A Study on the Network Characteristics of the Road Collection and Distribution System of Tianjin Port

Wang Guanhui*

School of International Business, Tianjin Foreign Studies University, Tianjin, 300204, China

*Corresponding author’s e-mail: newhop@126.com

Abstract. The competition among ports is changing from the competition in internal collection and distribution system to that in hinterland, in which road network plays a very important role. Focusing on the hinterland road network of Tianjin Port, this study takes it as a network, and analyzes its network topology feature. The conclusion has guiding significance for the optimization of Tianjin Port road network.

1. Introduction

Tianjin port is the largest port in the north of China. Its port scale and competitiveness are closely related to its own capacity of freight collection, distribution and transportation, which directly affects the development of the port. Generally speaking, good freight collection, distribution and transportation conditions can boost the expansion and development of the port. Otherwise, the development of the port will be negatively affected. Therefore, the importance of freight collection, distribution and transportation system has drawn more and more attention from the academic circle. Meanwhile, with the rapid development of port economy, the competition between ports is more and more fierce, which is extending from one on the level of the collection and distribution system of the port per se to one on the level of port hinterland.

Tianjin Binhai New Area is undoubtedly the hinterland of Tianjin Port. Whether the road freight collection, distribution and transportation network in this area can meet the requirements of port cargo transportation, whether the network is free from network failure, and whether the overall network is robust will directly affect the collection and distribution system capacity of the Port.

2. Model construction of Tianjin Port road collection and distribution system

Hypothesis: $N_1$ is container throughput, $N_2$ is highway mileage, both $r_1, r_2$ are greater than 0. $2 < \varepsilon < \eta$, and $0 < \nu < 1$. $N_1^*$ is container throughput in balanced state and $N_2^*$ is highway mileage in balanced state. If $\mu > 1, N_2^* \geq lN_1^*$; when $\mu < 1, N_2^* < lN_1^*$. For the convenience of later analysis and comparison, it is considered that when $N_2^* \geq lN_1^*$, then $0 < \nu < 1, 2 < \varepsilon < \eta < \mu + 1$.

The model is as follows:
In this model, considering that the influence of freight collection, distribution and transportation on port development is much greater than that of port development on freight collection, distribution and transportation, because the construction of freight collection, distribution and transportation is mainly restricted by the economic development of hinterland. \( \varepsilon \) and \( \eta \) are the influence of other factors on the system.

It can be seen from the model that the key to the analysis is that we need to guarantee \( \mu > 1 \). When container throughput and freeway mileage are in equilibrium, they will not change any more.

Then, \( \frac{dN_1}{dt} = 0, \frac{dN_2}{dt} = 0 \) Or

\[
\begin{cases}
\frac{dN_1}{dt} = 0 \\
\frac{dN_2}{dt} = 0
\end{cases}
\Rightarrow
\begin{cases}
-\frac{r_1}{K_1} N_1^2 + \frac{\mu r_1}{K_2} N_1 N_2 + \varepsilon r_1 N_1 = 0 \\
-\frac{r_2}{K_2} N_2^2 + \frac{\nu r_2}{K_2} N_1 N_2 + \eta r_2 N_2 = 0
\end{cases}
\]  

As we made \( 0 < \nu < 1, \ 2 < \varepsilon < \eta < \mu + 1 \) in the previous assumption, the positive balance condition of this point is \( \mu \nu < 1 \). At the same time, because \( N_2^* \geq lN_1^* \) needs to be satisfied in the practical sense, the condition that this point needs to meet is \( lK_1(\mu \eta + \varepsilon)(1 - \mu \nu) \leq K_2(\nu \varepsilon + \eta)(1 - \mu \nu) \), or \( (\mu \eta + \varepsilon)lK_1 \leq (\nu \varepsilon + \eta)K_2 \).

Under this equilibrium condition, we can find \( N_1^* > K_1, N_2^* > K_2 \). That is to say, when \( N_2^* \geq lN_1^* \), the two populations of container throughput and highway mileage are in a state of mutual benefit and symbiosis. And the number of populations in the equilibrium of both sides is larger than the maximum that could be reached when they develop alone.

3. Analysis of road collection and distribution system network in Tianjin Port

Based on the above formula, 163 nodes and 682 edges of Tianjin Port road freight collection, distribution and transportation network are calculated respectively, which is a relatively complex network. There are no two roads that are disconnected

With a diameter of 9, 9 routes need to be changed from West Ring Road to Huangshan Road. The average path length is 3.64304. That is to say, driving from any road to any other road requires less than four times of changing driving routes on average.

The average degree of each node is 5.96319, so on average each road is connected with nearly 6 other roads, which indicates that the connectivity of the network is still relatively high. Through further statistics, it can be found that the nodes with degrees between 2 and 7 account for 78% of all nodes, but the total degree only accounts for 50% of the total. That is to say, the distribution of the network is relatively uneven, which is related to the traffic capacity of the road and population density.

The degree distribution:
Remove the points with degrees of 0 and 1, and then rearrange the degree distribution function. 

Degree distribution function:

$$Y = 12.55e^{-0.8x}$$

with a goodness of fit of 75%. It passes F test and T test, and the overall fitting effect is good.

The network has a small average path length and a large aggregation coefficient, which shows that the network has the characteristics of a small world. At the same time, because its degree distribution conforms to the exponential distribution, it further shows that the network is a small world network. The characteristics of the small world network proves that the resistance of the highway network in the main urban area of Tianjin Port to random attack is higher, while the resistance to malicious attack is lower.

### 4. Conclusion

The road network in Tianjin Port has moderate diameter and short average path length, and the network is well connected. At the same time, the network has a relatively large average aggregation coefficient. However, compared with other cities in the world, there is still a large gap and development space. The degree distribution of the network basically is in accordance with the exponential distribution. The characteristics of the network shows that it is basically a small world network, which has strong robustness to random attacks, but poor robustness to malicious attacks. The collapse of the road freight collection, distribution and transportation system due to maliciously attacks will lead to the overall collapse of the network.

### Acknowledgments

The project is supported by Research project of Humanities and Social Sciences in Tianjin institutions of higher learning (Project No.20132127)

### References

[1] YANG S, LIU G, WANG Z, (2018), Research on coordinated development saturation model of port collection and distribution system. Journal of Ningbo University (NSEE), 31:76-81.

[2] YANG A, (2016), Research on the Container Collection and Distribution System of Xiamen Port. Logistics Sci-Tech, 2:1-3.

[3] KONG L, HE P, (2019), Study on Capacity Coordination of Collecting and Distributing System of Shenhua Heavy Haul Coal Line. Railway Transport and Economy, 39:57-62.
[4] MA L, SONG Y, WANG L, (2018) Logistics Collection and Distribution System of Wuxi Airport under the background of Supply-side Structural Reform. Journal of Wuxi Vocational Institute of Commerce, 18:33-37.
[5] YANG S, LIU G, WANG T, (2017), Study on influential factors of collecting and distributing system for port based on SEM. Journal of Waterway and Harbor, 38:103-108.
[6] KONG L, HE P, (2017), Coordination research on the collection and distribution system of Shenhua heavy haul railway Technology & Economy in Areas of Communications, 19:42-47.
[7] WU Q, (2015), Fuzhou Jiangyin Bonded Port Hinterland Development and Construction of Transportation System. Logistics Engineering and Management, 37:69-71.