

Complex Network Approaches to Analyze the Topology of China High Speed Railway Network

Chen Wang, Huaixi Wang, and Nina Shu

College of Electronic Engineering,
National University of Defense Technology,
Hefei, Anhui Province, China, 230037
permutation@163.com.

Abstract. The abstract should summarize the contents of the paper using at least 70 and at most 150 words. It will be set in 9-point font size and be inset 1.0 cm from the right and left margins. There will be two blank lines before and after the Abstract. ...

Keywords: complex network, graph theory, China high speed railway network

1 Introduction

1.1 the development of the high speed railways

Since the opening of the first intercity high speed railway-Beijing Tianjin railway in 2008, it has made great developments for the construction of high speed railway network in China. By 2019, China keeps the world's largest high speed rail (HSR) network with a length totaling over 35,000 km. Over 2,800 pairs of bullet trains numbered by G, D or C run daily connecting over 550 cities in China and covering 33 of the country's 34 provinces. The world's longest HSR line, Beijing-Hong Kong high speed railway, extends 2,440 km and Beijing-Shanghai high speed train links the two mega-cities 1,318 km away in just 4.5 hours [2].

With the longest high speed rail network in the world, China has achieved the goal of the Four Vertical and Four Horizontal High Speed Railway Plan with a total length of 25,000 km/15,534 miles high speed rail [3]. Based on the existing lines, China will expand the rail system into 8+8 HSR Grid to link cities that had no railways and upgrade the conventional railroads. Featuring high speed of 250-350 km/h, Chinas high speed rails has greatly cuts down the journey time and attracts numerous travelers for its comfort, convenience, safety and punctuality.

1.2 the research of the high speed railways

With the rapid developments of the high speed railways, it makes great differences in economic developments and social activities in China. Many researchers

have studied the various impacts of the high speed railway network [4, 6, 7] and analyzed the topological structure of HSR network [5, 8, 9].

Jiang analyzed the effect of scale-free network structure on the accessibility, spatial distribution and industrial development according to the the network index and the rank-scale distribution [4]. Luo et.al comprehensively studied impact of high-speed railways on eco-efficiency, which had important theoretical and practical significance [6]. Based on the data of 277 prefecture-level cities in China from 2006 to 2016, they used social network analysis(SNA) and spatial Durbin model(SDM) to verify the impact of development of rail network on urban eco-efficiency in China. Wang et.al Based on the panel data of five major urban agglomerations in China over the past 2004-2015 years, we use an econometric model to measure the impact of high-speed rail construction on the spatial evolution of urban agglomerations [7].

Liu and Ye studied the evolution features of HSR network in China based on the railway data from 2003 to 2015 with complex network theory to identify the topological attribute and evolution pattern of high-speed rail(HSR) network [5]. Xia studied China HSR network based on complex network methods, i.e. mainly estimated the HSR network in terms of the indicators (degree, betweenness and network location coefficient) and analyzed HSR site, HSR economy and the whole structure of HSR network in the level of the individual, group, and overall [8]. Yuan evaluated the hierarchy of high-speed railway stations and explored the key factor that affected the hierarchy of stations based on the structural characteristics of HSR network in China [9].

1.3 Contributions

In this paper, we deliberate the topology of China high speed railway network in three network models: undirected simple graph, undirected weighted simple graph, and undirected multiple graph. In the previous papers [5, 8, 9], they only adopted the undirected simple graph model which provided the link relation rather than the number of high speed railway through the HSR stations and the distances between different HSR stations.

- Three Network Models as the first time.
- Complex Network Method
- Detailed Information about the Network.

2 Complex Network Background

In this section, we describe the main measures and properties in network science [1].

2.1 Degree Distribution

With the rapid development of the high speed railway,

2.2 Betweenness

With the rapid development of the high speed railway,

2.3 Clustering Coefficient

With the rapid development of the high speed railway,

2.4 Scale-free Network

With the rapid development of the high speed railway,

2.5 Small World Network

With the rapid development of the high speed railway,

2.6 Community Discovery

With the rapid development of the high speed railway,

3 Network Model and Data Acquirement

3.1 Network Model

In order to analyze the properties of the HSR network, we make three models for the HSR network as follows:

Undirected Simple Graph
Undirected Weighted Simple Graph
Undirected multiple Graph

3.2 Data Acquirement

1. Python Crawler: Theory and Practice. Our Python crawler can be available at <https://github.io/>
2. Python NetworkX

4 Data Analysis for China Train Network Analysis

4.1 Degree Distribution

4.2 Betweenness

Betweenness describes the centrality. Small-world property is uniquely determined by the betweenness distribution.

Fig. 1. This is the caption of the figure displaying a white eagle and a white horse on a snow field

Table 1. The Top 10 HSR Sites under Node Degree in Undirected Simple Graph

Order	HSR Site	Order	HSR Site
1	Beijing	2	
3		4	g
5	g	6	g
7	g	8	g
9	g	10	g

Fig. 2. This is the caption of the figure displaying a white eagle and a white horse on a snow field

Table 2. The Top 10 HSR Sites under Node Degree in Undirected Multiple Graph

Order	HSR Site	Order	HSR Site
1	Beijing	2	
3		4	g
5	g	6	g
7	g	8	g
9	g	10	g

Table 3. This is the example table taken out of *The T_EXbook*, p. 246

Year	World population
8000 B.C.	5,000,000
50 A.D.	200,000,000
1650 A.D.	500,000,000
1945 A.D.	2,300,000,000
1980 A.D.	4,400,000,000

Fig. 3. This is the caption of the figure displaying a white eagle and a white horse on a snow field

Table 4. The Top 10 HSR Sites under Node Betweenness in Undirected Simple Graph

Order	HSR Site	Order	HSR Site
1	Beijing	2	
3		4	g
5	g	6	g
7	g	8	g
9	g	10	g

Fig. 4. This is the caption of the figure displaying a white eagle and a white horse on a snow field

Table 5. The Top 10 HSR Sites under Node Betweenness in Undirected Weighted Graph

Order	HSR Site	Order	HSR Site
1	Beijing	2	
3		4	g
5	g	6	g
7	g	8	g
9	g	10	g

4.3 Clustering Coefficient

4.4 Scale-free Network

4.5 Small World Network

4.6 Community Discovery

- The difference between GaoTie and DongChe
- The Visual Description in Chinese Map
-

5 Conclusion

References

1. Barabási, A.L.: Network Science. Cambridge University Press (2016)
2. Discovery, C.: China high speed rail (hsr) map & china bullet train map 2020. China Discovery (2019). URL <https://www.chinadiscovery.com/china-maps/high-speed-railway-map.html>
3. Jiang, B., Chu, N., Xiu, C., Zhao, Y., Li, X., Luo, C.: Comprehensive evaluation and comparative analysis of accessibility in the four vertical and four horizontal hsr network in china(in chinese). *Acta Geographica Sinica* **v.71**(4), 65–78 (2016)
4. Jiang, J.: Impact of high speed railway scale-free network on node cities. Master, Beijing Jiaotong University, Beijing, China (2018)
5. Liu, G., Ye, K.: Evolution features of high-speed rail in china based oncomplex network. *TRANSPORT RESEARC* **3**(3), 6–13 (2017)
6. Luo, N., Tian, M., Yang, J., Li, J., Wang, Y.: Impact of high-speed rail network on urban eco-efficiency: based on the spatial measurement of 277 prefecture-level cities nationwide. *China Population, Resources and Environment* **29**(11), 1–10 (2019)
7. Wang, C., Meng, W., Zhou, J.: Spatial evolution characteristics of chinese urban agglomerations in high-speed rail era. *Modern Economic Science* **40**(3), 103–113+128 (2018)
8. Xia, W.: Study on china high speed railway network based on complex network method. Master, East China Normal University, Shanghai, China (2017)
9. Yuan, X.: A study on the hierarchy phenomenon of high-speed railway stations in china. Master, Chongqing University, Chongqing, China (2017)