High-Speed Railway Access Pattern and Spatial Overlap Characteristics of the Yellow River Basin Urban Agglomeration

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Abstract: With the rapid development of high-speed railway (HSR) transportation in China, its impact on regional spatial patterns and shaping has become increasingly significant. This study took seven urban agglomerations in the Yellow River Basin as the research object, using the 2 h HSR access time in the Yellow River Basin to comparatively analyze the differences in HSR access in the urban agglomeration in the Yellow River Basin, and using the 3 h HSR access to central cities as the background to conduct regional division and overlapping space identification through cross-regional economic links, before finally selecting the overlapping city of Changzhi for long-term space development strategic planning. The main conclusions were as follows: First, the low-value area of HSR travel time in the Yellow River Basin urban agglomerations was biased toward the center of the urban agglomerations, while the peripheral areas were relatively high-value travel traffic circles, and the HSR travel time showed a circular spatial pattern characteristic of continuous expansion from the center to the peripheral areas. Four urban agglomerations in the upper reaches of the city achieved a 2 h access pattern within the urban agglomeration, whereas three urban agglomerations in the middle and lower reaches of the city only reached the 2 h access level in the center. Second, the Yellow River Basin was divided into six community spaces using the SLPA model based on the economic linkage between the central city and other cities, which were filtered by the 3 h access time from the central city to each city for HSR travel. Three of the six communities produced overlapping spaces, i.e., Community 3 and Community 4 produced overlapping spaces containing Linfen, Community 3 and Community 5 produced overlapping spaces containing Changzhi, Handan, and Xingtai, and Community 4 and Community 5 produced overlapping spaces containing Yuncheng and Sanmenxia. Third, the overlapping space of Changzhi City was selected as a case study for a visionary strategic planning outlook. Combining the geographic location characteristics and future development opportunities of Changzhi, we can try to transform a pass-through node like Changzhi into a hub node in the future, strengthening the gateway status and expanding the hinterland. According to the results of the research and analysis, policymakers can try to implement the expansion and renovation of HSR trunk lines, break the transportation bottlenecks in less developed areas, improve the coverage of the HSR network, and establish a “cross-urban agglomeration” cooperation and coordination mechanism.

Keywords: Yellow River Basin urban agglomeration; high-speed railway access pattern; overlapping community model; spatial overlap delineation; overlapping space identification

1. Introduction

In the past 20 years, promoted by policies such as Central Rise and Western Development, the Yellow River Basin has roughly nurtured or formed seven urban agglomerations. However, due to the development foundation and natural conditions, the development of the Yellow River Basin is relatively lagging behind [1]. As a complex territorial system in the advanced stage of urbanization development, urban agglomerations are both the main spatial carriers for national participation in the international division of labor
and global competition, and they are important territorial units for new urbanization and economic development [2,3]. Along with the introduction of the strategy of high-quality development, and the important instruction of General Secretary Xi Jinping on “promoting the formation of a regional economic layout with complementary high-quality development”, the latest deployment of the coordinated development of north–south and east–west complementary regions has given the Yellow River Basin a great development opportunity [4,5]. Transportation was the basis of regional spatial interaction in the Yellow River Basin, and a well-developed transportation network can strengthen the connection between nodes, reinforce the interaction between the central place and the surrounding cities, promote the functional division of labor in the regional town system, and increase the trend of urban agglomeration integration and scale effect expansion, which are prerequisites for high-quality regional development [6]. However, the natural lack of river navigation benefits in the Yellow River Basin [7] hinders the formation of a transportation artery across the entire region, requiring integrated land transportation to assume more urban–regional spatial linkages. In 2019, the State Council of the Central Committee of the Communist Party of China issued the “outline of the construction of a strong transportation country” [8], which pointed out that, at this stage, the overall goal of building a strong transportation country should be built around the “National 123 Travel Traffic Circle”, putting forward new requirements for the traffic access pattern. As an important part of comprehensive transportation, high-speed railway (HSR) travel time is of great significance to regional development.

Spatial accessibility is used to express the accessibility of a regional city to its surrounding areas [9–12]. Scholars have previously conducted studies on this topic. At the national scale, the increase in highway accessibility in Spain led to the expansion of regional spatial extent, and the phenomenon of high gains in some peripheral areas could form a significant spatial differentiation [13]. At the regional scale, the accessibility of Los Angeles was significantly associated with the growth of urban employment centers, and the increase in accessibility could further influence the urban spatial structure [14]. With rapid urbanization, Chinese scholars have conducted extensive research on the traffic accessibility of urban agglomerations. Since the 1980s, the accessibility of China’s major urban agglomerations has increased significantly, and the gap between the integrated transportation accessibility of Shanghai, Jiangsu, and Zhejiang in the Yangtze River Delta has narrowed [15]. The spatial pattern of accessibility in the Guangzhou–Foshan metropolitan area has shown a clear circular structure, decreasing from the geometric center of the metropolitan area to the periphery [16]. The accessibility of the inner layer of Beijing, Tianjin, and Hebei has expanded the spatial scope, resulting in an evolution of the spatial structure from a “polycentric” structure to a continuous “belt-like” structure [17]. Compared with the three major coastal urban agglomerations, the intercity axial links within the Central Plains urban agglomeration were stronger than those in the peripheral regions, and the spatial links highlighted the “double-center” and hierarchical structure characteristics of Zhengzhou and Luoyang, with a loose overall structure and obvious conglomerate effect [18,19]. The spatial structure of the transportation network of the Central Yunnan urban agglomeration has experienced three stages: “point-line structure”, “radial structure”, and “networked structure”, highlighting the development trend of integrated structure evolution [20]. In recent years, the impact of HSR on the traffic patterns of urban agglomerations has attracted extensive attention from scholars. Empirical studies in the Yangtze River Delta urban agglomeration showed that HSR compresses the spatial distance of cities within the agglomeration and improves the overall accessibility of the agglomeration region [21]. The construction of HSR promotes the rapid expansion of relatively better-located areas to surrounding territories and strengthens the urban development potential, as verified in the middle reaches of the Yangtze River urban agglomeration [22]. In summary, most of the existing studies focused on spatial characteristics, spatial and temporal evolution, spatial structure, and spatial effects of urban agglomeration transportation network development and spatial linkages. In terms of research objects, in addition to national urban agglom-
ations, regional urban agglomerations have received attention. However, the existing results have focused on a single transportation network or a combination of transportation networks, whereas the exploration of accessibility from the perspective of the integration of multiple transportation modes is rare. Therefore, it is of certain practical significance to explore the spatial pattern and spatial association characteristics of urban agglomerations in the context of the rapid development of modern transportation.

With increasing research on the spatial reconfiguration of regions affected by HSR transportation, some studies have begun focusing on the phenomenon of regional spatial overlap. Since the 21st century, scholars have successively found that the construction of HSR has expanded the influence of regional central cities, thus leading to an overlap of the urban hinterland, and changing the competition between cities. For example, Willigers argued that domestic and international HSR services can influence the attractiveness of different types of regions and that there was a significant interaction between the scope of HSR services and other regions [23]. Martin further analyzed regions that overlap with HSR service areas and pointed out that other modes of transportation and surrounding policies have a significant impact on competition in overlapping regions [24]. In recent years, Chinese scholars have also conducted some studies on the phenomenon of regional spatial overlap from the perspective of HSR flows. Dan pointed out that HSR would cause urban hinterland overlap and intensify intercity competition [25]. Chu further argued that HSR would drive the spatial pattern of regional town systems to create “overlapping areas” [26]. Guo concluded that HSR networks can reshape the spatial pattern of the daily exchange circle, with a trend of extending along the HSR corridor and dynamically expanding the overlap [27].

The current study proposes that the HSR network can cause the phenomenon of regional spatial overlap to some extent. For a successful investigation, applicable scientific methods need to be introduced. Currently, the mainstream network spatial analysis methods in geography mostly use complex network indicators to measure the topological properties of urban networks and node relationship patterns to explore the characteristics of subnetworks and their interrelationships. These methods cannot easily portray the regional overlapping patterns of urban networks and identify overlapping spaces. In recent years, an overlapping community discovery algorithm [28–31], which can effectively analyze complex network overlap problems, has been developed in the disciplines of information networks and public safety, and it has been successfully applied to mine network local clustering and subgroup interactions. For example, Nguyen used the overlapping community algorithm to mine the interaction of nodes of different ages and occupations in social networks and used the identified social overlapping cliques in different scenarios of business activities [32]. Das studied cybercriminal activities by constructing an overlapping community discovery algorithm to construct a criminal network for typing the interrelationships of different criminal members, which was used to predict criminal activities and take preventive measures [33].

Accordingly, a more indepth study is needed to further explore the kind of impact the HSR network will bring to the regional spatial order, considering this overlapping phenomenon, as well as determine how to identify and recognize these overlapping spaces. Since the overlapping community discovery algorithm can achieve overlapping community delineation while portraying the local clustering characteristics of the network [34], this study aims to introduce this algorithm into the study of traffic patterns of urban agglomerations, which is expected to provide a new perspective on the study and planning of urban travel traffic access patterns in the Yellow River Basin. The innovation of this study is that, compared with existing studies, this study uses the overlap model, which can identify the spatial overlap development in regional geospatial units and conduct a more scientific and quantitative identification. A possible contribution is the proposal of a new perspective for a closer understanding of the regional spatial pattern, along with suggestions and references for regional development. In view of this, this study takes seven urban agglomerations in the Yellow River Basin as the research objects, using the “2 h
access to urban agglomeration” and “3 h coverage of major cities in China” proposed in the “outline of building a strong transportation country” as the entry point, compares and analyzes the characteristics and differences of HSR access patterns of urban agglomeration in the Yellow River Basin, further divides the overlapping communities and identifies the overlapping spaces of cities in the Yellow River Basin using the cross-urban agglomeration linkage of central cities, and finally selects the overlapping city of Changzhi as the research case to carry out long-term spatial development strategic planning, in order to provide a reference for the overlapping development and transportation construction in the Yellow River Basin (Figure 1).

Figure 1. Research logic diagram.

2. Materials and Methods

2.1. Study Area

The Yellow River flows from west to east through seven urban agglomerations, namely, the Lanzhou–Xining Urban Agglomeration (LXUA), Ningxia Urban Agglomeration (NUA), Kuan-Chung Plain Urban Agglomeration (KCPUA), Hohhot–Baotou–Ordos–Yulin Urban Agglomeration (HBOYUA), Central Plains Urban Agglomeration (CPUA), Central Shanxi Urban Agglomeration (CSUA), and Shandong Peninsula Urban Agglomeration (SPUA), with reference to the planning texts of the Lanzhou–Xining Urban Agglomeration Development Plan, Kuan-Chung Plain Urban Agglomeration Development Plan, Hohhot–Baotou–Ordos–Yulin Urban Agglomeration Development Plan, Central Plains Urban Agglomeration Development Plan, and Shandong Peninsula Urban Agglomeration Development Plan (2021–2035), containing a total of 76 cities (Figure 2). LXUA is in
the upper reaches of the Yellow River and consists of Lanzhou and Xining as a regional twin center, radiating the development of both the Gansu and Qinghai regions. NUA, HBOYUA, and CSUA are in the upper reaches of the Yellow River “Jiziwan”, consisting of five provinces: Gansu, Ningxia, Inner Mongolia, Shaanxi, and Shanxi. KCPUA is led by Xi’an, the western growth pole, to drive the common development of 10 cities in Shaanxi, Shanxi, and Gansu Provinces. The CPUA is one of the cores of the regional development of the middle reaches of the Yellow River, located in an excellent location featuring a combination of coastal areas and central and western regions, forming a regional development pattern that includes 30 prefecture-level cities in Henan, Hebei, Shanxi, and Anhui Provinces. SPUA is the only urban agglomeration in the lower reaches of the Yellow River, located between the Beijing–Tianjin–Hebei Urban Agglomeration and Yangtze River Delta Urban Agglomeration, communicating the vast hinterland of the Yellow River Basin.

![Diagram of urban agglomerations](image)

**Figure 2.** Overview of the study area.

2.2. Data

The data of railroad passenger trips in 2021 were selected to express the railroad passenger travel time, and the data were obtained from the website of the 12306 Railway
Customer Service Center (https://www.12306.cn/index/; accessed on 15 April 2021). The collected data were summarized and categorized by train, station name, departure time, arrival time, and travel days to obtain the city-to-city running time of each train, as well as the O-D linkage matrix based on rail passenger trips (Table 1). Since this study only considers passenger trains that provide services within urban agglomerations, further screening was performed to identify trains that passed through ≥2 cities within the Yellow River Basin urban agglomeration. In this study, data processing and model construction were performed in the Python environment.

Table 1. Example of HSR trip data.

<table>
<thead>
<tr>
<th>Trains</th>
<th>Station Sequence</th>
<th>Name</th>
<th>Miles(km)</th>
<th>Arrival Time</th>
<th>Departure Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>G36</td>
<td>1</td>
<td>Zhuji</td>
<td>0</td>
<td>08:27</td>
<td>08:27</td>
</tr>
<tr>
<td>G36</td>
<td>2</td>
<td>Hangzhoudong</td>
<td>66</td>
<td>08:51</td>
<td>08:57</td>
</tr>
<tr>
<td>G36</td>
<td>3</td>
<td>Deqing</td>
<td>101</td>
<td>09:10</td>
<td>09:12</td>
</tr>
<tr>
<td>G36</td>
<td>4</td>
<td>Huzhou</td>
<td>137</td>
<td>09:25</td>
<td>09:30</td>
</tr>
<tr>
<td>G36</td>
<td>5</td>
<td>Jurongxi</td>
<td>296</td>
<td>10:09</td>
<td>10:11</td>
</tr>
<tr>
<td>G36</td>
<td>6</td>
<td>Nanjingnan</td>
<td>322</td>
<td>10:23</td>
<td>10:29</td>
</tr>
<tr>
<td>G36</td>
<td>7</td>
<td>Suzhou</td>
<td>585</td>
<td>11:31</td>
<td>11:33</td>
</tr>
<tr>
<td>G36</td>
<td>8</td>
<td>Xuzhou</td>
<td>653</td>
<td>11:52</td>
<td>11:54</td>
</tr>
<tr>
<td>G36</td>
<td>9</td>
<td>Tengzhou</td>
<td>754</td>
<td>12:20</td>
<td>12:25</td>
</tr>
<tr>
<td>G36</td>
<td>10</td>
<td>Jinanxi</td>
<td>939</td>
<td>13:10</td>
<td>13:13</td>
</tr>
<tr>
<td>G36</td>
<td>11</td>
<td>Dezhou</td>
<td>1031</td>
<td>13:37</td>
<td>13:40</td>
</tr>
<tr>
<td>G36</td>
<td>12</td>
<td>Beijing</td>
<td>1345</td>
<td>14:53</td>
<td>14:53</td>
</tr>
</tbody>
</table>

The data in the table were preliminarily compiled to include only HSR (G, C, D) opening data, with the data in 2021 shown as an example. Here, “1” in the station sequence indicates the starting station, and the maximum value of the station sequence indicates the terminal station.

2.3. Methods and Models

2.3.1. Gravity Model

The intensity of integrated economic linkages between regions characterizes the extent to which various flow elements move and exchange between regions [35]. In order to measure the intensity of economic linkages between cities in an urban agglomeration, the value of the intensity of economic linkages between two cities was portrayed by measuring the central mass and time distance between the two cities with the following equation:

\[ F_{ij} = \left( \sqrt{G_i \times P_i} \times \sqrt{G_j \times P_j} \right)^{1/2} / T_{ij}, \]  

where \( F_{ij} \) is the intensity of economic ties between two cities, \( G_j \) denotes the gross product of city \( j \), \( P_j \) denotes the population of city \( j \), and \( T_{ij} \) denotes the travel access time of the two cities.

2.3.2. Overlapping Community Discovery Model

The community discovery model captures the state of intercity functional linkages dependent on the flow of production factors to characterize agglomeration or diffusion capacity [36]. Compared with traditional research methods, community discovery models require fewer types of data, do not require large-scale surveys or human intervention, and are relatively objective and scientific. Existing community discovery models can be divided into two categories, nonoverlapping community discovery models and overlapping community discovery models. The nonoverlapping community discovery models were developed earlier [37], considering communities to be nonoverlapping with each other, whereby nodes belong to a community. Overlapping community models, on the other hand, represent an improvement and extension of the nonoverlapping community model, considering the transition between communities to be smooth, whereby nodes can belong to multiple communities.
The real-world overlapping structure is similar to the concept of statistical aggregates, where some characteristics of the aggregate can be generally inferred from the statistical information of the sample. The current evaluation of overlapping models can be broadly divided into two steps. First, the LFR benchmark network [38] is evaluated on the basis of the given parameters. The LFR benchmark is an algorithm for generating benchmark networks according to the given parameters. This algorithm can generate synthetic networks with controllable parameters, as well as obtain a priori known communities, considering metrics such as the node degree and heterogeneity of community size distribution. LFR is used to compare the performance of different community discovery algorithms. Then, the public dataset is then used to compare the analysis with related models. Xie [39] synthetically reviewed the SLPA model with 13 popular overlapping community discovery models (SLPA is a variant of the LPA label propagation algorithm that can detect one or more communities to which each node belongs), revealing that the SLPA model performed more similarly to the LFR benchmark network and had significant adaptability and robustness in public datasets. The SLPA model was also used in this study to partition the region space.

The computational logic of the SLPA model can be summarized as follows: first, several iterations were performed on the basis of city relations, and the list of city community labels was obtained after several iterations, according to the rule that the probability of selecting a city was proportional to the number of times that the city appeared in the list of city relations. Then, the maximum overlapping module degree was filtered by threshold \( r \) for community division [40]. The SLPA model uses a top-down operational model to divide and optimize the parameters on the basis of the global spatial division [41], while this study attempts to use the SLPA model for regional spatial division.

The SLPA model update rules are as follows:

\[
L(i) = \arg \max_{C_k} \{ S(C_k) \},
\]

where \( L \) denotes the label of a node or group, \( C_k \) is a subcommunity containing a set of nodes connected to node \( i \) and sharing the same label \( k \), and \( S \) is the score function of the subcommunity.

\[
S(C_k) = \sum_{j \in C_j} \{ 1 + C \cdot h_j(i) \},
\]

where \( h_j(i) \) is the number of links from node \( j \) to the entire neighborhood of node \( i \) (excluding node \( i \)), and \( C \) is a weight between 0 and 1. To evaluate the effect of community discovery results and to judge the applicability of the above model in different regions, this study introduces Nicosia [42] to propose an improved, overlapping modularity \( EQ \) suitable for overlapping communities based on the modularity proposed by Newman [43]. SLPA is a topology algorithm that does not consider spatial adjacency; this study refers to the research results of Hong [44] in using the strength of economic ties to carve intercity links. Considering the change in weights, the adjacency matrix was further modified to a weight accumulation matrix [45]. The overlapping module degree in the model takes values between \(-0.5\) to \(1.0\), with larger values indicating better community division. The overlapping modularity was calculated using the following formula:

\[
EQ = \frac{1}{2m} \sum_{u \in C_k, v \in C_i} \left( \frac{1}{Q_{uQ_v}} \left[ A_{uv} - \frac{k_u k_v}{2m} \right] \right),
\]

where \( EQ \) represents the module degree, \( 2m \) denotes the sum of edge weights, \( u \) and \( v \) denote the city nodes, \( Q \) denotes the association to which node \( u \) belongs, \( k_u \) denotes the degree of node \( u \), and \( A_{uv} \) denotes the modified adjacency matrix.
3. Results
3.1. HSR Access Pattern in the Yellow River Basin Urban Agglomeration

In the “outline of the construction of a strong transportation country”, it was proposed to build a convenient and smooth transportation network for urban agglomerations and to form a 2 h access transportation pattern for urban agglomerations. It was shown that the 2 h access range of urban agglomerations is the limit of travel time tolerated for commuting in general [46], and an efficient and fast transportation network can enhance regional connectivity and enable different cities to strengthen communication links, as well as interactions, generating network externalities and, thus, promoting the optimal development of urban agglomerations. Therefore, this study analyzed the overall pattern characteristics of the travel traffic circle of seven urban agglomerations in the Yellow River Basin through the travel access time of each city by HSR, and then comparatively evaluated each urban agglomeration according to the 2 h access standard of urban agglomerations in the “outline of the construction of a strong transportation country”.

3.1.1. The 2 h Access Pattern for Each Urban Agglomeration

According to the overall spatial characteristics, the low-value area of HSR travel time in the Yellow River Basin urban agglomeration was biased toward the center of the urban agglomeration, while the peripheral areas were relatively high-value area travel traffic circles. The HSR travel time showed a circular spatial pattern characteristic of continuous expansion from the center to the peripheral areas from low to high.

In terms of the spatial pattern (Figure 3), all four urban agglomerations in the upper reaches achieved a 2 h access pattern within the urban agglomerations, while the urban agglomerations in the middle and lower reaches reached the 2 h access level only in the central areas. LXUA consists of five cities, namely, Haibei, Xining, Haidong, Lanzhou, and Dingxi, forming a northwest–southeast strip-like 2 h travel corridor. Among them, Haidong benefits from the location advantage between Xining and Lanzhou, representing the only city in the urban agglomeration where the average travel time by HSR was less than 1 h. NUA, along the Yellow River, did not form a travel corridor, with Zhongwei, Wuzhong, and Yinchuan forming a “concentrated contiguous” distribution pattern. The CSUA 2 h travel traffic circle consisted of four cities, namely Taiyuan, Yangquan, Xinzhou, and Jinchong, with Taiyuan being the only city in the urban agglomeration with an access time of less than 1 h. Yangquan, Xinzhou, and Jinchong surrounded Taiyuan to the south, north, and east in the 2 h travel circle pattern. HBOYUA consisted of Hohhot and Baotou in the 2 h traffic circle. CPUA consisted of Qingyang, Xianyang, and Xi’an, with the cities forming an inverted T-shaped 2 h travel corridor. In the traffic circle beyond 2 h, Tianshui and Linfen were to the west and east of the inverted T-shaped corridor, respectively. CPUA consisted of 14 cities such as Zhengzhou, Kaifeng, and Luoyang within the 2 h traffic circle, which was generally concentrated in the central part of CPUA with a cluster-like distribution pattern. The remaining cities beyond 2 h were distributed around the urban agglomeration, forming a 2–3 h travel traffic circle. SPUA’s cities within the 2 h traffic circle were more concentrated in the western part of the urban agglomeration, consisting of Jinan, Tai’an, Zibo, and nine other cities, with an overall contiguous distribution pattern. The eastern part of the 2 h circle featured Qingdao, Yantai, and Rizhao with a sporadic distribution.
3.1.2. Two-Hour Access Pattern to the Central Cities of Each Urban Agglomeration

Central cities can lead the overall development of urban agglomerations and generate functional spillover effects, while acting as regional transportation hubs, which can promote integrated development with neighboring cities and realize the transformation from an “urban gateway” to an “urban living room”, whereby central cities and urban agglomerations become the main spatial forms for carrying development factors [32]. With reference to the development plan of each urban agglomeration and the provincial “14th Five-Year Plan”, the central cities of LXUA were Lanzhou and Xining, the central city of NUA was Yinchuan, the central city of CSUA was Taiyuan, the central city of HBOYUA was Hohhot, the central city of KCPUA was Xi’an, the central cities of CPUA were Zhengzhou and Luoyang, and the central cities of SPUA were Jinan and Qingdao. The spatial interpolation method was used to visualize the accessibility of the central cities of each urban agglomeration, analyze the spatial differences in the accessibility of the central cities through two-way comparisons within and between urban agglomeration, and evaluate the average travel access time by HSR from the central cities to other cities within the urban agglomeration.

The 2 h HSR travel coverage of the central cities of the seven urban agglomerations in the Yellow River Basin was compared (Figure 4). First, the coverage ratios of the central cities of NUA, HBOYUA, and CSUA were 100%, and these three urban agglomerations were located in the upper reaches of the Yellow River Basin, where the overall development...
of HSR was low, and fewer cities in the urban agglomeration were open to HSR. LXUA covered an area of 88%, reflecting a high level. The urban agglomeration in the middle and lower reaches of the Yellow River in CPUA and SPUA covered 80% and 67% of the area, respectively, reflecting significantly lower levels than other urban agglomerations. Second, comparing the extreme values of the coverage ratio of the central cities of each urban agglomeration, the highest values were recorded for Yinchuan, Ningxia, Hohhot, and Taiyuan, all with 100% coverage. The lowest values were recorded for Jinan and Qingdao in SPUA, both at 67%, with a 33% difference in the extreme values.

Comparing the 2 h HSR travel coverage of central cities in each urban agglomeration (Figure 5), when the central city was closer to the geometric center of the urban agglomeration, the HSR travel time for the central city to reach other points in the urban agglomeration was generally lower, and it was easier to expand the scope of its travel traffic circle. Central cities of SCUA and CPUA, Taiyuan and Xi’an, were located in the center of the urban agglomeration, and their location largely affected the size of their 2 h HSR travel traffic circle, with the two central cities covering a higher proportion of the 2 h HSR travel traffic circle, demonstrating stronger accessibility. There was a large difference in the value of the coverage ratio of the 2 h HSR travel circle between the central cities of LXUA, with Lanzhou covering 75% and Xining covering 100%, a 1.3-fold difference. The proportion of the area covered by the 2 h HSR travel traffic circle in CPUA, that of Zhengzhou (96%), was 1.5-fold larger than that of Luoyang (65%), and revealed the most extreme difference. The area covered by the 2 h HSR travel traffic circle of Jinan and Qingdao, the central cities of SPUA, was the same, indicating that the two central cities were balanced in terms of the proximity of HSR connections and the effect of radiation diffusion on other node cities in the region. It should be noted that the spatial interpolation is not visualized for NUA and HBOYUA in Figure 4, since the spatial interpolation effect was not significant due to the low development of HSR within these two urban agglomerations and the few cities reached by HSR.

Figure 4. The proportion of 2 h traffic circle coverage in central cities.
3.2. Spatial Overlap Analysis of Cross-Urban Agglomerations in the Yellow River Basin

The concept of 3 h access was derived from the Japanese definition of the “1 day communication circle” [47]. As the greatest advantage of a one day round trip is the time and cost savings by avoiding accommodation in a different location [48], the closeness of the connection between cities in a region depends to a large extent on the availability of a one day round trip between these two cities. Therefore, this study analyzes the spatial connection between central cities and the other cities by drawing on the 3 h intercity HSR travel access criteria.

3.2.1. Center City Spatial Connection

The intensity of interregional economic linkages can characterize the degree of exchange of various flow elements to and from regions depending on transportation facilities [35]. The average economic linkage intensity of central cities was divided into five levels using the natural break method (Figure 6), with the first level representing the highest economic linkage intensity and the fifth level representing the lowest economic
The intensity of interregional economic linkages can characterize the degree of exchange of various flow elements to and from regions depending on transportation facilities [35]. The average economic linkage intensity of central cities was divided into five levels using the natural break method (Figure 6), with the first level representing the highest economic linkage intensity and the fifth level representing the lowest economic linkage intensity. Specifically, the city pair (Zhengzhou–Xinxiang) with the highest economic linkage intensity of the 3 h HSR travel center cities was in CPUA, and its economic linkage intensity also ranked first among all city pairs. Within the urban agglomeration, Zhengzhou and Luoyang were characterized by a two-way linkage axis, and both cities radiated westward to Xi’an and Weinan in the Guanzhong Plain urban agglomeration and Jincheng in the central Shanxi urban agglomeration, forming a cross-regional pattern of high economic linkage intensity. The CPUA initially formed a pattern of close linkages with Xi’an as the absolute core. Xi’an–Xianyang and Xi’an–Weinan were in the first level of linkage intensity, forming high-intensity linkage bridges within the urban agglomeration. Externally, the second level of cross-regional city pairs, Xi’an–Luoyang, supported the interconnection from KCPUA to CPUA. Lanzhou–Haibei within LXUA was the city pair with the lowest intensity of economic level among all city pairs, with a 44-fold difference between the highest and lowest values. HBOYUA, NUA, and CSUA had a low degree of urban development, with a lack of core skeleton channels within the urban agglomeration and cross-regional linkage city pairs, and the urban agglomeration was loosely connected. The cities of Jinan–Tezhou and Qingdao–Yantai in the SPUA belonged to the first level, and the two central cities were connected to the secondary cities to form city pairs with the highest economic linkage intensity within the urban agglomeration, which were relatively tightly connected within the urban agglomeration but loosely connected externally and did not form cross-regional linkage channels.

Figure 6. The 3 h HSR travel space links among the central cities and other cities.

3.2.2. Regional Spatial Overlap Analysis

On the basis of the economic connections between the central city and other cities, the SLPA model was used to divide the Yellow River Basin into six communities with “strong internal connections and few interconnections” using the 3 h travel time from each city to the central city as a filtering condition. Overall, the scope of this study was generally larger than that of the urban agglomeration, which reflects the new spatial pattern of the Yellow River region from the perspective of HSR travel to a certain extent.
From the perspective of spatial division (Figure 7), under the interaction of the urban agglomeration economy and the provincial economy, the regional space was split or merged into several clusters, and was reflected in each community, forming a community pattern with the central city within the urban agglomeration as the core, along with some cities closely connected around the central city. Specifically, Community III consisted mainly of the central urban agglomeration of Shanxi, involving both the KCPUA Linfen and the CPUA Xingtai, Handan, and Changzhi, consisting of eight cities. The spatial range encompassed Xinzhou in Shanxi to the north, Linfen in Shanxi to the west, and Xingtai in Hebei to the east, with an inverted T-shaped distribution pattern. The central cities of Taiyuan and Jinzhong had the highest intensity of economic level within the community. However, Taiyuan was relatively poorly connected to other cities, reflecting its weak radiation-driven capability. Community IV involved LXUA, KCPUA, and some cities within CPUA, consisting of 15 cities. The spatial pattern extended from Haibei Tibetan Autonomous Prefecture in the western corridor to the central region to Sanmenxia in Henan Province, with communities spanning 11 cities, highlighting an east–west strip-like distribution and a more continuous overall system. Community V, with CPUA as the main body, absorbed KCPUA Yuncheng. In terms of spatial scope, it encompassed Xingtai in Hebei to the north, Xinyang in Henan to the south, Suizhou in Anhui to the east, and Yuncheng in Shanxi to the west, involving some cities in CPUA and KCPUA, and consisting of 25 cities overall, with a concentrated and continuous community space and a significant regional integration posture. Community VI was mainly composed of 11 cities in SPUA, with a relatively concentrated community space, and two central cities, Jinan and Qingdao, leading the spatial development pattern within the community, with a significant regional dual-core development trend. Community I and Community II were mainly composed of some cities in HBOYUA and NUA, with a lower degree of development within the communities and weaker interaction with other communities, thus forming two relatively independent communities.

The SLPA model was used to further identify the overlapping spaces (Figure 7), and three communities were identified in the Yellow River Basin that generate overlapping spaces. Community III and Community IV generated overlapping spaces in Linfen, Community III and Community V generated overlapping spaces in Changzhi, Handan, and Xingtai, and Community IV and Community V generated overlapping spaces in Yuncheng and Sanmenxia.

Linfen, as the overlapping space, was the core of the north–south basin-type corridor running through Shanxi. With the special topographic conditions of the Taiyue Mountains in the east and the Luliang Mountains in the west, located in the hinterland of the river valley, Linfen has been an essential place for exchanges between the Qin and Jin regions since ancient times. With modern socioeconomic development, Linfen, as a key area of communication between Guanzhong and Jinzhong regions by virtue of its superior geographical location, played a role in supporting the connection between Community III and Community IV and in realizing intercommunity communication and interaction by relying on the Daxi HSR corridor.

Changzhi, as another overlapping space, is a provincial subcentral city and a central city in southeast Jinjiang. Similar to Linfen in terms of topography, Changzhi is located in the river valley plain between the Taiyue Mountains and the Taihang Mountains, and is the core hub city of Shanxi region connecting to Henan region. Relying on its natural location, through the Zheng–Tai HSR, Changzhi assumed the function of a bridge between Shanxi and Henan, while acting as the communication fulcrum between Community III and Community V. The overlapping city of Handan is not only the central city in the south of Hebei province, it is also a national comprehensive transportation hub, which, together with the neighboring city of Xingtai, under the influence of the strong economic radiation of the Bohai Sea Rim, dovetails with the Beijing–Tianjin region to the north, integrates into the Central Plains Economic Circle to the south, and dovetails with the Jinzhong region to the west. Thus, it assumes the role of a spatial connection and interaction between different regions, promotes the division of functions of the town system in the regional system,
and assumes the role of bridge between Community III and other parts of Community V, relying on the Beijing–Guangzhou development spine.

Figure 7. Spatial division of urban overlap in the Yellow River Basin.

The overlapping space of Sanmenxia was located in central CSUA, KCPUA, and the peripheral area of CPUA, while also establishing a spatial connection between the eastern
coast of China and the inland central and western regions. Furthermore, it was the gateway to the inland of the Guanzhong region, as well as the hub of the east–west Longhai Passage.

3.2.3. Case Study of Strategic Planning for the Development of the Overlapping Space Changzhi Visionary Space

Changzhi is on the periphery of CSUA, KCPUA, and CPUA. In terms of spatial characteristics, Changzhi is characterized by a small city scale and low central agglomeration. It is located on the periphery of the urban agglomeration and far from the core area. In the context of the traditional development model, Changzhi has limited total resources that can be deployed in the fierce regional competition, and it risks being further siphoned off and weakened, making it a typical study case. Compared with other overlapping cities, Changzhi has special characteristics in terms of geographical location and future development trend. In terms of its geographical location, Changzhi is to the southeast of Jin, relying on the Zheng–Tai HSR to connect CSUA and CPUA. In the future, it can be integrated into KCPUA to the west and docked to the Beijing, Tianjin, and Hebei synergistic development to the east, highlighting the importance of its geographical location. From the point of view of future development trend, there is an opportunity to construct a factor gathering place and realize a channel city with smooth internal access and close outreach.

For the transformation of pass-through nodes to hub-type nodes, the regional transportation development pattern was an important foundation and core element for Changzhi to participate in the regional division of functions. Therefore, Changzhi tried to link the regional corridor, where its own value can be identified in the strategic corridor, and it can participate in the division of functions of the core cities of the corridor, enhance its indispensability, and strengthen the competitiveness of the city. If Changzhi can be connected to Xi’an via the Datong–Xi’an HSR to the west, it can be integrated into the Taiyuan–Xi’an–Zhengzhou triangle, thus leading to a greater development potential for Changzhi in terms of regional functions. Changzhi can be transformed from a passing node on the Zheng–Tai HSR to a regional transportation hub node at the T intersection of the Zheng–Tai HSR and the Datong–Xi’an HSR. In addition, a functional identification of the strategic corridors in which Changzhi was located revealed that the Longhai Railway corridor adjacent to Changzhi carries important equipment manufacturing transport functions in China, while the north–south corridor of the Taijiao Railway and the Waji Railway are important corridors for the southward transportation of coal from the north of China. The intersection of these two lines allows Changzhi to assume some specialized functions in China’s logistic network, as well as in the wider urban network, making Changzhi a hub city in the Jin–Shaan–Yu region (Figure 8).

To strengthen the gateway and expand the hinterland, Changzhi’s close contact with cities along the Zheng–Tai HSR line in the cross-regional latitude should be considered, especially Taiyuan, Jinhzhong, Jiaozuo, and Zhengzhou (Table 2). On the one hand, relying on coal transportation channels such as the Taijiao Railway and the Waji Railway, energy logistics can be developed, a vertical division of labor chain can be formed with manufacturing bases in CPUA, and the status of the Central Plains hinterland can be strengthened as a secondary node for goods circulation. At the same time, Changzhi should take the initiative to strengthen co-construction and co-connection relationships with the surrounding areas, realize the sharing of infrastructure, and strengthen the regional gateway status of Changzhi. On the other hand, Changzhi should strengthen its industrial ties with Xi’an, Zhengzhou, Taiyuan, Luoyang, and other cities with comprehensive strength in the region, highlighting its characteristics while focusing on achieving industrial transformation. This can improve the overall competitiveness of the region with the help of innovative development to improve the overall competitiveness of the region, and play the role of a gradient transit station, prompting the four cities of Changzhi, Jinhzhong, Luoyang, and Jiaozuo to form new alliances and new synergies to expand their own hinterlands.
the regional corridor, where its own value can be identified in the strategic corridor, and it can participate in the division of functions of the core cities of the corridor, enhance its indispensability, and strengthen the competitiveness of the city. If Changzhi can be connected to Xi’an via the Datong–Xi’an HSR to the west, it can be integrated into the Taiyuan–Xi’an–Zhengzhou triangle, thus leading to a greater development potential for Changzhi in terms of regional functions. Changzhi can be transformed from a passing node on the Zheng–Tai HSR to a regional transportation hub node at the T intersection of the Zheng–Tai HSR and the Datong–Xi’an HSR. In addition, a functional identification of the strategic corridors in which Changzhi was located revealed that the Longhai Railway corridor adjacent to Changzhi carries important equipment manufacturing transport functions in China, while the north–south corridor of the Taijiao Railway and the Waji Railway are important corridors for the southward transportation of coal from the north of China. The intersection of these two lines allows Changzhi to assume some specialized functions in China’s logistic network, as well as in the wider urban network, making Changzhi a hub city in the Jin–Shaan–Yu region (Figure 8).

Figure 8. Strategic planning for Changzhi visionary space development.

Table 2. Cooperation directions of Changzhi.

<table>
<thead>
<tr>
<th>Central City</th>
<th>Cooperation Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Taiyuan</td>
<td>Strengthen cooperation and exchange with Taiyuan equipment manufacturing industries and promote the level of intelligent equipment manufacturing industry.</td>
</tr>
<tr>
<td></td>
<td>Strengthen the docking with the Zhengzhou International Port and the Zheng–European Train, build an important sub-pivot of Zhengzhou International Logistics Port, and radiate the Shanxi and Shaanxi areas.</td>
</tr>
<tr>
<td>With Zhengzhou</td>
<td>Strengthen the docking with Xi’an, focusing on attracting innovative resources such as technology, talent, capital, and enterprises from Xi’an to provide support for industrial structure adjustment and scientific and technological innovation.</td>
</tr>
</tbody>
</table>

4. Discussion

As an important geospatial unit in China, the Yellow River Basin is in a constant process of spatial structure renewal and adjustment. Along with the vigorous promotion of the construction of a strong transportation country and the rapid development of the HSR network, the impact of HSR travel access time on the regional urban system is immeasurable.
4.1. Urban Agglomeration HSR Access Pattern

As an important metric indicating inter-regional interactions, spatial accessibility has become an expression to portray cities and regional systems performing agglomeration and diffusion functions. As an important factor influencing economic development and regional development dynamics, HSR transportation is becoming increasingly significant to regional spatial patterns. In the analysis of the HSR access pattern of urban agglomeration, it was concluded that the four upstream urban agglomerations achieved the 2 h access pattern within the urban agglomeration, whereas the three urban agglomerations in the middle and lower areas reached the 2 h access level only in the central area. Contrary to the traditional impression, the upstream region, as a northwest inland region, had a lower level of HSR access than the two downstream urban agglomerations. The reason for this may lie in the sparser distribution of cities in the upstream region, where there are fewer HSR stops, instead facilitating efficient access between cities. Some studies have shown that HSR has the highest market share in the range of 200–500 km compared with other transportation modes [49], which also indicates that a certain spatial distance is more suitable for the spatial expression of HSR between regions.

4.2. Spatial Overlap across Urban Agglomeration

With the superimposed intercity economic and spatial connection via 3 h of HSR access, the pattern of different scales of urban and regional systems such as communities and urban agglomeration was highlighted, and the multiscale urban functional territorial system gradually emerged. Starting from spatial correlation and taking the regional central city as the anchor, this study identified six communities. These six communities exhibited a relatively continuous and compact spatial association pattern, with a continuous reach within communities and, to a large extent, an obvious trend of spatial integration and a significant pattern of regional integration and development.

4.3. Overlapping Space Recognition

The SLPA model was used to further identify the overlapping spaces, and it was found that there were three communities in the Yellow River Basin that generated overlapping spaces, containing five cities. As overlapping spaces generated by spatial overlap across urban agglomeration, these cities had some commonalities in terms of spatial morphology, regional location, and factor flow. In terms of population and economy, overlapping cities were generally small in scale and volume due to the constraints of the natural topography and hinterland. In terms of spatial organization characteristics, overlapping cities generally had low central concentration. In terms of spatial location, overlapping cities were generally at the periphery of the urban agglomeration and far from the core. Under the traditional development model, the overlapping space has limited resources to be deployed in a regional competition, and there is a risk of further siphoning and weakening. Along with the globalization of economic activities and the advent of the HSR era, urban systems tend to flatten and expand their network, prompting the regional development from a “core–edge” model to a regional integration model. As a medium to connect cities for exchange and interaction, HSR transportation catalyzes and accelerates the attraction of big cities to small cities, prompting a gradual increase in communication and exchange between different regions and urban agglomerations. The study of overlapping cities can clarify the division of labor and cooperation with core cities, actively locate their specialized functions, and create opportunities for urban development transformation.

4.4. Policy Suggestions

On the basis of the characteristics of travel access patterns, spatial overlapping divergence, and overlapping spatial characteristics of the urban agglomerations in the Yellow River Basin, this study proposes the following policy recommendations:

One: on the one hand, HSR mainline expansion and renovation projects, for Jiyuan, Dongying, Heze, and other cities not connected to HSR, should be implemented with new
local branch lines and liaison lines, thereby smoothing the “neck” section, and improving the HSR network. On the other hand, the comprehensive transport network can be improved around the main channel, close to Lanzhou, Yinchuan, Hohhot, Taiyuan, and other regional development poles and the Longhai main channel link, thus strengthening the main channel and comprehensive transport channel connection, while giving full play to the endowment and characteristics of important node cities and transport hubs and optimizing the organization of HSR.

Two: for the better development of the city and the region, measures can be taken for optimization and adjustment. For the characteristics of community division, on the one hand, the construction of HSR can be promoted in blank areas within the community to break the traffic bottleneck in less developed areas. On the other hand, the HSR axes of Community I, Community II, and Community III can be constructed, so as to realize a railroad network layout structure with an internal network, internal and external smoothness, and point-line coordination. To take advantage of any overlapping space, regional railroad connection lines can be expanded to establish intercity railroad backbone channels for overlapping cities such as Changzhi. Furthermore, an intercity railroad network can be established for other areas with overlapping space to further improve the HSR network and expand the coverage.

Three: a governmental dialogue mechanism can be built to serve the integrated development of cross-urban agglomerations. The dialogue and cooperation between cities in the upper Yellow River Basin and cities in the lower river basin can be strengthened, by holding regular joint meetings, and a “cross-urban agglomeration” cooperation and coordination mechanism can be established. The in-depth cooperation among cities can be strengthened in terms of the industrial division of labor, infrastructure interconnection, public service docking, and sharing, ecological environment joint prevention and control, etc., so as to promote the deep integrated development of overlapping Communities III, IV, and V.

4.5. Limitations and Prospects

Due to the limitations of data sources and their access, the actual frequency spillover effect caused by the “stopover phenomenon” in HSR passenger transportation was ignored to a certain extent; moreover, this study failed to obtain HSR flow data at a finer scale to examine the regional structure at different scales (e.g., county-level units) and the urban correlation patterns between scales. Currently, the multiscale interaction perspective enables the traditional spatial fundamental theory to be continuously deepened, bringing new perspectives and theoretical perceptions to the spatial relationships at different scales, which can be combined with the evolutionary perspective as the next breakthrough direction in the future.

5. Conclusions

This study took seven urban agglomerations in the Yellow River Basin as the research object, using the 2 h HSR access time in the Yellow River Basin to comparatively analyze the differences in HSR access in the urban agglomeration in the Yellow River Basin, and using the 3 h HSR access to the central cities as the background to conduct regional division and overlapping space identification through cross-regional economic links, before finally selecting the overlapping city of Changzhi for long-term space development strategic planning. The main conclusions are as follows:

One: the low-value area of HSR travel time in the Yellow River Basin urban agglomerations was biased toward the center of the urban agglomerations, while the peripheral areas were relatively high-value travel traffic circles. The HSR travel time showed a circular spatial pattern characteristic of continuous expansion from the center to the peripheral areas. Four urban agglomerations in the upper reaches of the city achieved a 2 h access pattern within the urban agglomeration, whereas three urban agglomerations in the middle and lower reaches of the city only reached the 2 h access level in the center.
Two: the SLPA model was used to divide the Yellow River Basin into six community spaces, three of which produced overlapping spaces, i.e., Community III and Community IV produced overlapping spaces in Linfen, Community III and Community V produced overlapping spaces in the cities of Changzhi, Handan, and Xingtai, and Community IV and Community V produced overlapping spaces in Yuncheng and Sanmenxia.

Three: the overlapping space of Changzhi City was selected as a case study for a visionary strategic planning outlook. Combining the geographical location characteristics and future development opportunities of Changzhi, we can try to transform a pass-through node like Changzhi into a hub node in the future, strengthen the gateway status, and expand the hinterland.

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