The High-Speed Railway Network in Yangtze River Delta:
An Analysis of the Accessibility Impact

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ABSTRACT: Historically, changes in transport infrastructures have produced a progressive contraction of space, in the sense that travel times have been shortened and transport costs have been reduced. Improvement of transportation networks reduces interaction costs, increases the overall competitiveness of the system and allows for more specialization such that economies of scale and specialization benefits can be utilized. Hence, we should expect that production and other economic activities can be carried out more efficiently as the quality and capacity of a region's transportation networks increase (Forslund and Johansson, 1995). High-speed railway is the most visible form of new technology accompanying and enhancing the transformation to an information-based economy, and it is likely to have the greatest spatial development effects among any other technologies (Brian D. Sands, 1993).

The development of High-Speed Railway has been one of the central features of recent China’s transport infrastructure policy. From the initial Beijing-Tianjin inter-city railway to the recent Beijing-Shanghai high-speed railway, the High-Speed Railway Age of China is coming. Based on the mid-long term railway network plan (2008), the High-Speed Railway mileage of China is expected to be more than 18 thousand kilometers in 2020, which will constitute more than half of the world’s High-Speed Railway mileage, formatting a network structure of ‘4 length lines and 4 breadth lines’.

Since the Reform and Open Policy Age, the Yangtze River Delta area has grown into an area with the highest level of economic development and overall economic strength in China and it is also the area enjoying the most intensive High-speed Railway networks. This paper evaluates the accessibility impact of the future High-Speed Railway in Yangtze River Delta, by reducing time distance between places and modifying their relative location. We compare the current situation with that foreseen for the year 2020, according to the Outline Plan of the China’s High-Speed Railway Network, in order to analyze whether the cities will benefit from construction and improvement of the infrastructure and how spatial pattern changes of Yangtze River Delta’s accessibility under the impact of High-Speed Railway. It concludes that the High-Speed Railway will certainly enhance accessibility within Yangtze River Delta area, greatly shorten temporal and spatial distance between cities and promote the integrated development of the Yangtze River Delta.

The traditional pattern of regional governance will face a new challenge. On the other hand, the High-Speed Railway will also increase imbalances between the other main cities and their hinterlands because it differently affects the accessibilities of different areas. There is evidence of increasing concentration into the main metropolitan centers served by the emerging network. So, different cities should seek their own development strategies according to their different characteristics under the High-Speed Railway Age.

Accessibility denotes the ease with which activities may be reached from a given location using a particular transportation system. A weighted average travel time indicator is applied for regional accessibility calculation. This measure identifies the spatial distribution of accessibility in the area of study, emphasizing the high-speed railway effects, and locates accessibility changes at the regional level. A geographic information system (GIS) was used to carry out this study.

KEY WORDS: Yangtze River Delta, high-speed railway, accessibility, spatial pattern
1 Introduction

As regional centers, cities develop rapidly through polarization effect of space and resources. In the background of economic globalization and regional integration, the economic links and interaction between cities are increasingly integrated with the expanding of urban scale and improving of intercity transportation. Since the development of cities breaks the limitation of a single city and leads to regionalization, cities grow into urban agglomerations which are leading space units of elements centralization and economic development [1]. The development of urban agglomerations strengthens the links between cities and intensifies the division and cooperation of cities, which also increases the demand of intercity transportation. Many studies show that the transportation network system plays an important role in the optimization of the spatial structure of urban agglomeration. As a space vector of population flow, material flow, capital flow and technology flow, transportation grows into a tie of regional economic links and an important vector of urban agglomerations space constitution. It also has influence on functional structure of urban agglomerations through leading industrial agglomeration and diffusion and regional division and cooperation. As a result, the functional structure of urban agglomerations is evolving into an entirety with a coordinated development of economy and society.

Since the reform and open policy age, the Yangtze River Delta area has grown into an area with the highest level of economic development and overall economic strength in China. The results show that the spatial evolution of the Yangtze River Delta urban agglomeration was promoted from dispersion to agglomeration, from monocenter to multicenter. Although the regional spatial structure of the Yangtze River Delta is increasingly clear, the spatial evolution is still dynamic continuing [2]. And the history has proved that the formation and evolution of the Yangtze River Delta spatial pattern is clearly traffic-oriented. (Tab.1)

| Tab.1 Spatial Pattern Changes of Yangtze River Delta under the Impact of Different Ways of Transportation |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Period                                       | Transportation                                | Industry Characteristics                       | Spatial structure              |
| Railway Age                                  | From 1978 to 1980s                            | Relying on Shanghai-Nanjing Railway and Shanghai-Hangzhou Railway | The leading industries are textile industry, petrochemical industry, steel industry, etc. | Z-shaped                      |
| Highway Age                                  | From 1990s to early 21st century               | Highway network                               | The leading industries are electromechanical industry, high-tech industry, etc. |                           |
| High-speed Railway Age                       | Since 2010                                    | Shanghai-Nanjing High-speed Railway and Shanghai-Hangzhou High-speed Railway, etc. | Industry transfer from the east to the west, simultaneous development of high-tech industry and traditional industry, rapid development of financial and commercial industry | Networked                    |

The development of High-Speed Railway has been one of the central features of recent China’s transport infrastructure policy. From the initial Beijing-Tianjin inter-city railway to the recent Beijing-Shanghai high-speed railway, the High-Speed Railway Age of China is coming. Based on the mid-long term railway network plan (2008), the High-Speed Railway mileage of China is expected to be more than 18 thousand kilometers in 2020, which will constitute more than half of
the world’s High-Speed Railway mileage, formatting a network structure of ‘4 length lines and 4 breadth lines’. Since the Yangtze River Delta is enjoying the most intensive High-speed Railway networks, we can foresee that the continuous development of high-speed railway will have a great influence on the spatial structure of the Yangtze River Delta.

The studies of regional formation mechanism and spatial distribution pattern are major themes of special structure study. With the deep research, many analytical methods and metrics are used to carry out the special structure study. In recent years, domestic and foreign scholars apply accessibility calculation to the study of spatial pattern changes under the impact of High-Speed Railway. Gutierrez J and Gonzalez R evaluated the impact of the future European high-speed train network and the high-speed line Madrid-Barcelona-French border on accessibility, by reducing time distance between places and modifying their relative location [3, 4]. Murayama Y demonstrated the transformation of the Japanese urban system since the beginning of modernization in 1868 (the Meiji era), with special reference to changes in the railway accessibility of cities [5]. Luo Pengfei and others chose seven sample cities between Shanghai and Nanjing, and they researched into the changes of regional accessibility under the impacts of HSR from three analytical indicators [6]. Wei Lihua and Cong Yanguo started from the analysis on commuter characteristics in Beijing-Tianjin-Tangshan metropolitan area and discussed the advantages of inter-cities express passenger train and its influence on spatial structure [7]. Jiang Haibin and others discussed the influences of the Beijing-Shanghai high-speed railways on center cities’ accessibility [8].

From the related studies, there are still some inadequacies: First of all, most of the studies analyzed the high-speed railway’s influence on special structure at a time nod or contrasted the influence with and without high-speed railways. They didn’t forecast nor analyze the influence from the perspective of planning in the circumstance that the high-speed railway is continuously improving. Secondly, the scope of the study mainly focused on the areas along the high-speed railway. As the high-speed rail is increasingly networked, the regional spatial structure is evolving under the impact of lines of high-speed rail network.

For the above deficiencies, this paper evaluates the accessibility impact of the future High-Speed Railway in Yangtze River Delta, by reducing time distance between places and modifying their relative location. We compare the current situation with that foreseen for the year 2020, according to the Outline Plan of the China’s High-Speed Railway Network, in order to analyze whether the cities will benefit from construction and improvement of the infrastructure and how spatial pattern changes of Yangtze River Delta’s accessibility under the impact of High-Speed Railway.

2 Research Methods

2.1 Data Selection

The objects of the research are the 16 cities in Yangtze River Delta including Shanghai, Nanjing, Yangzhou, Taizhou, Nantong, Zhenjiang, Changzhou, Wuxi, Suzhou, Hangzhou, Jiaxing, Huzhou, Shaoxing, Ningbo, Zhoushan and Taizhou, which are the basic space units for data collection, processing and analysis. According to the passenger volume and freight volume of Jiangsu-Zhejiang-Shanghai during 2003 to 2005, we can see that the volume of highway and railway accounts for the vast proportion of the total volume. So this paper chooses the
transportation network composed of highway and railway as route of accessibility analysis and compares the situation in 2010 with that foreseen for the year 2020.

2.2 Analysis Methods

2.2.1 Accessibility indicator

Accessibility denotes the ease with which activities may be reached from a given location using a particular transportation system. A weighted average travel time indicator is applied for regional accessibility calculation, calculating a weighted average of the impedances separating each node with regard to the chief economic activity centers through the transport network and taking as weights the GDP of centers as follows:

\[ A_i = \frac{\sum_{j=1}^{n} (T_{ij} \times M_j)}{\sum_{j=1}^{n} M_j} \]

Where:

- \( A_i \) is the accessibility of node \( i \)
- \( T_{ij} \) is the impedance (travel time) through the network between nodes \( i \) and \( j \)
- \( M_j \) is the gross domestic product of the destination economic activity center

This model is more suitable than others such as economic potential and daily accessibility to measure the degree of separation between different places throughout the transport network in Yangtze River Delta:

(1) The shortest travel time intuitively shows the degree of transportation convenience and the change of accessibility.

(2) Levels of economic development also affect the accessibility in addition to transportation facilities and spatial location. So it is scientific to take GDP as the weights.

2.2.2 Network building

In order to carry out this project using GIS, a dense intermodal transport network dataset1 of high-speed railways, railways and highways was mapped. Two temporal situations are taken into account:

1Source: Jiangsu Province’s Expressway Map (May 2010), Zhejiang Province’s Main Roads Traffic Map, Zhejiang Province (2010), Baidu Map, the Outline Plan of the China’s High-Speed Railway Network(2020), the Outline Plan of the Yangzi river’s High-Speed Railway Network(2020)
consideration: one corresponding to 2010 and the other to 2020, according to the Outline Plan of the China’s High-Speed Railway Network.

Suppose the average driving speed on highway is 120 kilometers per hour, the average driving speed on railway is 140 kilometers per hour and the average driving speed on high-speed railway is from 160 to 400 kilometers per hour according to different levels of the high-speed railway.

Closest Facility is applies for Network building. We take administrative centers of the 16 cities as nodes and travel time as impedance to search the route cost the shortest time. The accessibility index calculated after weighting and Standardization.

3 Results

3.1 Accessibility Calculation

3.1.1 Analysis of Space Accessibility Changes

<table>
<thead>
<tr>
<th>City</th>
<th>2010</th>
<th>2020</th>
<th>change rate</th>
<th>City</th>
<th>2010</th>
<th>2020</th>
<th>change rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changzhou</td>
<td>0.608</td>
<td>0.770</td>
<td>20.94</td>
<td>Shaoxing</td>
<td>0.741</td>
<td>1.113</td>
<td>33.42</td>
</tr>
<tr>
<td>Hangzhou</td>
<td>0.644</td>
<td>0.934</td>
<td>30.78</td>
<td>Suzhou</td>
<td>0.531</td>
<td>0.692</td>
<td>23.26</td>
</tr>
<tr>
<td>Huzhou</td>
<td>0.690</td>
<td>1.283</td>
<td>46.20</td>
<td>Taizhou</td>
<td>1.497</td>
<td>2.240</td>
<td>33.18</td>
</tr>
<tr>
<td>Jiaxing</td>
<td>0.525</td>
<td>0.724</td>
<td>27.48</td>
<td>Taizhou</td>
<td>1.071</td>
<td>1.407</td>
<td>23.86</td>
</tr>
<tr>
<td>Nanjing</td>
<td>0.868</td>
<td>1.183</td>
<td>26.67</td>
<td>Wuxi</td>
<td>0.569</td>
<td>0.725</td>
<td>21.52</td>
</tr>
<tr>
<td>Nantong</td>
<td>0.780</td>
<td>1.282</td>
<td>39.20</td>
<td>Yangzhou</td>
<td>0.844</td>
<td>1.130</td>
<td>25.29</td>
</tr>
<tr>
<td>Ningbo</td>
<td>0.972</td>
<td>1.599</td>
<td>39.20</td>
<td>Zhenjiang</td>
<td>0.744</td>
<td>0.910</td>
<td>18.24</td>
</tr>
<tr>
<td>Shanghai</td>
<td>0.606</td>
<td>0.783</td>
<td>22.62</td>
<td>Zhoushan</td>
<td>1.454</td>
<td>2.009</td>
<td>27.60</td>
</tr>
</tbody>
</table>

This paper supposes that we can seamless exchange between highways and only exchange in downtown areas by other means.
From the results, Space Accessibility Changes show the following characteristics:

(1) **Regional accessibility is fully upgraded.** The indices of 16 cities have been differently improved. The regional accessibility index changes from 1.174 in 2010 to 0.822 in 2020, changed by 28.71%. It shows the regional transportation convenience will be totally improved and that the cities will be more closely linked as the constant improvement of the high-speed rail.

(2) **Regional accessibility level is more balanced.** The standard deviation of regional accessibility is changed from 0.46 in 2010 to 0.30 in 2020. It proves that regional special pattern of Yangtze River is more balanced. The gap between traditional advantageous cities and disadvantageous cities will be gradually reduced and the Multi-center structure will be strengthened.

(3) **From the horizontal comparison, the change rate of accessibility shows significant local areas differences.** Since the rise of accessibility will be gradually decreased with the improving of transport infrastructure networks [11], the change rate of the southern wing of Yangtze River Delta which was more complete in transportation facilities is significantly greater than the rate of the northern wing.

3.1.2 The Impacts on Regional Accessibility of High-Speed Railway

It can be seen from the comparison between the Yangtze River Delta’s transportation networks in 2010 and 2020 that Yangtze River Delta has already initially formed accessible inter-city highway network which will not be significantly changed during 2010 to 2020. That is to say that the change of highway network has less influence on the change of regional accessibility. While in the railway system, the high-speed rail is in a stage of rapid expansion, developing from linear system to networked system. Roughly speaking, the total length of high-speed railway in Yangtze River Delta will be changed from 988 kilometers in 2010 to 3728 kilometers in 2020 and coverage area will also be changed from the area along the Nanjing-Shanghai-Hangzhou-Zhoushan in 2010 to almost all cities of Yangtze River Delta in 2020.

In order to analyze different transport facilities’ impacts on regional accessibility pattern, we use variable manipulation method to compare Yangtze River Delta’s accessibility change rate in highway network and comprehensive transportation network. The result shows that the changes of Yangtze River Delta’s accessibility pattern are mainly affected by the development of...
high-speed railway.

3.2 Analysis of Yangtze River Delta’s accessibility spatial pattern in 2010

3.2.1 Analysis of the high-speed railway’s impacts in 2010

In 2010’s spatial pattern, Suzhou-Jiaxing Area is the center of Yangtze River Delta’s accessibility pattern. Accessibility reduces irregularly from the center to the outlying areas. It shows a certain similarity with Yangtze River Delta’s spatial location and economic level. The high-speed railway’s layout has an impact on accessibility pattern. The areas along the high-speed railways show greatly higher accessibilities than those uncovered by high-speed railway. The higher accessibility areas constitute a ‘Z’ shaped spatial pattern.

Due to the differences in timing and scale of high-speed railway construction, the accessibility of Yangtze River’s northern wing is higher than that of Yangtze River’s southern wing, which is consistent with northern and southern wings’ industrial characteristics. Traffic convenience affects the location choices of foreign investment gathering which will also cause the differences in development path between the northern and southern wings.

3.2.2 Analysis of accessibility spatial pattern in 2010

Seen from the regional differences, Shanghai and its surrounding cities such as Suzhou, Jiaxing, Wuxi and Changzhou constitute the first echelon of accessibility pattern owing to their superior spatial locations and better transport facilities. Nanjing, Zhenjiang, Hangzhou and Shaoxing constitute the second echelon of accessibility pattern because even though their transport facilities are relatively better, their spatial location advantage is not that good. Since Yangzhou, Tó
izhou, Nantong, Huzhou, Zhoushan and Taizhou have no advantages in both aspects and be separated by natural elements such as Yangtze River, Taihu Lake and Hangzhou Bay, their accessibilities are relatively lower.

3.3 Analysis of Yangtze River Delta’s accessibility spatial pattern in 2020

3.3.1 Analysis of the high-speed railway’s impacts in 2020

Continuous improvement of the high-speed rail network will greatly shorten the spatial distance in Yangtze River Delta. Relative to the ‘Z’ shaped spatial pattern in 2010, the spatial pattern in 2020 is more balanced and it annularly decreases from the center Suzhou-Jiaxing-Wuxi-Shanghai to the outlying areas. Comprehensively enhanced accessibility will accelerate regional integration of the Yangtze River Delta. The traditional urban economic groups will be weakened and Yangtze River Delta will gradually form a relatively balanced and multi-central spatial structure.

With the construction and upgrading of high-speed railway in Zhejiang Province, the southern wing’s accessibility has improved significantly, which is relatively balanced with the northern wing. The improvement of southern wing’s accessibility will not only speed up its industrial integration into Yangtze River Delta or even the global production network, but also impact on developed private economy and speed up the transferring and upgrading of southern wing’s industry.

3.3.2 Analysis of accessibility spatial pattern in 2020

Due to the differences in spatial locations and transport facility construction levels, High-Speed Railway distinctly affects the accessibilities of different areas. As the members of first echelon of accessibility pattern, Suzhou, Wuxi, Changzhou, Jiaxing, Shanghai and other cities’ advantages are more obvious. These cities should make full use of the accessibility advantages, promote industries to the periphery and build regional centers such as R&D design center and modern logistics center. At the regional level, they should form multi-central and networked urban space with the efficient transportations and their city effects. In addition, since the advantages of Shanghai’s immediate hinterlands will be more apparent, they should speed up the integrative development with Shanghai and form the specialization and coordination system of ‘store in the front, factory in the back’.

In the second echelon of accessibility pattern, because of the improvement of southern wing’s accessibility, Huzhou, Hangzhou, Shaoxing and Ningbo’s location advantages are further enhanced. As the economic, cultural and other functional centers, Hangzhou and Ningbo should
strengthen the city effects with Shanghai to enhance their international level and actively undertake the industrial transfer from Shanghai to speed up industries updating. However, because of the networked high-speed railway, Nanjing’s traditional special location advantages are impacted and its hinterland is in shrinking. In the new pattern, Nanjing should strengthen the development of the Nanjing metropolitan area and enhance the competition and cooperation with other cities in Yangtze River Delta. Furthermore, it also should collect the resource elements in Midwest areas such as Anhui province and Jiangxi province to lead the development of the Midwest.

Yangzhou, Tàizhou and Nantong constitute the third echelon of accessibility pattern. The construction of north line of Shanghai-Nanjing high-speed railway enhances these cities’ accessibility and expands their markets and raw material sources. They should actively undertake the task of industry transformation from Southern Jiangsu and of the complementary development to form the characteristic in the high-tech, advanced manufacturing, etc. and build the Yangzhou-Tàizhou-Nantong high-speed railway economic Zone.

Although Tàizhou and Zhoushan’ accessibilities are continuous improved, they are still in the last echelon of Yangtze River Delta’s spatial pattern because of their marginal location and comparatively backward high-speed railway. Since the different effects, these cities should seek their own development strategies according to their different characteristics. Zhoushan should make full use of the coastal strengths and natural and cultural resources to develop its port transport, culture, tourism and other industries. Tàizhou should avoid homogenous development in interacting with Ningbo, Hangzhou and Shanghai and support the development of private economy to form a unique economic development pattern.

4 Conclusion

With the introduction of the concept of accessibility and the measurement factors of weighted shortest travel time of the transport network of 2010 and 2020, we think that the development of high-speed railway has an important impact on accessibility spatial pattern and reveals Yangtze River Delta’s spatial evolution trend and planning strategy.

We also conclude that the development of High-Speed Railway has the following effects on the Yangtze River Delta regional spatial structure: First of all, High-Speed Railway completely enhances accessibility within Yangtze River Delta area, greatly shortens temporal and spatial distance between cities, promotes the integrated development of the Yangtze River Delta and boosts formation of regional balance of the spatial structure by formation and development of metropolitan area and economic developing axis. Secondly, High-Speed Railway accelerates the formation of multi-central spatial structure, but it differently affects the accessibilities of different cities. So, different cities should seek their own development strategies according to their different characteristics under the High-Speed Railway Age.

References


