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Vulnerability and Impact of China-Europe Train Network Under the Background of Main Channel Interruption

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Abstract: In order to study the impact on the China-Europe freight trains when the three main passages including Alashankou Port (Khorgos), Manzhouli, and Erenhot were attacked, Count the running routes of the China-Europe trains, make the running routes into an adjacency matrix, and calculate the changes of the network average degree, isolated node ratio, network efficiency, and network average distance of the China-Europe trains under the background of the interruption of the three main channels to analyze the changes of the China-Europe trains. The impact of train operation, The research shows that the container network of the China-Europe freight train is very sensitive to the connectivity of the three main channels, and the Alashankou Port (Khorgos) has the greatest impact. Next is Manzhouli, and again is Erenhot. When the three main channels are attacked, the average degree and network efficiency of the network drop significantly. In order to ensure the normal operation of the China-Europe freight train, the alternative routes are discussed, the perspective of ensuring safety is discussed, and corresponding safeguarding countermeasures are put forward. When the Alashankou port is blocked, trains departing from Alashan (Khorgos) in Xinjiang can take a detour from Erenhot. When Erenhot is blocked, trains departing from the Erenhot port in Inner Mongolia can take a detour from Manchuria. When Manzhouli is blocked, trains departing from Manzhouli, Inner Mongolia, can take a detour from Erenhot.

Keywords: China-Europe Railway, Vulnerability, Network, Eigenvalue Analysis

1. Introduction

Vulnerability is a concept in the field of geography, which is used for important applications in climate change, disaster management [1]. Such as the vulnerability of ecosystems under climate change [2-3]. The regional vulnerability of natural disasters [4-5]. In the field of transportation, the vulnerability of the transportation network refers to the degree of impact on the network connectivity when the network is attacked or locally failed, mainly considering the impact on the system as a whole when some nodes or paths and other elements fail or are disturbed. Wu Di studied the vulnerability of the container shipping network of the Maritime Silk Road under random attack and deliberate attack, counted the ports and affiliation routes along the route, analyzed the vulnerability of the network under random attack and deliberate attack, and proposed the method of port stratification, pointed out the ports that needed key protection, and proposed relevant strategies for risk control and security

guarantee of the maritime network [6]. Wu Di studied the network vulnerability under the background of the interruption of the main waterway of the maritime network, and calculated the changes in the average degree of the network, the average distance, the network efficiency, the aggregation coefficient, and the proportion of isolated nodes were calculated on the basis of the statistics of global container routes, and the research showed that the order of impact on Container Shipping in China was the Strait of Malacca, the Suez Canal, and the Panama Canal. When the three main shipping lanes are attacked, the network efficiency is significantly reduced, and in order to ensure the smooth progress of ports around the world, countermeasures for alternative routes are discussed [7]. Wang Nuo In view of the trend of vulnerability of global container shipping networks, based on the container route distribution data in 2004 and 2014, a method for quantitative research on network vulnerability was constructed, which was gradually deleted according to the proportion of 1%-10% of the node degree,

and the indicators of complex networks were used as quantitative indicators to provide reference for deepening the research of port geography [8]. Duan Jiayong Aiming at the problem of network vulnerability in complex network research, duan jiayong et al. proposed that based on node importance and network efficiency as indicators to measure the vulnerability of complex networks, single nodes and multi-nodes were attacked through simulation experiments, and the results obtained showed that the prediction results were better than those of the high number node method and the high median method [9]. Wu Di in view of the vulnerability of the container shipping network of the Maritime Silk Road, it reveals the critical point where the network began to collapse and completely collapse under deliberate attacks, with the sub-protection as the basis for the key protection of ports [10]. Wu Shan Analyze the changes in network vulnerability in view of the unexpected situations on container routes, and provide a theoretical basis for the re-optimization of container shipping network routes [11]. Fang Xingming Based on the perspective of the "Belt and Road" construction. She proposed a dual differential method to analyze the impact of China-Europe express trains on the trade opening of Chinese cities, and concluded that the impact on cities is proportional to the number of openings, which is of great significance to promote China's high-level development [12]. Liu Xiaoyu applied the entropy weight method to study the logistics index in the logistics structure along the European express train [13]. Zhang Xin analyzed the vulnerability of the container liner shipping network, and the study showed that the network is more vulnerable when it is attacked deliberately [14]. Zhu Yueyue analyzed the vulnerability of subway network in order to improve the safety of subway operation,

and evaluated risk factors through DEA model to determine the influence weights and effective indicators of risk factors [15]. Mu Nengzhi proposed two network failure modes, intentional and random, in view of the impact of emergencies on the structure and performance of urban express delivery networks, indicating that the failure of a single node in sequence has less impact on the network, and the cascading failure of nodes has a greater impact on the network [16].

The results showed that the China-Europe express train effectively improved the economic relationship pattern between Chinese and European cities, which is conducive to promoting the construction of modern logistics hubs and further promoting the optimization of the logistics structure along the route.

2. China-Europeexpress Network

The China-Europe Express refers to the intermodal railway train that runs according to a fixed line, fixed time schedule, and is used to transport containers between China and Europe and countries along the Belt and Road. So far, the China-Europe express train has formed three major channels such as the West Passage, the Middle Passage and the West Passage, and the four major ports exiting from Alashankou, Khorgos, Manzhouli and Erenhot are transported to the Eu, the Middle East, Central Asia, Southeast Asia, Russia and other five directions, consisting of Six major lines composed of Chengdu, Zhengzhou, Chongqing, Wuhan, Xi'an, suzhou with relatively high operating quality trains, and According to statistics, there are 54 trains in China and Europe, 31 trains leaving the country through Alashankou port (Khorgos), 11 trains leaving the Erenhot port, and 12 trains leaving from the Manzhouli port. It is shown in Figure 1 below:
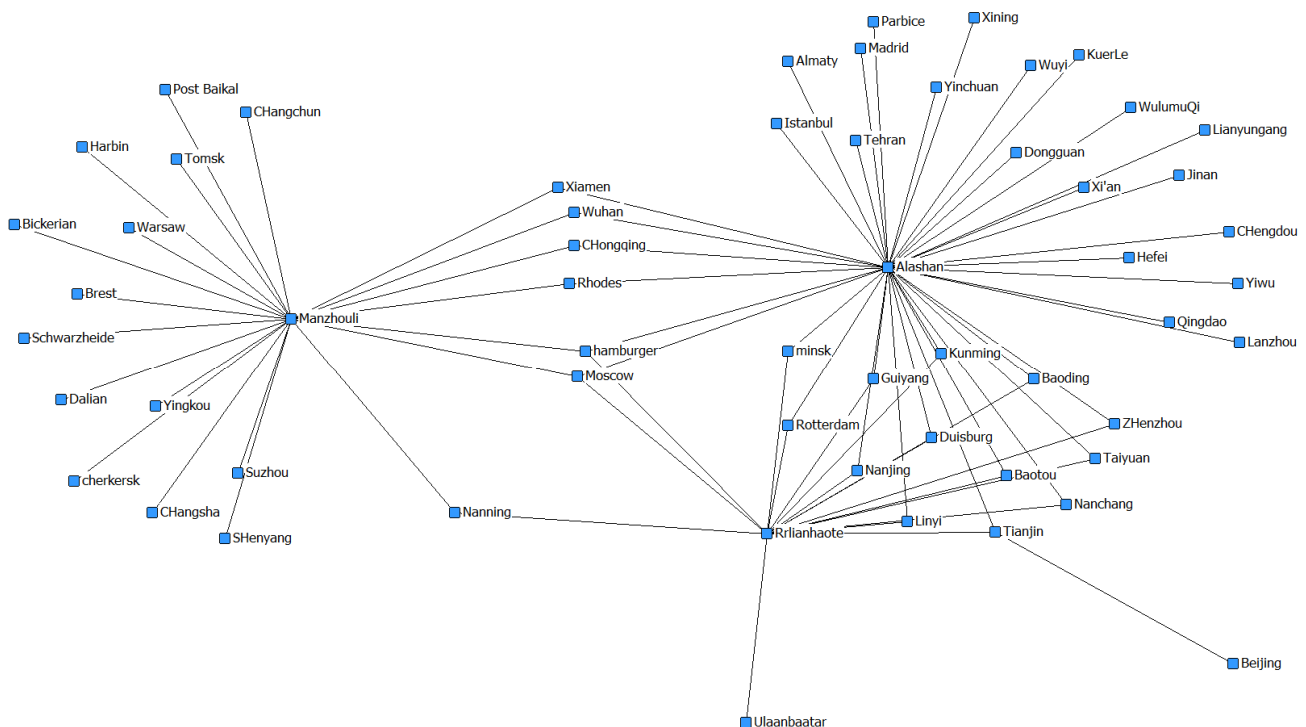

***Figure 1.** China Railway Express Network.*

As can be seen from the above figure, the China-Europe express train network is distributed in a star-like manner, which statistically counts the network characteristic values under the condition of interrupting different main channels, and analyzes the network average, the proportion of isolated nodes, the network efficiency, and the average path length as the criteria for measuring the vulnerability of the network.

3. Network Characteristic Analysis

The so-called vulnerability of the network refers to the impact on the connectivity of the network when the structure of the network changes. The vulnerability of the China-Europe train network refers to the changes in the connectivity of the network due to military blockades, epidemics, and natural disasters. Therefore, the vulnerability of China-Europe express trains can be analyzed by the change of characteristic values after the network is attacked.

3.1. Average Node Size of the Network

The concept of network average refers to the average node degree of all nodes in the network, which is the average of all nodes in the network when the main channel of the China-Europe express train is attacked. In fact, when the main channel of the network is attacked, the nodes and edges of the network are also reduced, the average degree of network nodes also changes, the greater the average degree of change rate, the more sensitive the network means that the more

vulnerable, set N as the total number of nodes in the China-Europe train network, K is the average degree of the Central European train network, k_i is the node degree of the node i, then

$$K = \frac{1}{N}\sum_{i=1}^{N} k_i \qquad (1)$$

The site is the node of the China-Europe train, the node degree of the site reflects the importance of the site, if a site is a hub point, the node degree will also be larger, when the three major channels are attacked, the train between some stations will change, the average node degree of the network will also change, the larger change will mean that the network is more sensitive and more vulnerable, ΔK means that when a channel is attacked, the change rate of the average node degree of the network, the rate of change is:

$$\Delta K = \left(1 - \frac{K^*}{K}\right) \times 100\% \qquad (2)$$

Among them, K and K^* are the average degree of network nodes before and after the channel is attacked.

When the three channels are attacked by Equation (1) and Equation (2), the average node degree change ratio of the network is shown in the following table:

Table 1. *The proportion of network nodes that change when the three major channels are attacked.*

Target of attack	N/A	Alashankou Port	Erenhot	Manzhouli
Average node degree	2.655	1.368	2.105	1.965
Rate of change (%)	——	48.47%	20.72%	25.98%

As can be seen from the above table, when the Alashankou port was attacked, the average node degree of the China-Europe train network changed the most, when the Manzhouli port was attacked, the average node degree of the China-Europe train network changed second, and when the Erenhot was attacked, the average node degree of the China-Europe train network changed the least.

3.2. Proportion of Orphaned Nodes

Orphaned nodes are the proportion of nodes to which they have no edges attached. When a site in a network is attacked and the network transportation cannot operate normally,

which in turn affects the size and connectivity of the entire network, the proportion of isolated nodes is:

$$\Delta N = \left(1 - \frac{N^*}{N}\right) \times 100\% \qquad (3)$$

Among them, N and N^* are the total number of nodes before and after the network is attacked. From Equation (3), it can be obtained that when the three major channels are attacked, the proportion of isolated nodes in the network changes as shown in the following table:

Table 2. *The proportion of network nodes that change when the three major channels are attacked.*

Target of attack	N/A	Alashankou Port	Erenhot	Manzhouli
The number of orphaned nodes	0	19	1	14
Proportion of orphaned nodes (%)	——	32.21%	1.69%	23.72%

As can be seen from the above table, when the main channel is attacked, the average node degree change of the network is the largest change in Alashankou port, followed by the change in Manzhouli, and the smallest in Erlianhot.

3.3. Average Path Length

The average path length refers to the average of the shortest paths between all node pairs in the network, and it is also an

important indicator of network vulnerability. In general, when the network is attacked, but the network has not yet caused the network to fragment, the average path length can reflect the average degree of separation between nodes, set d_{ij} as the shortest path length between nodes i and node j, that is, the calculation formula of the average path length of the network L is:

$$L = \frac{2}{N(N-1)} \sum_{i=1}^{N} \sum_{j=i+1}^{N} d_{ij} \qquad (4)$$

Let ΔL represents the proportion of changes in the average distance of the network when the China-Europe express train network is attacked, ΔL is shown in the following equation:

$$\Delta L = \left(1 - \frac{L^*}{L}\right) \times 100\% \qquad (5)$$

Among them, L and L^* are the average network distance before and after the attack of the China-Europe express train network. From Equations (4) and (5), it can be obtained that the average path length change rate of the China-Europe express train network is shown in the following table when the three main channels are attacked:

Table 3. *Ratio of network distance when the three major channels are attacked.*

Target of attack	N/A	Alashankou Port	Erenhot	Manzhouli
Average distance	2.655	2.809	2.669	2.111
Rate of change (%)	——	5.41	0.15	20.78

It can be seen from the changes in the average distance of the network when the three major channels are attacked separately that when the Alashankou port is attacked, the average distance of the network increases significantly, indicating that the number of transits has increased during the transportation process, and the change in Erenhot is not obvious. When Manzhouli was attacked, the average distance of the network decreased, indicating that the network was broken down into multiple sub-networks.

3.4. Network Efficiency

Network efficiency refers to the sum of the efficiency of all nodes, it reflects the difficulty of network transportation, the higher the network efficiency indicates that the better the connectivity of the network, set 1 is the reciprocal of distance 2, 3 is the network efficiency, then

$$E = \frac{1}{N(N-1)} \sum_{i=1}^{N} \sum_{j=1(j\neq i)}^{N} h_{ij} \qquad (6)$$

Let ΔE represent the proportion of change in the efficiency of the China-Europe express train network, and ΔE is shown in the following equation:

$$\Delta E = \left(1 - \frac{E^*}{E}\right) \times 100\% \qquad (7)$$

Among them, E and E^* were the network efficiency before and after the attack on the China-Europe express train network. From Equations (6) and (7) it can be obtained that when the three major channels are attacked, the network efficiency ratio changes as shown in the following table:

Table 4. *Proportion of changes in the efficiency of the attacked networks of the three major channels.*

Target of attack	N/A	Alashankou Port	Erenhot	Manzhouli
Network efficiency	0.432	0.184	0.414	0.287
Rate of change (%)	——	57.4	4.16	33.56

As can be seen from the above table, when the three major channels are attacked, the network efficiency decreases significantly, indicating that the difficulty of network operation increases, and when the Alashankou port is attacked, the network efficiency change is the most sensitive.

Based on the above characteristics, the average change value of each feature value is calculated and summarized. The results show that when the main channel is attacked, the vulnerability of the network to the sensitivity of the three major channels is Alashankou port, Manzhouli, and Erenhot. When the three main waterways are blocked by natural disasters, terrorist attacks, military blockades and other factors, they will face the use of alternative trains for transportation. When the Alashankou port is blocked, trains from Alashankou (Khorgos port) to Poland, Germany and other countries can be detoured from Erenhot. When Erenhot is blocked, trains leaving the

Erenhot port in Inner Mongolia and entering Western Europe can take a detour from Alashankou. When Manzhouli is blocked, trains from Manzhouli in Inner Mongolia to Western Europe can be detoured from Alashankou.

In order to ensure the normal operation of China-Europe express trains and maintain China's economic stability. The following suggestions are put forward: (1) Enhance the understanding of the importance of the safety and security of China-Europe express trains, maintain the security of countries and cities along the Belt and Road, and strengthen the construction of train safety and security forces. (2) Actively seek alliances between countries near the main channel to build a community of interests between powerful countries. (3) Take advantage of the opportunity of the Belt and Road Initiative to seek to open up new traffic arteries and reduce the restrictions on China's transportation by the main channel.

4. Conclusions

This paper calculates the transportation routes of China-Europe express trains, constructs the corresponding container transport network, analyzes the situation of different main channel interruptions, introduces complex network theory into geopolitical research to analyze the changes in the characteristic values of China-Europe express train networks, analyzes the impact of the smoothness of transport channels on the network vulnerability of China-Europe express trains, points out the areas that need key protection, and puts forward corresponding countermeasures and suggestions.

Acknowledgements

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