSR) /V (%)	79	79	92	89
(V&MSR)/MSR (%)	2	2	0	0

Note: Conn= Connections; V=Vietnam

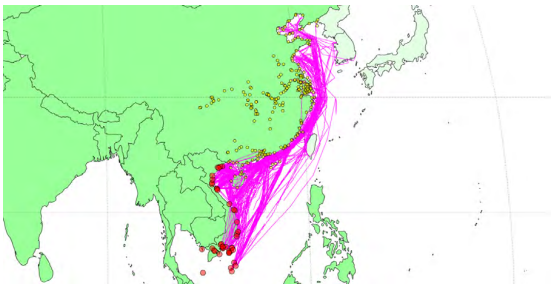

FIGURE 11. Vietnam playing with china.

TABLE 4. Vietnam's interaction with china through maritime connections.

	Conn	Vessels	Travels	Tonnages
V	3267	3267	19,925	4.2E+08
V&C	867	867	4,767	1.01E+08
C	64,709	647,09	12,372,635	1.21E+11
V&C /V (%)	27	27	24	24
V&C /C (%)	1	1	0	0

Note: Conn= Connections; V=Vietnam; C=China

although its overall maritime connections just account for at most 2% of MSR.

It is curious that how much the above projection of Vietnam maritime connections to China accounts for, because China is a dominant trade partner of Vietnam and also a dominant maritime player connecting with Vietnam. In Figure 11, the interaction network between them is presented. Here, two economies are taken as two independent networks and we use the similar method described above to compute four metrics of three networks. The results are given in Table 4. Twenty-five percent of flows from/to Vietnam connect with China, while the connections with Vietnam just account for 1%. China is the largest maritime partner of Vietnam. As presented in Figure 7, China is the largest import partner and one of the largest export partners of Vietnam.

In Figure 12, we further compute and depict the top thirty flows among the interaction networks studied above, namely, *Vietnam&World*, *Vietnam&MSR*, and *Vietnam&China*. The top flows indicate the prominent connections or maritime channels existing between Vietnam and these economy groups (World, MSR and China). In a summary, the main channels in these interaction networks exist between Vietnam and China or Strait of Malacca (Figures 12(a) and 12(b)). The three Vietnam economic deltas (North, Red River Delta; Central economic zone; South, Mekong River Delta) all connect with China prominently.

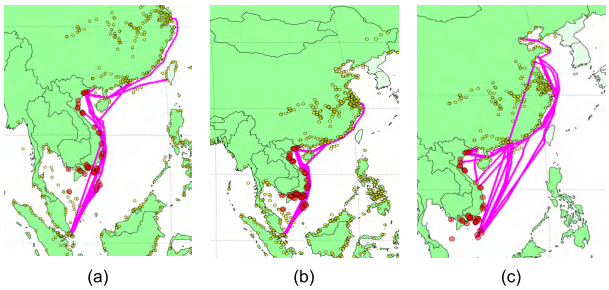

FIGURE 12. Top thirty maritime flows between vietnam and world/MSR/china. (a) Vietnam & World (b) Vietnam&MSR (c) Vietnam&China.

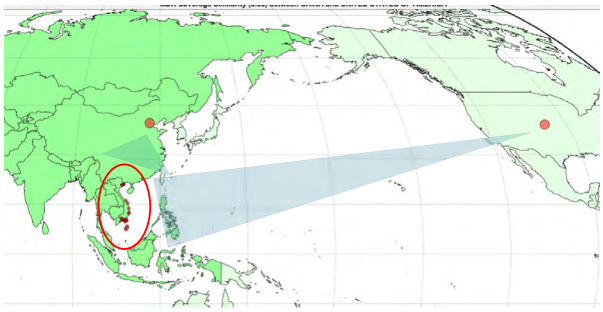

FIGURE 13. Vietnam between USA and china.

D. MARITIME INTERSECTION

In Figure 7, USA is Vietnam's largest export partner and China is Vietnam's largest import partner and maritime partner. Their intersection on Vietnam is examined below. First, we introduce a similarity based on set intersection, as denoted by $S(A, B) = |A \cap B|/|A \cup B|$. Second, the set of Vietnam ports connecting with China is denoted as A, and the set of Vietnam ports connecting with USA is denoted as B. The similarity based on intersection of USA and China on Vietnam is then computed by $S(A, B)$. As presented in Figure 12, 56% Vietnam maritime ports are connected by China and USA simultaneously, S (China, USA). The result also indicates that USA and China play different roles in Vietnam's development.

Using the same analyzing method, two representative ports (Shanghai and Singapore) from the two big maritime clusters around Vietnam in the maritime triangle (Figure 9) are examined considering their intersection on Vietnam, as presented in Figure 14. The similarity between Shanghai and Singapore is as high as 81%, S (Shanghai, Singapore). These two representative ports play different but consistent roles to Vietnam. Shanghai is the center of the cluster, China-Korea-Japan, while Singapore is corresponding to the Strait of Malacca. Through Shanghai, the maritime trade with China, Korea, Japan and partially North America can be realized; through Singapore, the maritime trade with ASEAN, Oceania, Europe and partially North and South America can be realized. If we cut the MSR into two segments by Vietnam, Shanghai is a center of the eastern part, while Singapore is a gateway of Vietnam to the western part. So, these two ports are important bridges for Vietnam to the world.

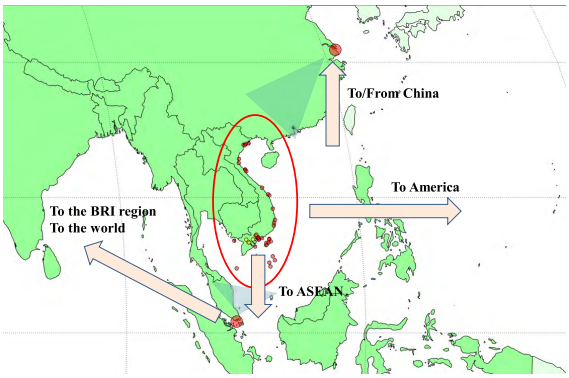

FIGURE 14. Connections with shanghai and singapore.

V. IMPLICATIONS

Vietnam presents trade, economical, political and geopolitical importance recently. Geographically, Vietnam is between two big maritime clusters: China-Korea-Japan and Strait of Malacca along the MSR. Although Vietnam's maritime network itself is not competitive, it plays globally with most prominent economies and maritime clusters.

1) The trade and maritime connections are much consistent between Vietnam and other economies. The import and export distributions of economies traded with Vietnam depict different roles of these economies in the global logistics and supply chains of Vietnam. The differences between trade economies and maritime connected economies indicate interesting opportunities: existing maritime connections will possibly help to develop new maritime connections with low costs for the potential trade economies, which have maritime connections while no trade value.

2) Although Vietnam's trade is developing fast and even plays an increasingly important role globally, Vietnam's maritime network is not prosperous compared with its close maritime clusters. By clustering the ports in the global maritime network, Vietnam is found to be exactly located in a big maritime triangle: China-Korea-Japan, Strait of Malacca and Europe. The China-Korea-Japan locates on the upper of Vietnam while the Strait of Malacca is under Vietnam. Through two supper big maritime clusters, Vietnam builds strong trade connections by direct transportation or transshipment with its largest trade partners, mainly including USA, China, ASEAN and Europe. Although Vietnam is strengthening its maritime investment, creating a third maritime cluster is not rational between two supper maritime clusters (China-Korea-Japan and Strait of Malacca). So, the possible optimal decisions are: first, develop Vietnam's ports as feeders to the main hubs of these two clusters (e.g., the Singapore, Hongkong and Shanghai ports); second, develop limited clusters among the Vietnam ports to increase the effects of economy of scale on cargo handling and transportation.

3) Vietnam's trade should depend more on maritime transportation. However, its trade volume projected to maritime connections is not prominent when the percentages of the intersection flows comparing to the overall flow in world,

MSR or China. In this aspect, the Vietnam's trade value is comparatively higher than its maritime volume, which indicates that Vietnam's trade is value-added. However, Vietnam' maritime connections drastically depend on two big maritime clusters in its north (China-Korea-Japan) and south (Strait of Malacca). It is necessary to improve Vietnam's maritime hubs and clusters to increase the effect of economy of scale on maritime cargo handling and transportation. However, most important, there should be fine channels to these two clusters. Within the maritime triangle (China-Korea-Japan, Strait of Malacca, and Europe), developing competitive maritime network of Vietnam itself is not so necessary and cost-saving.

4) Vietnam connects the world (especially USA, ASEAN and Europe) directly through two maritime clusters (China-Korea-Japan, and Strait of Malacca). However, the connections between Vietnam and the world are also consistent with the connections with MSR that covers the two dominant maritime clusters. In this sense, improving the maritime connectivity with the world is to improve the connectivity to the MSR. These two aspects are equivalent. To Vietnam, the MSR and the world are consistent in terms of maritime connectivity. Although there are many assertions about the geopolitical ambitions of MSR, the MSR is also consistent with the economic requirements and situations for some economies, e.g., Vietnam.

5) Conflicts and disputes are embedded in the economical activities between any two economies especially when they both play important roles in the international affairs and environments. Many triangles exist to constrain and reflect the practical relations and reality among the economies. Vietnam's two largest trade and maritime partners, USA and China, also project economical, political and geopolitical lights on Vietnam. However, indeed, their roles for Vietnam are different. USA is mainly a market while China is mainly a partner in supply chain and regional economy.

6) Maritime network is a hierarchical system of ports with different scales and roles. Between two maritime clusters (China-Korea-Japan and Strait of Malacca) in the big maritime triangle (China-Korea-Japan, Strait of Malacca and Europe), it is rational for Vietnam to develop coordination strategies with the clusters and utilize the network to expand its maritime trade connections. It is a promising strategy to develop Vietnam's local maritime hubs and clusters to connect these two big maritime clusters.

7) Vietnam is in the maritime triangle and connects the world's large economies through the port and shipping facilities in the triangle. Considering MSR, Shanghai and some mega ports of China-Korea-Japan are hubs for Vietnam to explore the market in the eastern part of the MSR; and Singapore is a gateway for Vietnam to connect the central (ASEAN) and western (Central and West Asia, and Europe) part of the MSR. Besides, Singapore is also an important transshipment hub for cargos from Vietnam to Oceania and America. In these aspects, MSR will also benefit Vietnam when it can come as initiated and expected.

VI. CONCLUSION

Vietnam is a fast-developing economy in trade and economy and takes USA and China as its largest trade and maritime partners. Vietnam is at the throat of the MSR in the BRI firstly proposed by China. So, the Vietnam's connectivity and embeddedness in the global maritime network are curious in the context of MSR and globalization. Based on our big data system, a group of maritime networks are constructed by coupling with the trade data. Four aspects are analyzed for Vietnam's global connectivity and embeddedness, and typical relations with dominant maritime clusters and economies, which includes USA and China. Based on the analyzing results, the implications on management and policies are elucidated. As a conclusion, Vietnam is along the MSR, and plays globally with prominent economies through maritime connections.

This study contributes to three research streams: Vietnam studies, MSR studies, and networking and embeddedness research methodology. First, the Vietnam maritime network is examined in the context of global maritime clusters coupled with trade data. The projections of prominent economies and maritime clusters are investigated by data-driven complex networks. Second, considering Vietnam's special position separating the MSR into eastern and western parts, global maritime triangle is firstly identified to elucidate Vietnam's choices between two big maritime clusters. The roles of Vietnam maritime network, China-Korea-Japan and Strait of Malacca are analyzed for the connections to North and South America, Europe, Oceania and ASEAN. The coordination strategies of Vietnam to cooperate with the maritime hubs along the MSR are also analyzed by introducing a new intersection-based similarity measure ($S(A, B) = |A \cap B|/|A \cup B|$, discussed in Section 4.4). Third, in the methodology aspect, network connectivity and embeddedness are firstly developed for maritime networks based on a data-driven complex network analysis.

Vietnam is a beautiful and important economy in the future trade and economical developments in the world. Its geographical positions and resources may change the regional niches and global industrial distribution. Maritime networks, regional initiative and various agreements may reshape the Vietnam economies and industrial development routes, which will reversely affect the neighbor economies (e.g., landlocked Laos, largest trade and maritime partner China, and allied ASEAN). Therefore, the concerns of internal structures and external embeddedness of Vietnam may produce many research opportunities. In the methodology aspect, this research can be extensively studied by using multiplex multi-scale networks. Using the real-world data system, new networking and analyzing methods can be developed in the future.

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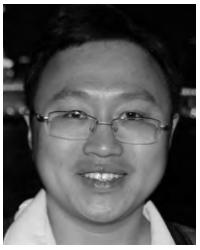

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