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# Exploring Container Market Pattern: A Sight of Route Network Evolution

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## Abstract

**Shipping is the pillar of the global economy. The change of world pattern will bring the alteration of port status, which can be reflected by the world shipping network. This paper introduces Degree Centrality, Closeness Centrality and Betweenness Centrality to explore the topologies of 25 ports in Asia, Europe, North America, South America, the Middle East and Australia. After summarizing the political, economic, and other events related to these trends, we concluded that: First, the analysis of these topologies can reflect the status of each port. Second, the development of ports in different regions varies greatly. Europe, Asia and North America hold a higher position in the world shipping network than those in other regions. Third, the ports involved in this paper generally do not have a robust intermediary role, the importance and influence of each port in the whole network have decreased.**

## Keywords

**Shipping; Container Market; Complex Network; Port.**

## 1. INTRODUCTION

Global shipping evolves alongside the development of trade and the elaboration of commodity chains, thus making it a meaningful looking glass for analyzing the global economy (Valentine et al., 2013). As the primary way of sea transportation, container liner accounts for nearly 80% of the total sea freight transportation. It is also the fastest-growing mode of transport for goods, with an average annual growth rate of 8.0% between 1980 and 2018 (UNCTAD, 2019). Therefore, container liners play an essential role in the development of the global economy. With the increasing volume of container trade, the number of container lines and the complexity of the network also increase day by day.

With the rapid development of complex network theory in recent ten years, more and more network analysis methods are used to study the actual transportation system. Most current studies can be classified from three perspectives as follows. From a geographical perspective, current shipping network researches can be divided mainly into three parts: First, Global shipping network study (Wang and Cullinaneb, 2015; Calatayud et al., 2017; Li et al., 2014). Xu et al. (2015) investigate the evolution of regional inequality in the global shipping network by analyzing the changing positions of 17 world regions during the period from 2001 to 2012. Ducruet and Notteboom (2012) present an analysis of the global liner shipping network in 1996 and 2006. Second, regional shipping network study (Seoane et al., 2013; Guo et al., 2017; Hu and Zong, 2013) As for Greece, Tsiotas and Polyzos, (2015) apply socioeconomic evaluation of the Greece maritime network's topology by using a sophisticated network approach. Ducruet et al. (2010) apply conventional techniques of network analysis to the graph of Northeast Asian liner networks in 1996 and 2006. At last, some specific routes research, such as East-West

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corridor (Tran and Haasis, 2014), the lines of Maersk (Fremont, 2007), the lines of Compagnie des Messagenes Marltines (CMM) & Compagnie Generale Transatlanonque (Mu et al., 2009). Since the "Belt and Road", which focus on the maritime transportation network composed of ports and routes were proposed in 2013. the "Marine Silk Road" has become a hot topic. For example, Jiang et al., (2018) select 706 ports and 2306 container liner routes along the Maritime Silk Road from June to December in 2017 as the sample data of the "Maritime Silk Road" container shipping network to study the network feature. As for the different context these researches focus, they can be divided into vulnerability study (Ducruet, 2016; Liu et al., 2017; Huang et al., 2017) and status study (Ducruet and Notteboom, 2012; Hu et al., 2020; Ducruet and Zaidi, 2012). Calatayud et al. (2017) explore the risks that international freight flows are exposed to as a function of the multiple complex structures of liner shipping networks. Viljoen and Joubert (2016) apply and evaluate two link-based disruption strategies on the global container shipping network. Li et al. (2014) wish to understand the dynamic changing of the centrality in the GSN during the period from 2001 to 2012. Laxe et al., (2012) explore the evolution of worldwide shipping network between 2008 and 2010. In terms of the measurement of the topological statistical characteristics of the world shipping network, scholars apply many indicators, such as degree and degree distribution, centrality analysis, average path length and Complex network properties and so on. Wang and Cullinaneb, (2015) use Degree Centrality, Closeness Centrality and Betweenness Centrality to find the determinants of port centrality in maritime container transportation. Tsiotas and Polyzos, (2017) study Graph density, centrality, clustering, modularity and average path length of Greece maritime network. Ducruet (2013) apply clustering coefficient, betweenness centrality and degree centrality to compare between container shipping network and other shipping networks.

## 2. DATA SOURCES AND EVALUATION METHODS

### 2.1. Data Sources

This paper selects 25 ports according to the container throughput of ports in 2019 from Lloyd's Top 100 Container Ports List concerning the influence of ports and the availability of data. Their shipping routes from 2016 to 2019 are searched and sorted out from Container Forecaster quarter reports published by Drewry. Asia is represented by Shanghai, Ningbo, Guangzhou (Nansha), Singapore, Port Klang, Laem Chabang and Tanjung Pelepas, Europe is represented by Rotterdam, Valencia, Antwerp, Piraeus and Hamburg, North American is represented by Los Angeles, New York, Savannah, Long Beach, Seattle and Vancouver, Callao, Guayaquil and San Antonio represent South America, the Middle East is represented by Jebel Ali (Dubai) and Jeddah, Australia is represented by Melbourne and Sydney (Botany).

### 2.2. Evaluation Methods

The centrality in a network can reflect the importance of nodes. Degree Centrality is used in this paper to reflect the number of routes through ports in several regional shipping networks, Closeness Centrality is used to reflect relative accessibility, and Betweenness Centrality is used to reflect the transfer and connection functions of ports.

(1) Degree Centrality

Degree centrality is measured by degree index, and the degree index is normalized as follows. In a network with N nodes, the degree of one node will not exceed N-1, the degree centre normalized by the degree of the node is calculated as follows:

$$C_D(i) = \frac{k(i)}{N-1}$$

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Degree centrality is one of the indexes that can directly reflect the node's centre. The higher Degree Centrality value the node is, the more critical it is. The degree of a complex network indicates the number of connections between a node and the outside world and reflects the importance of nodes in the network, which is positively correlated with the degree value. Degree Centrality is a direct reflection of the importance of a node in the network. In this paper, the degree of any port node represents the number of routes passing through the port. The larger the value is, the more routes are attached to the port, the stronger its shipping connection ability is, and the more obvious its hub status is.

(2) Closeness Centrality

Closeness centrality is used to describe the difficulty for nodes to reach other nodes through the network. Its value is the reciprocal of the sum of the shortest distance for a given node to reach other nodes, which reflects the relative accessibility of nodes. Assuming that there are N nodes in the network, the Closeness Centrality value of node i is calculated as follows:

$$\mathrm{P(i)} = \left[\sum_{j=1, j\neq i}^{N} l_{ij}\right]^{-1}$$

Closeness centrality is extended from Degree Centrality, which pays more attention to the possibility of indirect ties between nodes, that is, the possibility of reaching the target node through several nodes, and pays more attention to the indirect connections between nodes rather than the direct ones. It uses the shortest distance between a node and other nodes in the network to evaluate whether the node has an advantage in spatial position. This index reflects the possibility of establishing shipping links between a port and other ports, that is, the shipping accessibility of container ports. In terms of container shipping accessibility, it reflects the hub status of ports in the whole shipping network. The higher the value is, the better the shipping accessibility of the port is.

(3) Betweenness Centrality

Betweenness Centrality is used to express the number of times the shortest path between all pairs of port passes through a given port, which can be used to measure the port's transit function. If $\mathbf{B}_{\boldsymbol{C}}(\boldsymbol{k})$ is used to represent the betweenness centrality, its calculation formula is:

$$\mathrm{B}_C(k) = \frac{2}{n^2 - 3n + 2} \sum_{i=q, j\neq k}^{n} \sum_{j\neq k}^{n} \frac{\delta_{ij}^{k}}{\delta_{ij}}$$

Betweenness number refers to the number of times that a shipping area is located on the shortest path between other regions in the network, reflecting the capacity of a shipping area to act as a container liner transport intermediary between other regions, that is, the extent to which the area is integrated into the world container shipping network. The larger the value is, the more integrated the port is, and the more potent its influence in the world shipping is.

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# 3. RESULT

## 3.1. Degree Centrality

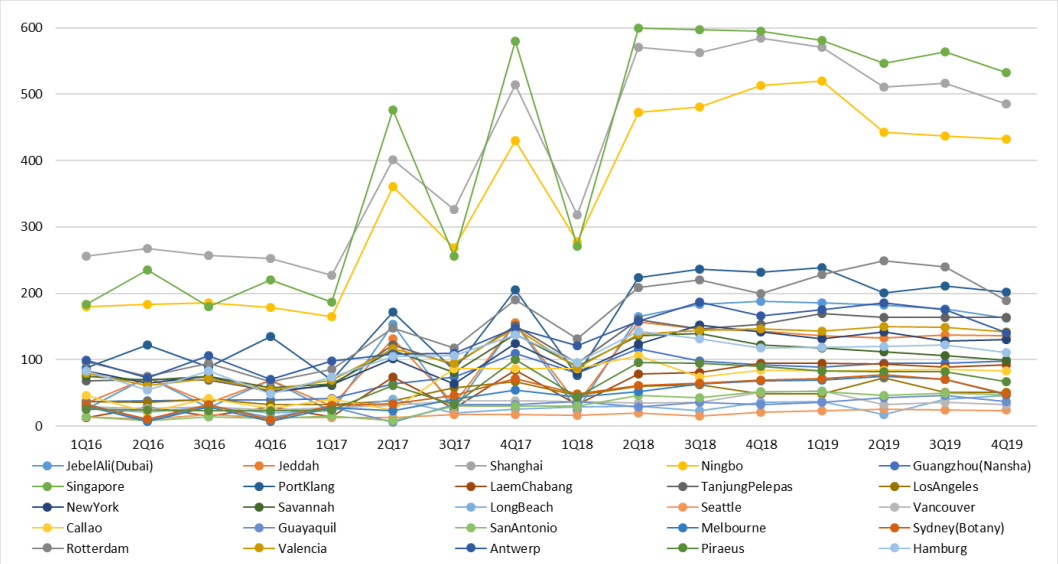


**Figure 1**. Trend of Degree Centrality value of ports

The degree values of 25 ports are shown in Figure 1. In 2016, the degree centrality values of all ports in the world were generally low. They increased significantly in the second and fourth quarters in 2017 (2Q17 and 4Q17, the same below). Although the Degree Centrality values of all ports decreased in 1Q18, they slowly increased from 2018 to 2019. By 4Q19, 4 of the 25 ports had a Degree Centrality value of more than 200, accounting for 16%; 8 of the 25 ports had a value between 100 and 200, accounting for 24%; 6 ports are between 50 and 100, accounting for 28%; 7 ports are below 50, accounting for 28%. The Degree Centrality value of Shanghai, Ningbo and Singapore are far ahead. Since 2017 the gap between them and other ports is continually widened. Finally, the Degree Centrality value in these three regions in 4Q19 become stable, between 400 and 600, while other areas are below 250. Different regions vary differently; the highest Degree Centrality values in Singapore and the lowest Degree Centrality value in Seattle very nearly 503.

As can be seen in Appendix 1:

For Asia, the mean Degree Centrality value increased from 125.30 in 2016 to 201.30 in 2017 (increased by 60.65% y-o-y(y-o-y, the same below)), 279.86 in 2018 (increased 39.03% y-o-y), and 299.84 in 2019 (increased 7.14% y-o-y).In terms of each year, the Degree Centrality value in 2016 is relatively stable. There is a large range of changes in 2Q17 (118.52% higher than 1Q17) and 4Q17 (84.21% higher than 3Q17) compared with 1Q17 and 3Q17. The mean value of 1Q18 decreased by 44.6% compared with 4Q17. It then increased by 93.23% in 2Q18, reaching the highest level, and then the change was relatively stable. From 2Q18 onwards, Singapore surpassed Shanghai and became the port with the highest Degree Centrality in Asia. By 4Q19, Singapore ranked first, followed by Shanghai and Ningbo, with a Degree Centrality value of around 400-500, and then followed by Port Klang, Laem Chabang and Tanjung Pelepas, with the values of around 100-200.

The mean Degree Centrality value in Europe was only 65.63 in 2016; in 2017, the mean value reached 103.66 (increased 57.95% y-o-y); in 2018, the mean value is 125.89 (increased 31.09% y-o-y); and 2019 saw its peak, 147.57 (increased 8.6% y-o-y). In terms of each year, in 3Q16, the mean value had a brief rise, with an increased rate of about 31.26%. 2017 showed a steady rise, with a significant increase in 2Q17 (increased 54.26% than 1Q17) and 4Q17 (increased 56.76% than 3Q17). The mean value of 1Q18 fell briefly (33.76% lower than 4Q17), then

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recovered from 2Q18 (55.19% higher than 1Q18), after which the Degree Centrality values of ports remained stable. By 4Q19, the mean value decreases again, Rotterdam still maintains the highest Degree Centrality value, the value of Antwerp and Valencia are also high, ranging from 150 to 200, Hamburg and Piraeus are between 50 and 150.

In 2016, North America had a low Degree Centrality value (mean Degree Centrality value is 39.67), with only New York and Savannah having higher Degree Centrality value. The mean value rose in 2017 (52.05), values are stable except New York and Savannah in 2Q17 (New York grows 54.86% than 1Q17, Savannah grows 79.37% than 1Q17) and 4Q17 (New York grow 96.98% than 3Q17, Savannah grow 71.31%than 3Q17). In 1Q18, Degree Centrality values have dropped, but 2Q18 began to rise again, in particular, New York (grow 53.09% than 1Q18) and Savannah (grow 51.45% than 1Q18) saw significant increases. In 2019, the value of North America was relatively stable with little change. By 4Q19, the value of New York and Savannah were stable between 100 and 150, and Los Angeles, Long Beach, Seattle, and Vancouver were below 50.

In 2016, the mean Degree Centrality value of South American was 22.15, lower than that of other regions, then grow to 35.04 in 2017 (grow 58.22% y-o-y), and become stable in 2018 (54.56) and 2019 (57.60). According to each year, the mean Degree Centrality value of 3Q16 and 1Q17 in South America have increased, with increases of 130.87% and 67.11% respectively. 3Q17 saw a significant increase, especially the Callao, which has increased by 287.83%, changes became more stable in 2018 and 2019. By 4Q19, the Degree Centrality value of Callao is the largest (82.80). San Antonio and Guayaquil are below 50.

From 2016 to 2019, the mean Degree Centrality value in the Middle East are 51.07, 88.17, 129.98 and 155.97, respectively, increasing year by year. From 2017, the growth rates y-o-y are 72.66%, 47.42% and 19.99%. 2Q16 and 4Q16 grow 144.13% and 119.25% than 1Q16 and 3Q16. 2Q17 and 4Q17 are 445.52% and 432.64% higher than 1Q17 and 3Q17. From 2Q18, the value remained stable. By 4Q19, the Degree Centrality value remained above 130.

The Degree Centrality of Australia in 2016 was low (19.51), with a 109.91% y-o-y increase to 40.95 in 2017, a 43.98% y-o-y increase to 58.96 in 2018, and a further 11.87% y-o-y increase to 65.96 in 2019. In terms of each year, 3Q16 and 1Q17 have increased by more than 260.12% and 268.84% respectively, compared with 2Q16 and 4Q16. The Degree Centrality value of Australia is stable between 40 and 50 by 4Q19.

## 3.2. Closeness Centrality

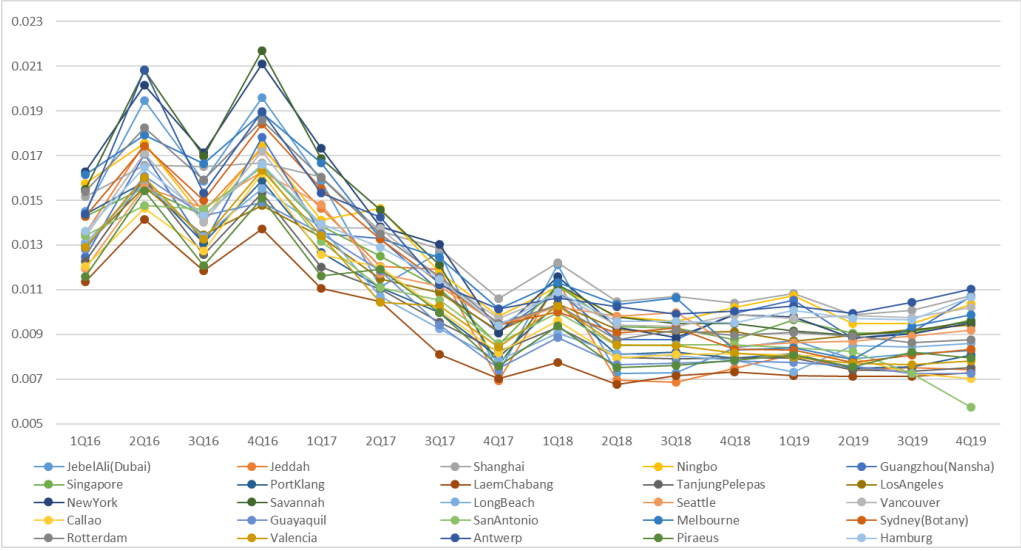


**Figure 2.** Trend of Closeness Centrality value of ports

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The Closeness Centrality values of ports in the world are shown in Figure 2. From 2016 to 2019, the Closeness Centrality value of most ports declines with fluctuation. Among the 25 ports, by 4Q19, six ports, accounting for 24%, had a Closeness Centrality value higher than 0.01; 11 (4%) ports were between 0.008 and 0.009; 7 (28%) ports are between 0.007 and 0.008; The remaining one with a value below 0.007, accounting for 4%. In general, after the recovery in the 2Q16 and 4Q16, the Closeness Centrality value has been declining since 2017. Although some ports have recovered, the general trend is still decreasing, from around 0.01 to 0.015 in 1Q16 to around 0.005 to 0.01 in 4Q19, and service accessibility of most ports is relatively close, with most ports' value between 0.007 and 0.011.

As can be seen in Appendix II:

In general, the Closeness Centrality value of all regions showed an overall downward trend.

The mean Closeness Centrality value in Asia over four years was 0.0149, 0.0113 (24.43% lower than that in 2016), 0.0092 (18.10% lower than that in 2017), and 0.0089 (3.90% lower than that in 2018), respectively. In terms of each year, the Closeness Centrality value of most ports in 2Q16 (17.79% higher than 1Q16) and 4Q16 (18.74% higher than 3Q16). In 2017, the Closeness Centrality value of Asia declined overall, then picked up in 1Q18 (19.07% higher than 4Q17) and has remained stable since then. The Closeness Centrality value of Guangzhou, Shanghai and Ningbo is high, keeping above 0.01, while that of other ports is below 0.008.

As for Europe, the mean Closeness Centrality value dropped from 0.01557 in 2016 to 0.01164 in 2017 (decreased 25.24% y-o-y), to 0.00927 in 2018 (decreased 20.35% y-o-y), and then to 0.0090 in 2019 (decreased 2.87% y-o-y). Among them, in 2Q16 and 4Q16, the Closeness Centrality value increased respectively by 28.17% and 20.72% compared with the previous quarter. However, since 2017, the Closeness Centrality value of Europe ports has been steadily declining, with a small increase in 1Q18, and finally, become stable in 2018 to 2019. Antwerp and Hamburg are around 0.011, while Rotterdam, Piraeus and Valencia are between 0.007 to 0.009.

North America has a mean Closeness Centrality value of 0.01601 in 2016, 0.01194 in 2017 (25.43% lower than 2016), 0.00952 in 2018 (20.30% lower than 2017), and 0.00909 in 2019 (4.51% lower than 2018). In 2016, New York (mean Closeness Centrality value is 0.01867) and Savannah (mean value is 0.01874) had higher Closeness Centrality value. The ports of 2Q16 and 4Q16 have the largest increases, 26.14% and 18.89% respectively compared with the previous quarter. In 2017, the value declined, among which the decline in 4Q17 was largest, with an average decline of 22.25%. From 2018 to 2019, it is relatively stable, and the final Closeness Centrality values in North America are around 0.009.

South America's Closeness Centrality value was 0.1496 in 2016, 0.01077 in 2018 (28.02% lower than 2016), 0.00845 in 2018 (21.54% lower than 2017), and 0.00803 in 2019 (5.01% lower than 2016). On a year-by-year basis, the values fluctuated significantly in 2Q16 and 4Q16, with an average increase of 18.94% and 14.33% compared with the previous quarter, respectively. In 2017, the Closeness Centrality value of all ports decreased, with a small increase in 1Q18 (17.35% higher than 4Q17). Then, the values continued to decrease, but with a smaller amplitude than before, and the Closeness Centrality value gradually stabilized around 0.005 to 0.007 by 4Q19.

The Middle East showed a high Closeness Centrality value (mean value is 0.01654) in 2016, which decreased to 0.01156 in 2017 (decreased 30.15% y-o-y), 0.00846 in 2018 (decreased 26.79% y-o-y), and 0.00793 in 2019 (decreased 6.25% y-o-y). According to each year, 2Q16 and 4Q16 showed an increase, with 31.88% and 21.61% higher than the previous quarter respectively. In 2017, the value of Closeness Centrality continued to decline, with a significant decrease in 4Q17 (42.15% lower than 3Q17), and recovery in 1Q18, but then it returned to a low level and finally stabilized between 0.005 and 0.01.

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Australia's Closeness Centrality value was highest in 2016, reaching 0.01684, before dropping 24.26% to 0.01276 in 2017, then continue dropping 24.30% to 0.00966 in 2018, and 12.02% to 0.00850 in 2019. In terms of each year, the Closeness Centrality value of Australia increased significantly in 2Q16 (16.09% compared with the previous quarter) and 4Q16 (17.95%). Finally, the value stabilized around 0.009.

### 3.3. Betweenness Centrality

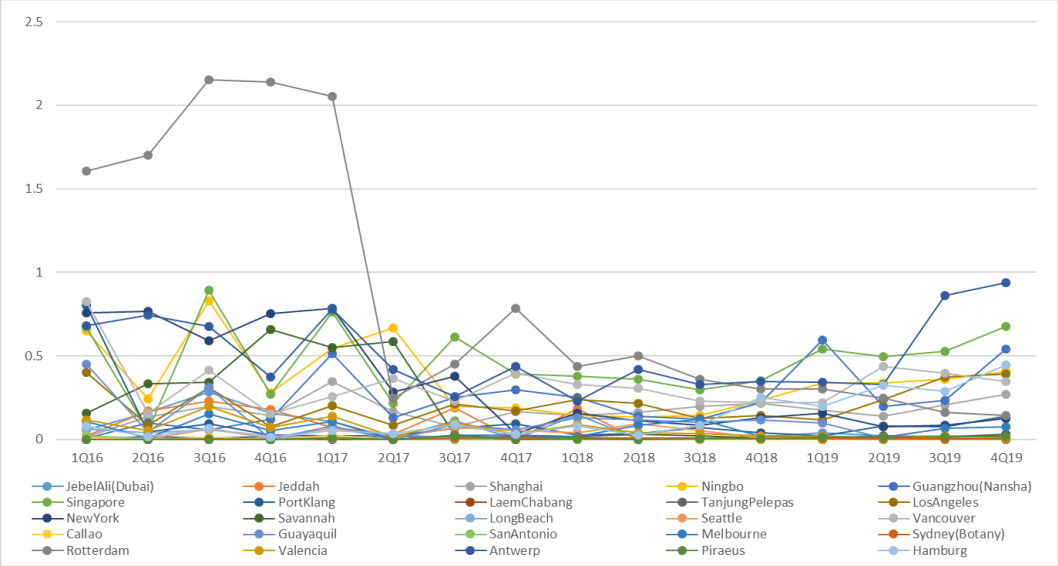


**Figure 3.** Trend of Betweenness Centrality value of ports

The Betweenness Centrality values of the 25 ports are shown in Figure 3. From 2016 to 2019, the Betweenness Centrality values changes significantly, and there is no general rule can be found. In 2016, Antwerp took the lead and had a significant influence in the world. However, it declined sharply in the 2Q17. By 4Q19, among the 25 ports, only Antwerp's value is more significant than 0.9, accounting for 4%. There were 6 (19%) ports whose Betweenness Centrality values are between 0.3 and 0.6. 4 (24%) ports were between 0.1 and 0.3. There were as many as 14 (66%) ports between 0 and 0.1. At 4Q19, Antwerp is the port with the most substantial Betweenness Centrality value, which close to 1 and has a significant influence in the world. In contrast, most other ports are close to 0.

As can be seen in Appendix III:

The Betweenness Centrality value in Asia from 2016 to 2019 is 0.20331, 0.20735 (1.98% higher than that in 2016), 0.13250 (36.10% lower than 2017), and 0.22946 (73.18% higher than 2018). To be specific, the Betweenness Centrality value of Ningbo and Singapore from 2016 to 2019 is relatively large. The value of Port Klang at 1Q16 (0.80444) is also large, but it suddenly drops from 2Q16 (0.04513) and has remained at a low level ever since. The value in 1Q17 and 1Q19 of Guangzhou increased by 317.14% and 172.99% respectively. The fluctuation of other ports was small from 2016 to 2019.

The mean Betweenness Centrality value in Europe is 0.53500, 0.29883 (44.14% lower than that in 2016), 0.17856 (40.25% lower than 2017), and 0.23532 (31.78% higher than 2018) respectively, from 2016 to 2019. In 2016, Rotterdam (Betweenness Centrality value is 1.90 on average) and Antwerp (0.62 on average) had relatively high Betweenness Centrality value, and Rotterdam was much higher than others. In Rotterdam, the value decreased by 87.91% at 2Q17 but increased by 82.24% and 73.46% in the following two quarters. From 2018 to 2019, the Betweenness Centrality value of the interface tends to be stable, with all ports except Antwerp being 0.94 and other ports below 0.5.

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From 2016 to 2019, values in North America were 0.29381, 0.20045 (31.78% lower than that in 2016), 0.10806 (46.09% lower than 2017), and 0.13107 (21.30% higher than 2018). In 2016, New York (mean value is 0.72) had a higher Betweenness Centrality value, Vancouver had a decrease in 2Q16 (62.94% lower than 1Q16), and Savannah had an increase in 2016 (an average increase of 70.37% per quarter). In 2017, the values of Savannah (decrease 46.66% per quarter on average) and New York (decrease 28.95% per quarter on average) declined a lot. In 2018, the values were relatively stable with little change. The Betweenness Centrality value of Vancouver and Los Angeles remained at 0.3 to 0.4, while the rest ports were around 0 to 0.1 by 4Q19.

Values in the Middle East is 0.15806, 0.06582 (58.36% lower than that in 2016), 0.04523 (31.28% lower than 2017), and 0.01680 (62.85% lower than 2018) from 2016 to 2019. Generally, the Betweenness Centrality value of the Middle East was low in 2016. However, it showed an upward trend in the first three quarters, with an average quarterly increase of 106.84% and a decline in the fourth quarter. 3Q17 increased by 605.87%, then back down in 4Q17, and boom 7076.67% in 1Q18. From the 2Q18 to 2019, the Betweenness Centrality value in the Middle East remained stable near 0.

From 2016 to 2019, the Betweenness Centrality values in South America were 0.07247, 0.02328 (decrease 67.88% y-o-y), 0.04029 (increase 73.09% y-o-y), and 0.01291 (decrease 67.95% y-o-y). In 2016, Guayaquil had a large Betweenness Centrality value. It fluctuates in the 2nd and third quarters, 2Q17 decreased again, and the gap with other ports decreased. Starting from 3Q17 to 2019, Guayaquil has a small fluctuation. However, the final Betweenness Centrality value tends to 0, while the rest ports remain close to 0, with little fluctuation.

From 2016 to 2019, the Betweenness Centrality value of Australia is 0.04065, 0.02324 (42.83% lower than that of 2016), 0.03447 (48.29% higher than 2017), and 0.02381 (30.93% lower than 2018). The Betweenness Centrality value of Sydney is close to 0, and the variation range is small. The value of Melbourne also fluctuates, but the amplitude is smaller than that of other ports in other regions.

## 4. DISCUSSION

### 4.1. The Analysis of Degree Centrality, Closeness Centrality and Betweenness Centrality Can Reflect the Operation Status of Each Port

By combining the Degree Centrality, Closeness Centrality, Betweenness Centrality and significant political, economic, cultural and shipping events of each quarter, it can be found that the fluctuation of topological values often corresponds to these events.

Political

The Middle East had a low Degree Centrality value in 2016. This is since, in 2016, oil-importing countries faced with political instability, and suffer economic reversals. For example, the number of tourists in Egypt dropped to 1.2 million in the 1Q16, decrease 2.2 million compared with the same period last year. Port operations have also been affected, such as Jebel Ali in Dubai, where cargo volume dropped by 5.3% (about 820,000 TEUs). Jordan affected by the war in Iraq and Syria, the trade routes disrupted, with tourists and exports reduce 12% and 13%.

In 3Q17, the Degree Centrality value in Asia declined as a result of the new environmental policy put forward by China, which leads to weak exports of China in the 3Q17, fell by nearly 2% compared with 2Q17. As a significant power in the region, China's shipping development affects other ports to a large extent. In 3Q17, most ports in Asia also have fewer routes and weaker shipping contact ability.

Economic

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The Degree Centrality value of Asia in 2016 was low with few fluctuations. The Asian economies generally slowdown in growth in 2016, it is difficult for the big countries in the region to provide incremental market space for Asian economies to destock their products as before. It also affects the routes to Asian ports. In 2Q17, Asia's Degree Centrality value increased by 200 to 300 compared with 1Q17 and 2Q16. While China's export recovery in 2Q17, export trade volume reached 388,317,0.93 million yuan, more than the growth of 16.7% in 1Q17, and14.8% of 2Q16 (data from the customs of the People's Republic of China), more and more goods are shipped from the port in north China in containers. The recovery of China's exports has led to an increase in the volume of trade with other ports in Asia and a corresponding increase in the number of shipping links, Asia's shipping becomes more accessible.

The situation is similar in North America, where the Degree Centrality was low and relatively stable in 2016 due to the continued downward trend of global economic growth in 2016 and the apparent deceleration of developed economies. Take the United States as the representative, in the first three quarters of 2016, the annual rate of GDP growth was 0.8%, 1.4% and 2.9%, with y-o-y growth of 1.6%, 1.3% and 1.5% respectively. The economic growth was weak, and this growth rate was also significantly lower than its potential economic growth rate. The sluggish container trade led to a decrease in the number of routes connecting of the United States.

Besides, South America had a low Degree Centrality value compared with other regions in 2016. In 2016, the economy of South America continued to suffer from recession, fundamental indicators continued to deteriorate, and short-term recession and divergence continued and became more and more prominent. As a result, economic structural reform in South America entered a stage of deadlock, which was challenging to breakthrough. The economic governance capacity is relatively weak, the policy counter-cyclical insufficiency, the economic growth rate is -2.3%, the economic regression also affects the shipping, causes the reduction of routes to South America, the shipping industry depression.

Major events of the shipping company

In 2Q16, the Degree Centrality value in Rotterdam increased significantly as COSCO Pacific Limited signed an equity transfer agreement with HUTCHISON Ports Group to acquire 35% of the Euromax container terminal in Rotterdam. After the acquisition, COSCO Pacific Limited became the largest shareholder with a 47.5% stake in Euromax Container Terminal. This state-of-the-art unmanned cargo terminal handles about 7millom TEUs a year. It is connected to the railway, providing an ideal option for cargo to and from the European hinterland. This promoted the trade between Rotterdam and China and improved Rotterdam's accessibility.

The port of Callao in South America experienced a significant increase in its Degree Centrality value starting from 2017, as its APM terminal won a public tender for the privatization, Coupled with the purchase of new conventional freight equipment and the tremendous efforts of the team to implement new procedures, extend best practices, improve planning processes, initiate training programs and enhance services. In 2017, the productivity of substantial bulk increased by 100% and bulk cargo by 135% compared to 2011 APM Terminals Callao. The hydrocarbon terminal modernization project handled 88% of the country's liquid volume in 2017. All this has brought an increase in the number of routes to Callao.

In 2018, Singapore surpassed Shanghai, become the port which has the highest Degree Centrality value in Asia, due to PSA Singapore develop a series of methods to improve terminal operation efficiency, such as data analysis tools and cargo handling solutions, which brought great operating benefits. Also, the group's terminal construction projects overseas, such as Mumbai container terminals (BMCT) have been put into operation. In December, PSA signed a memorandum of cooperation with COSCO Maritime Port on new berths for the COSCO-Xingang Terminal, and later announced the establishment of a joint venture with Japan's Ocean Network

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Shipping (ONE), making Singapore the most active, accessible and influential port in Asia in 2018, surpassing Shanghai.

Shipping alliances

Forming a shipping alliance allows carriers to jointly purchase and share larger ships, which can give play to the advantages of economies of scale. In other words, significant cost savings are possible if partner operators are willing to cooperate (Lei et al., 2008). Shipping alliances can bring carriers competitive advantages in terms of low prices and a wide range of services. Therefore, the emergence and change of shipping alliances and the decisions made by shipping alliances often have an impact on the ports in the shipping routes. For example, the COSCO Shipping group is part of the OCEAN Alliance, which includes China Maritime Transportation Group (CMCC), CMA CGM (CMA), Evergreen (Evergreen) and Orient Overseas (OOCL). The scope of cooperation includes Asia-Europe, Asia-Mediterranean, Asia-Red Sea, Asia-Middle East, Trans-Pacific, East Coast of Asia and North America, and trans-Atlantic trade. The new alliance started operations on April 1, 2017, has reorganized their services and launched eight new ships. Seven of them are for ocean navigation, and the other one is for maritime navigation. Also in 2017, six liner companies including Herbalold, Yang Ming, Mitsui OSK Shipping Company, Japan Post, Kawasaki Yusen and Hanjin Shipping allied with a total capacity of approximately 3.5 million TEU. The scope of cooperation includes Far East-Northern Europe routes, Far East-Mediterranean routes, Far East-U.S./West Coast routes, Trans-Atlantic routes and Far East-Middle East (Persian Gulf/Red Sea) routes. The establishment of the two alliances increased the number of routes across Asia and the Middle East in 2Q17. The available network capacity from Asia to the Middle East increased by 13%, and from the East to the West increased by 18%. Besides, as the OCEAN Alliance also transferred routes from Port Klang to Singapore, Singapore's routes also increased.

Also, the shipping alliance's ship allocation and renewal decisions have a high impact on the port. In 1Q16 and 2Q16, G6 and CKYHE suspended the line from Asia to Northern Europe, but increase five 4250 TEU ships on Transpacific routes in May, G6 increased ten 9000-10000 TEU ships, O3 downgrade its ships' deadweight in Asia - northern route, this led to Europe's routes decreased, part of the ports' mediation functions therefore also be affected, Asia and North America remained mostly stable. Between the end of 2016 and the beginning of 2017, two 16800TEU container ships were added to the Transpacific route by 2M alliance. In April 2017, THE added seven 8200TEU ships on Asia-South-Central Asia route, and OCEAN also added 31 ships of 6000-1000TEU on this route. In May, OCEAN increased the average deadweight of its ships in Transatlantic (Europe) from 4170TEU to 6200TEU, and 2M joined new ships on the route. On Asia-Nordic route, THE and 2M joined one and three 20000TEU ships in May and June respectively. These measures led to an increase in the number of affiliated routes in Asia, Europe and the Middle East in 1Q17, as well as an increase in the intermediary role of Asia, South America and North America.

However, according to the International Transport Forum (Figure 4), as more and more shipping alliances are formed, connections among ports are reduced, and relations are gradually weakened. Fewer port-to-port connections mean some ports are lost. At the moment, two kinds of container ports seem to be under particular pressure. First, transhipment ports are located in areas where competition is fierce with other transhipment ports, such as the Mediterranean. The second type of port under pressure is the Gateway port, which is located next to the Gateway ports in other areas. By contrast, successful access to new container ports is far rarer. In shipping alliance booming at the same time; therefore, we can see the Closeness Centrality value is falling in the world, connectivity between the ports getting worse. In ports with multiple terminal operators, there is a winner-takes-all model, in which the winner gets more cargo than he can handle with and the loser gets little or no cargo.

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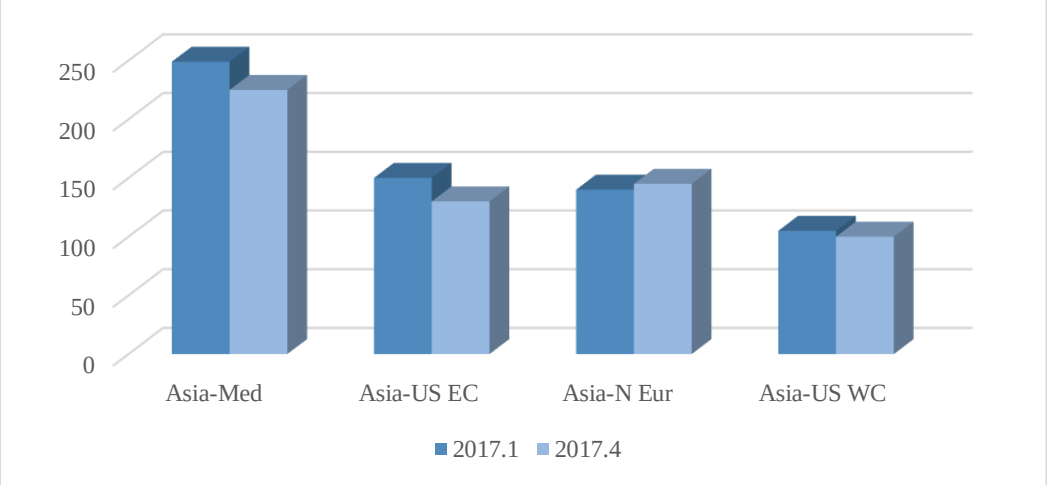


**Figure 4.** Direct port-to-port connections before and after new alliances (2017)

## 4.2. The Development of Ports in Different Regions Varies Greatly

Among the 25 ports selected in this paper, ports in the Northern Hemisphere develop faster than those in the Southern Hemisphere. Ports in Europe, Asia and North America have a higher status in the world shipping network than those in other regions.

After calculating the mean value Degree Centrality, Closeness Centrality and Betweenness Centrality values in each quarter of four years, it can be found (see Table 1, Table 2 and Table 3):

**Table 1.** Distribution of Degree Centrality values in various regions of the world

| Year | Value | Asia | Europe | North America | Australia | South America | Middle East | Total |
|---|---|---|---|---|---|---|---|---|
| 2016 | >200 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| | 100-200 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| | 50-100 | 1 | 4 | 2 | 0 | 0 | 1 | 8 |
| | <50 | 2 | 1 | 4 | 2 | 3 | 1 | 13 |
| 2017 | >200 | 3 | 0 | 0 | 0 | 0 | 0 | 3 |
| | 100-200 | 2 | 4 | 0 | 0 | 0 | 0 | 6 |
| | 50-100 | 1 | 1 | 2 | 0 | 1 | 2 | 7 |
| | <50 | 1 | 0 | 4 | 2 | 2 | 0 | 9 |
| 2018 | >200 | 3 | 0 | 0 | 0 | 0 | 0 | 3 |
| | 100-200 | 2 | 4 | 2 | 0 | 0 | 2 | 10 |
| | 50-100 | 2 | 1 | 1 | 2 | 1 | 0 | 7 |
| | <50 | 0 | 0 | 3 | 0 | 0 | 0 | 3 |
| 2019 | >200 | 4 | 1 | 0 | 0 | 0 | 0 | 5 |
| | 100-200 | 1 | 3 | 2 | 0 | 0 | 2 | 8 |
| | 50-100 | 2 | 1 | 1 | 2 | 1 | 0 | 7 |
| | <50 | 0 | 0 | 3 | 0 | 2 | 0 | 5 |

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**Table 2.** Distribution of Closeness Centrality values in various regions of the world

| Year | Value | Asia | Europe | North America | Australia | South America | Middle East | Total |
|---|---|---|---|---|---|---|---|---|
| 2016 | >0.01 | 7 | 5 | 6 | 3 | 2 | 2 | 25 |
| | 0.008-0.009 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0.007-0.008 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2017 | >0.01 | 6 | 5 | 6 | 3 | 2 | 2 | 24 |
| | 0.008-0.009 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| | 0.007-0.008 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2018 | >0.01 | 2 | 1 | 0 | 0 | 1 | 0 | 4 |
| | 0.008-0.009 | 4 | 4 | 6 | 3 | 1 | 2 | 20 |
| | 0.007-0.008 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 2019 | >0.01 | 2 | 2 | 0 | 0 | 0 | 0 | 4 |
| | 0.008-0.009 | 2 | 1 | 5 | 0 | 1 | 1 | 10 |
| | 0.007-0.008 | 3 | 2 | 1 | 3 | 1 | 1 | 11 |

**Table 3.** Distribution of Betweenness Centrality values in various regions of the world

| Year | Value | Asia | Europe | North America | Australia | South America | Middle East | Total |
|---|---|---|---|---|---|---|---|---|
| 2016 | >0.9 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | 0.3-0.9 | 2 | 1 | 3 | 0 | 0 | 0 | 6 |
| | 0.1-0.3 | 2 | 1 | 1 | 1 | 0 | 2 | 7 |
| | 0-0.1 | 3 | 2 | 2 | 2 | 2 | 0 | 11 |
| 2017 | >0.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0.3-0.9 | 2 | 2 | 2 | 0 | 0 | 0 | 6 |
| | 0.1-0.3 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| | 0-0.1 | 3 | 3 | 4 | 3 | 2 | 2 | 17 |
| 2018 | >0.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0.3-0.9 | 1 | 2 | 0 | 0 | 0 | 0 | 3 |
| | 0.1-0.3 | 3 | 1 | 3 | 1 | 0 | 0 | 8 |
| | 0-0.1 | 3 | 2 | 3 | 2 | 2 | 2 | 14 |
| 2019 | >0.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0.3-0.9 | 3 | 2 | 1 | 0 | 0 | 0 | 6 |
| | 0.1-0.3 | 1 | 1 | 2 | 0 | 0 | 0 | 4 |
| | 0-0.1 | 3 | 2 | 3 | 3 | 2 | 2 | 15 |

In 2016, 2 ports with a Degree Centrality value higher than 200 were all from Asia. The Closeness Centrality values of 25 ports were all greater than 0.01. There was only Rotterdam in Europe where the Closeness Centrality value was more significant than 0.9. All the ports with the Betweenness Centrality value between 0.3 and 0.9 came from Asia, Europe and North America, accounting for 2, 3 and 1. In 2017, 3 ports with a Degree Centrality value higher than 200 were all from Asia. The Closeness Centrality value of all ports was more significant than 0.01 except Laem Chabang. In 2018, all the two ports with a Closeness Centrality value higher than 200 were from Asia. There are two ports came from Asia, one from Europe and one from Australia, with the Closeness Centrality value higher than 0.01. Among the ports with Betweenness Centrality values of 0.3 to 0.6, 1 came from Asia. Two came from Europe. 2 Among the five ports with a Degree Centrality value higher than 200 in 2019, 4 are from Asia, and one is from Europe. There were two ports in Asia and two ports in Europe with Closeness Centrality value greater than 0.01. 3, 2 and 1 ports in Asia, Europe and North America whose Between Centrality values are between 0.3 and 0.6.

It can be seen from the data above that, From 2016 to 2019, Asia, Europe and North America have a higher Degree Centrality, Closeness Centrality, Betweenness Centrality values than in other areas, they have more shipping routes, shipping link capacity is relatively stable, hub

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status is evident, better-integrated capacity within the scope of significant influence in the world shipping.

### 4.3. Most of the Ports Involved in This Paper Generally Do Not Have A Robust Intermediary Role

The 25 ports selected in this paper generally have a low Betweenness Centrality values (Table 2), which in early 2016, Rotterdam is the only one in the Betweenness Centrality value more than 1, other ports are all below 1, with the time going on, by 4Q19, only Antwerp has a Betweenness Centrality value greater than 0.9. There were six ports have a Betweenness Centrality value between 0.3 and 0.6. four ports were between 0.1 and 0.3. There were as many as 14 ports are between 0 and 0.1. Generally speaking, these ports do not play a robust intermediary role and their importance and scope of influence in the whole network decrease. Ports mainly affect other ports in the vicinity of their regions but have less influence on ports in other regions.

Thus, despite the global container transportation route structure under the influence of Hub-Spoke network which generally used, most of the area, to a certain extent, has formed a hub port. However, the hub port's sphere of influence is more and more confined to their region or adjacent geographic area, and influence around the world become smaller.

## 5. CONCLUSION

Along with the progress of trade and the improvement of the commodity chain, container shipping accounts for an increasing proportion of the sea freight volume, followed by the evolution of the complexity of container route network. Combined with the complex network, the complex network research of container lines conformed. Under such a background, this article select 25 ports from Lloyd's Top 100 Container Ports List to represent Asia, Europe, North America, South America, Middle East, Australia, and then, collect data of container lines from 2016 to 2019, explore the network topologies in the world and regional container shipping network, including degree Centrality, Closeness Centrality and Betweenness Centrality, excavates the political, economic, cultural, shipping and other events that may be related to the trend of changes in different regions and tries to find out their connections. The conclusions of this paper are as follows:

First, the analysis of degree Centrality, Closeness Centrality and Betweenness Centrality can reflect the status of each port. Political and economic events, Major events of the shipping company and the form and change of shipping alliance closely related to the trend of port status. Second, the development of ports in different regions varies greatly. Among the 25 ports selected in this paper, the ports in the northern hemisphere develop faster than those in the southern hemisphere. Europe, Asia and North America hold a higher position in the world shipping network than those in other regions. From 2016 to 2019, there are 13 ports whose Degree Centrality value greater than 200, and they all from Europe, Asia and North America. Similarly, 71% ports where Closeness Centrality value greater than 0.01 are also from these three regions. Besides, only one port from Europe have a Betweenness higher than 0.9. Third, the ports involved in this paper generally do not have a robust intermediary role, by 4Q19, only Antwerp has a Betweenness Centrality value greater than 0.9. There were six ports have a Betweenness Centrality value between 0.3 and 0.6, four ports between 0.1 and 0.3, and as many as 14 ports are between 0 and 0.1. From 2016 to 2019, as the Betweenness Centrality value become lower, the capacity of shipping areas to act as a container liner transport intermediary between other regions also become weaker.

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## 6. APPENDIX I DEGREE CENTRALITY VALUE IN REGIONS

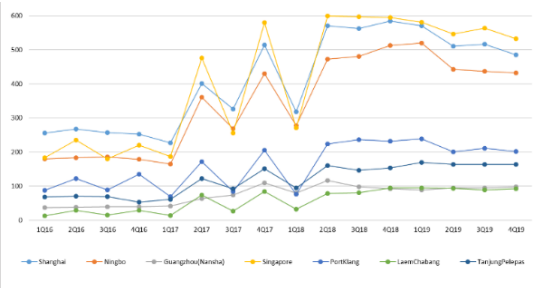


Figure 1. Trend of Degree Centrality value in Asia

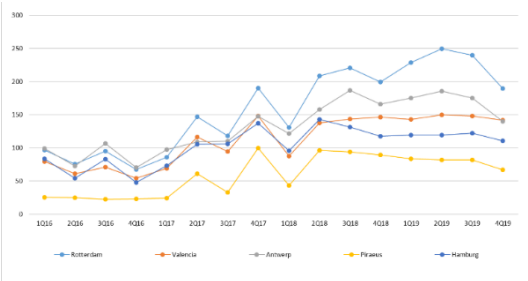


Figure 2. Trend of Degree Centrality value in Europe

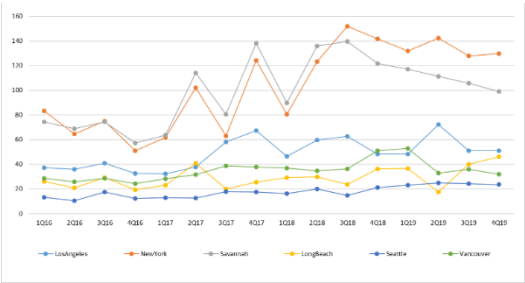


Figure 3. Trend of Degree Centrality value in North America

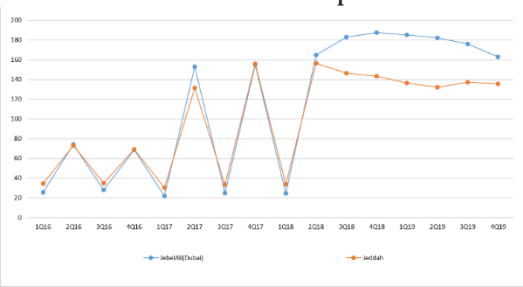


Figure 4. Trend of Degree Centrality value in the Middle East

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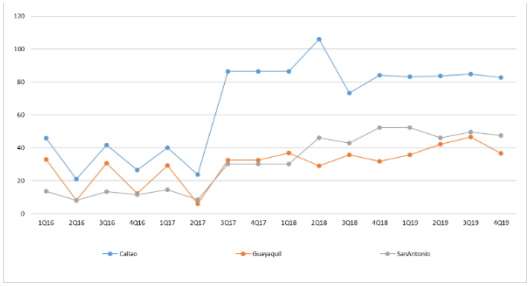

Figure 5. Trend of Degree Centrality value in South America

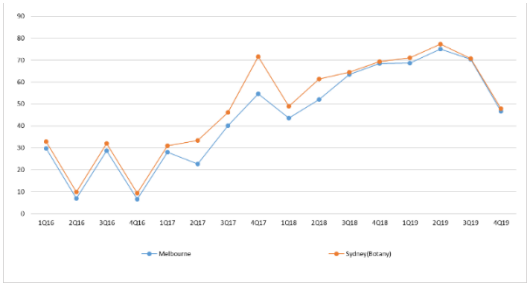

Figure 6. Trend of Degree Centrality value in Australia

## 7. APPENDIX II CLOSENESS CENTRALITY VALUE IN REGIONS

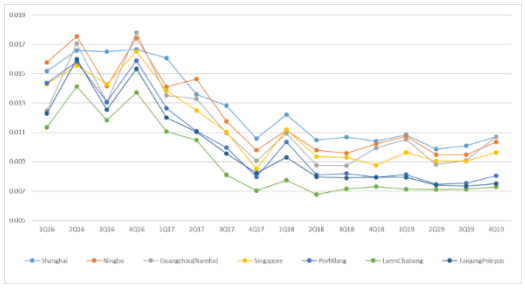

Figure 1. Trend of Closeness Centrality value in Asia

Figure 2. Trend of Closeness Centrality value in Europe

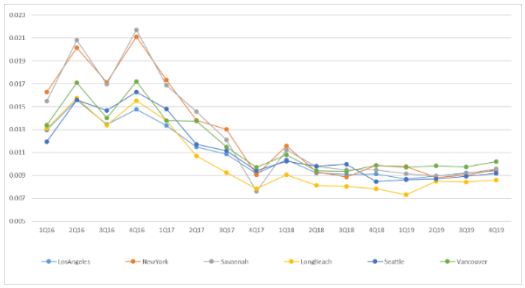

Figure 3. Trend of Closeness Centrality value in North America

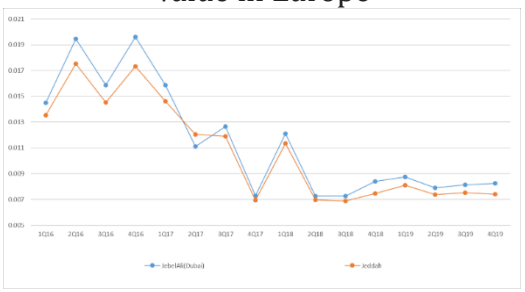

Figure 4. Trend of Closeness Centrality value in the Middle East

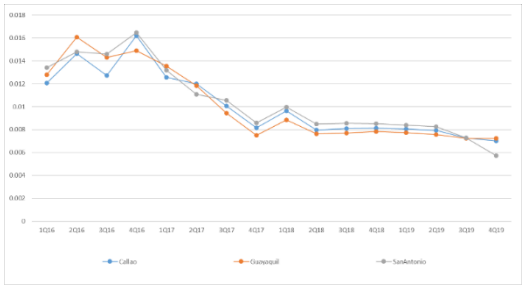

Figure 5. Trend of Closeness Centrality value in South America

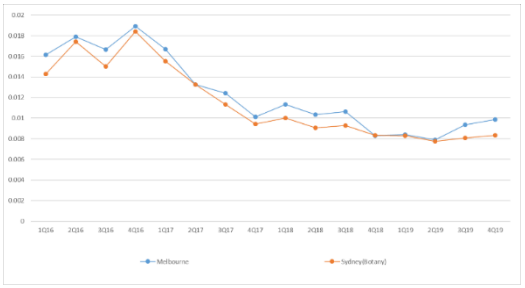

Figure 6. Trend of Closeness Centrality value in Australia

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# 8. APPENDIX III BETWEENNESS CENTRALITY VALUE IN REGIONS

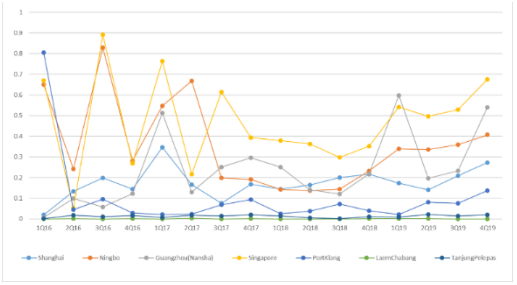

Figure 1. Trend of Betweenness Centrality value in Asia

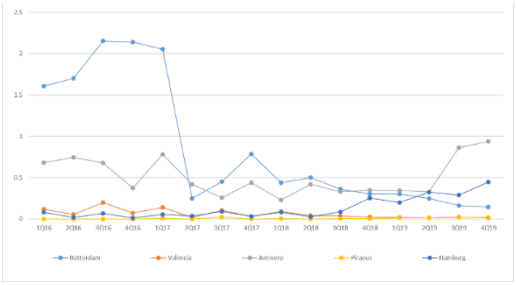

Figure 2. Trend of Betweenness Centrality value in Europe

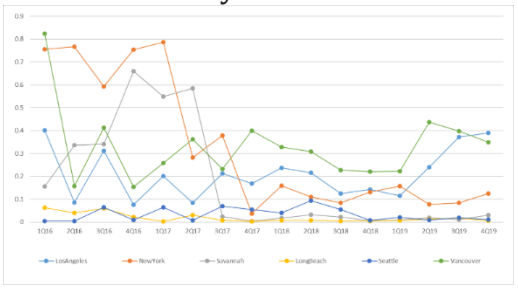

Figure 3. Trend of Betweenness Centrality value in North America

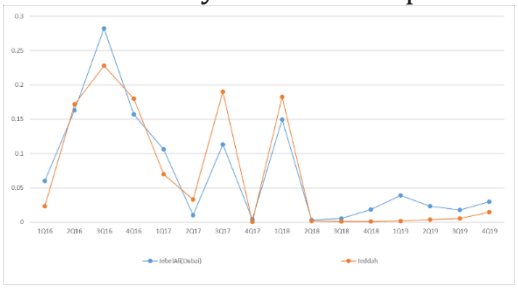

Figure 4. Trend of Betweenness Centrality value in the Middle East

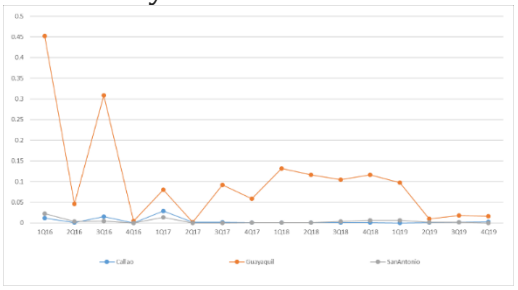

Figure 5. Trend of Betweenness Centrality value in South America

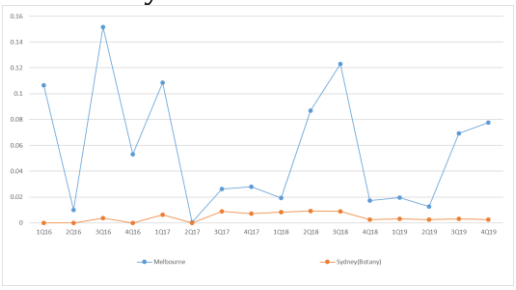

Figure 6. Trend of Betweenness Centrality value in Australia