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Characteristics of the evolution of the industrial structure of the high-speed railway station area under the influence of location factors

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Abstract: *At present, the large-scale construction of the high-speed railway is in the stage of accelerated urbanization, and the industrial space of the high-speed railway station area has also emerged with many problems in its development. This paper takes the current characteristics of China's high-speed railway construction and the problems faced by the current industrial space in station areas as a starting point. Six urban central and fringe station areas are selected as research cases to explore the characteristics of location factors on the industrial structure and spatial aggregation of high-speed railway station areas. The study finds that the early service system of urban central stations is more complete than that of urban fringe stations, and the industrial structure of fringe stations changes more obviously and is more influenced by the economic impact of high-speed rail passenger flow; the increase in the number of enterprises in urban central stations and fringe station areas is spatially directional, while the overall clustering pattern shows an opposite trend.*

Keywords: *location; high-speed railway station area; industrial space; evolutionary characteristics; evolutionary mechanism; comparative analysis*

1. Introduction

Since the implementation of the Medium and Long Term Railway Network Plan approved by the State Council in 2004, China's railways have achieved rapid development. Due to its powerful rapid transport effect, the high-speed railway has gradually become an important lever to pull the economic development of urban areas. The demand for agglomeration development in new urbanisation development has gradually transformed HSR stations from urban transportation nodes into functional nodes, growing into areas where economic activities are concentrated. However, on the whole, the development and construction of high-speed railway station areas in China are still in its initial stage, and some of the high-speed railway station areas still have problems such as excessive construction scale and unreasonable functional positioning, which have negative effects on the development of a social economy. To promote the reasonable development and construction of the areas around high-speed railway stations, in 2018, the National Development and Reform Commission, together with the Ministry of Natural Resources and the Ministry of Housing and Construction, issued the "Guidance on Promoting the Reasonable Development and Construction of the Areas Around High-speed Railway Stations", emphasising that the development and construction of high-speed railway station areas should be, in a measured manner, gradual and orderly, while giving full play to the radiation-driven role of high-speed railway stations to promote the integration of industries and cities, and livability and industry. Therefore, optimising the industrial structure of the high-speed railway station area and promoting the integrated development of the station and city will become the key direction for the study of the high-speed railway station area.

In the field of research related to the industrial space of high-speed railway stations, domestic and foreign scholars mainly focus on two aspects of the industrial space of high-speed railway station areas and its influencing factors. Research on the industrial space of high-speed railway stations includes the characteristics of economic agglomeration in high-speed railway station areas, the spatial sphere of influence of industries, industrial structure, development patterns and the evolutionary characteristics of certain types of industrial space. For example, Zhou Wenzhu[1] takes Shanghai-Nanjing moving train passengers as an example and studies the circle scale of station space, the spatial distribution characteristics of industries and their associated land-use layout by analysing the travel distance

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characteristics of passengers. Wang Li[2] et al. take the travel distance characteristics of passengers of Nanjing Station of Shanghai-Nanjing City Railway as an example and use spatial analysis methods to explore the distribution and spatial clustering characteristics of industries in the high-speed railway station area.

In terms of the influence of high-speed rail on the industrial space of station areas, scholars at home and abroad have mostly conducted research in terms of passenger flow, the scale of high-speed rail, spatial accessibility and the functional positioning of high-speed rail stations. For example, Ma Xiaoyi and Huang Jialing[3] et al. use information on the number of passengers sent by high-speed railways and passenger demand, combined with several cases such as Guangzhou Railway Station, to explore the driving mode of high-speed railways in regional industries and propose countermeasures for industrial planning in the areas around high-speed rail stations. Wang Li, Liu Kewen and Cao Youxiang[4] review the economic spatial structure and effects of high-speed railway station areas from the perspectives of economic geography and urban planning, including the attributes and circle space, population clustering, industrial layout and land use, and conduct a comparative study on the development patterns of different types of station areas under the hierarchical classification system of high-speed railway stations, and propose the assessment of the effects and optimization paths of the spatial pattern of high-speed railway station areas.

According to the findings of domestic and international scholars on the influencing factors, the location of high-speed railway stations is an important factor influencing the industrial space of station areas. Due to the different demand and supply characteristics of HSR stations in different parts of the city, the station area space shows different development characteristics, which in turn leads to its different roles. At the same time, station location as an important influencing factor will have an impact on other factors, indirectly affecting the industrial space of the high-speed railway station area[5]. Wang Lan, Wang Can, Chen Chen and Gu Hao[6] take stations and their surrounding areas in 22 cities along the Beijing-Shanghai high-speed rail line as a sample to explore the mechanism of the impact of high-speed rail station settings on the development of the surrounding areas. Sun Fang, Wang Ying and Zhang Wenxin[7] explored the impact of the location, grade and development scope of HSR stations on urban industrial development and the types of industries significantly affected, using a feature selection model for 13 prefecture-level cities along the Beijing-Shanghai HSR.

Existing studies cover multiple spatial levels from macro scope to micro scope but mostly focus on exploring the current industrial structure of high-speed railway stations or the analysis of the evolution of certain types of industries, and most of the studies focus on the Wu-Guang and Beijing-Shanghai lines, without taking into account the fact that different locational characteristics can have an essential impact on the industrial structure and clustering fireworks characteristics of high-speed railway station areas. Therefore, this paper builds on the existing research and uses several typical examples to explore the industrial structure and clustering fireworks characteristics of high-speed railway station areas under the locational factors.

2. Research data and research methods

2.1 Study population and data sources

2.1.1 Object of study

This paper takes the location conditions of high-speed railway stations themselves, their spatial extent in cities and the construction characteristics of high-speed railway stations as the selection conditions[8], and finally, some high-speed railway stations in four cities, namely Shanghai, Guangzhou, Jinan and Harbin, are used as the research objects of this paper. The research subjects are all central and edge stations in mega megacities in China. Because of the mature spatial development and obvious structure of mega and megacities, the influence of location factors on the station area of HSR stations is significant. At the same time, these types of HSR stations have been built for a long time and the data are perfect, so it is convenient to study the characteristics of the agglomeration and evolution of location factors on the industrial structure of the station area of HSR stations[9].

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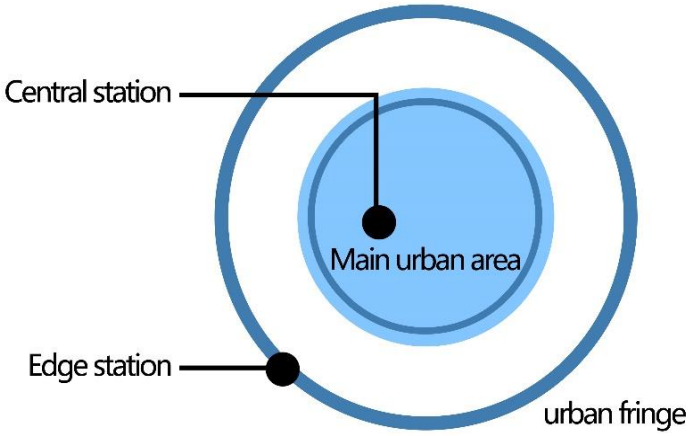

Figure 1: Urban space corresponding to the initial zones of the central and peripheral stations (Source: Author's drawing)

In this paper, based on the existing pedestrian network of the high-speed railway station area, the network analysis tool in GIS is used to obtain the actual reachable area of 800m and 1500m as the spatial core and expansion areas of the existing high-speed railway station area, taking the entrance and exit of the station as the starting point. [10]

Table 1: Summary of typical target high-speed rail stations

City	High-Speed Rail Station	Location	High-speed opening time	Alteration or new construction	Station class	Number of stations
Shanghai	Shanghai Station	Central Station	April 2007	Alterations	Premium Station	7 units 15 lines
	Shanghai Hongqiao Station	Edge stations	July 2010	New Construction	Premium Station	16 units 30 lines
Guangzhou	Guangzhou East Station	Central Station	August 1998	Alterations	Premium Station	7 units 14 lines
	Guangzhou South Railway Station	Edge stations	January 2010	New Construction	Premium Station	15 units 28 lines
Jinan	Jinan Station	Central Station	July 2008	Alterations	Premium Station	7 units 10 lines
	Jinan West Station	Edge stations	June 2011	New Construction	Premium Station	8 units 17 lines
Harbin	Harbin Station	Central Station	June 2003	Conversions	Premium Station	8 units 14 lines
	Harbin West Station	Edge stations	December 2012	New Construction	Premium Station	10 units 22 lines

2.1.2 Data sources

In this paper, we used the SkyEye app as the base data source, downloaded the data of enterprises within a 2.5km diameter of the selected high-speed railway station, used Excel to clean and reject the data, and transformed the original data into the final experimental data through the Baidu Map Open Platform.

In terms of the types of industries in the HSS, this paper divides the service industry into four categories based on the four divisions of the Western service industry and China's national economic industry classification, which are the production service industry, distribution service industry, consumer service industry and social system service industry, in that order. Based on the primary classification, a subdivision is carried out according to the National Economic Classification of Industries (GB/T4754-2017), the Statistical Classification of Living Services (2019) and the Classification of Productive Services (2019), to explore the differences and connections between the spatial agglomeration patterns of different nature of service industries in the high-speed railway station area, and finally determine the specific industrial space research types in the following table.

ISSN 2663-1563 Vol. 4, Issue 2: 60-67, DOI: 10.25236/AJAGE.2022.040210

Table 2: Spatial typology of industries in the HSR station area

Level 1 Classification	Secondary Classification	Three levels of classification
Productive Services	Financial Services	Monetary and financial services, capital market services, insurance, and other financial services
	Real Estate	Real estate development and management, property management, real estate agency
	Information transmission, software and information technology services	Telecommunications, radio, television and satellite transmission services, software and information technology services
	Scientific research and technical services	Research and experimental development, professional and technical services, science and technology promotion and application services
	Leasing Industry	Rental of machinery and equipment, sports and cultural equipment and supplies
	Business Services	Organization and management services, general management services, security and protection services, conferences, exhibitions and related related services, other business services, travel intermediary agency services, travel agencies, etc., consulting and Research, advertising, legal services
Circulation services	Transport, storage and postal services	Rail transport, road transport, water transport, air transport, pipeline transport, stevedoring and warehousing, multimodal transport and transport agency, postal services
	Wholesale and retail trade	All types of wholesale trade, all types of retail trade
Consumer Service	Accommodation	Tourist hotels, general hotels, B&B services
	Catering	Full meal service, fast food service, beverage and cold drink service
	Residential services, repairs and other services	Residential services, repair of motor vehicles, electronic goods and daily necessities, other residential services
	Culture, sport and entertainment	Arts and Culture, Sports Services, Radio, Film and Television Services, Sound and Video Production
Social services	Hygiene	Hospitals, primary health care services, specialist public health services, and other health activities
	Education	Pre-school etc., primary education, higher education, special education, skills training, educational support and other education
	Water, Environment and Utilities Management	Ecological protection and environmental management, public facilities management, land management
	Social Work	Welfare and relief activities that provide temporary and permanent accommodation, care and assistance activities that provide non-residential accommodation, and other social work activities such as charity and fundraising

2.2 Research Methodology

2.2.1 Mesh density analysis method

The grid density analysis method is used in ArcGIS to count the number of enterprises within a 2.5km radius of the station to visually reflect the degree of aggregation and separation of enterprises at the HSR station at different times. The darker the colour of the grid, the more enterprises are clustered, while areas with no enterprises have no colour.

2.2.2 Kernel density estimation method

The kernel density estimation method provides a visual representation of the number and pattern of business distribution. During the mapping process, a circular area of a 2.5km radius is searched with the HRL site as the centre, corresponding to the density values calculated per unit grid, and the weight

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assigned decreases as the distance from the centre increases. The expressions are.

$$\hat{\lambda}_h(p) = \sum_{i=1}^{n} \frac{1}{h^2} k[\frac{p - p_i}{h}] \quad (1)$$

Where: p is the location of the point to be estimated. λh (p) table the density value of point p; k denotes the weight function; p-pi denotes the distance between the point p and pi where the density valuation is required; h is the search radius, also known as the bandwidth, whose size affects the smoothness of the distribution density estimation, so the value for h is usually elastic. This section requires the use of ArcGIS 10.2 software to analyse the spatial distribution characteristics of different lost enterprise data.

3. Analysis of results

3.1 Characteristics of the evolution of the industrial structure

A comparative summary of the evolutionary characteristics of the industrial structure of the urban centre and urban fringe station areas can be found by analysing the changes in industrial increments and historical industrial structure changes in the HSR station areas from the first year of HSR opening to the end of 2021.

In the early years of the HSR, the service sector in the city's central station area was more developed than in the city's peripheral stations. In terms of the change in the number of enterprises, the number of enterprises in the four categories of primary service industries in the central station area far exceeded the number of enterprises in the peripheral stations. In terms of the change in industry structure, the difference in the ratio between the number of enterprises in the central station area and the peripheral station area is mostly smaller than that in the peripheral station area. The main reason for this is the difference in the regional environment in which they are developed and built. The central stations are mostly transformed from old stations in the former urban centres, relying on the good facilities and industrial layout system of the former cities. On the other hand, most of the urban fringe stations are located in the fringe areas of the city, where the facility system is not yet perfect, the development and construction time is short, and the industrial layout system has not yet been formed. In addition, the gathering of population and business, and the convenient transportation environment are all key factors that promote the gathering of distribution services in the high-speed railway station area.

After the opening of the HSR, the change in industrial structure is more pronounced in the urban fringe stations than in the city centre stations. In terms of business growth, the industrial structure in the city centre stations does not change significantly in 2021 compared to the initial period. For example, the consumer service sector in the Harbin West Station area exceeds the value added by the distribution service sector in 2019. A detailed analysis of the changes in the industrial structure shows that most of the city centre stations maintain their distribution services-based industrial structure, while the Guangzhou South and Harbin West stations, among the peripheral stations, have changed from distribution services-dominated to balanced service stations. The main reason for this is that the industrial space of the city centre stations was formed under the leadership of the market, and the construction of the railway has led to the formation of commercial areas of a certain scale around the stations, with a high degree of population and commercial gathering and convenient transportation; while the edge stations are mostly under the leadership of the government, focusing on the development of knowledge-intensive industries such as scientific research and technology and financial industries in the production service industry, with a slow rate of population and commercial gathering and The connectivity in the national railway network is not advantageous.

During the gradual construction and development of the HSR stations, the impact of the HSR passenger flow economy on the urban fringe stations is greater than that of the urban centre station areas. In terms of enterprise increment, the value added of enterprises at urban fringe stations was originally higher than that of urban centre stations. This is mainly because urban fringe stations have undergone large-scale development and construction after the opening of the HSR, while urban centre stations are mostly for spatial replacement and renewal, with a slow rate of enterprise increase; on the other hand, HSR stations bring a large number of specific passenger flows, such as business people and tourist crowds, which will attract specific businesses to gather, but the central station has perfect transportation facilities, and the surrounding areas with high accessibility and excellent comprehensive quality will have a There is also a strong diversion effect, and the space available in the city centre stations is also more scarce, while the edge of the city stations attracts industries to gather in the station area due to more

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unused space and low accessibility to meet the needs of specific high-speed rail crowds, which are also more influenced by the economy of high-speed rail passenger flows.

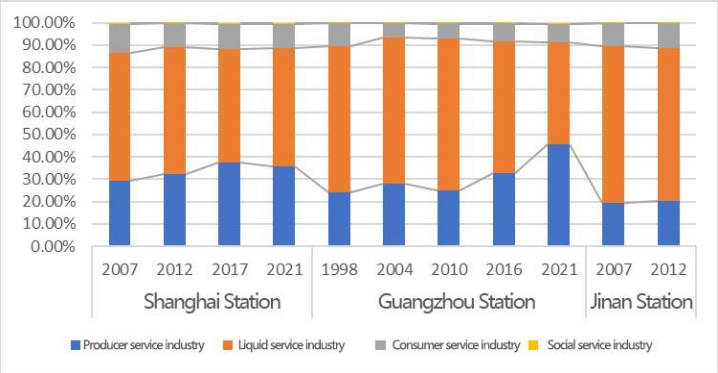

Figure 2: Evolution of the industrial structure of the city centre station (Source: Author's drawing)

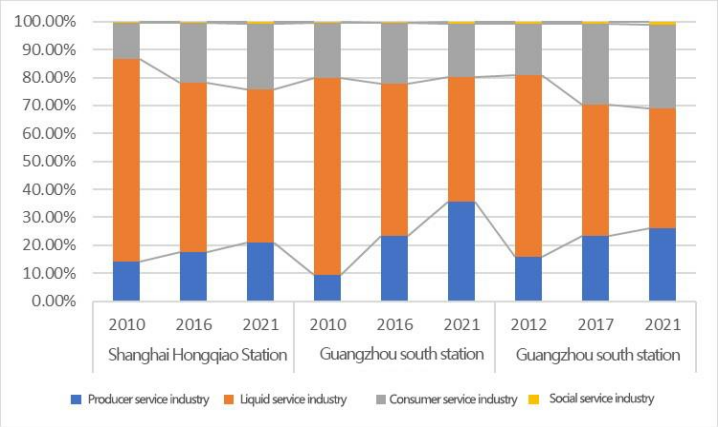

Figure 3: Evolution of the industrial structure of urban fringe stations (Source: Author's drawing)

3.2 Characteristics of the evolution of industrial spatial agglomeration

By analysing the industrial agglomeration characteristics of the industrial space in the HSR station area from the first year of HSR opening to the end of 2021, and comparing and summarising the industrial agglomeration evolution characteristics of the urban centre station and urban fringe station areas, it can be found that

The increase in the number of enterprises in the station areas of city centre stations and edge stations is directional in spatial terms. The main body of enterprise increment in city centre stations is close to the business districts or entrances and exits around the station area, forming a circle-like expansion, while the main body of enterprise increment in city fringe stations is close to the main urban areas of the city, showing a semi-circular spatial pattern. It can be seen that the linkage of different zones to the main urban areas and major business districts can have an important impact on the spatial aggregation of enterprises.

The overall pattern of industrial clustering in the central and peripheral areas of the city shows an opposite trend. The industrial agglomeration in the urban centre station area shows a pattern of "dense inside and sparse outside", mostly in the layout pattern of "commercial inside and residential outside"; while the urban fringe area becomes a spatial pattern of "sparse inside and dense outside The spatial pattern of the urban fringe is "sparse inside and dense outside" or mostly concentrated in a buffer zone of 800 - 1500m radius. The main reason for this phenomenon is that, as new transport hubs, urban fringe stations are mainly transport stations and interchange facilities in the core area, and development is strictly controlled, and station squares occupy the main area, resulting in low business density.

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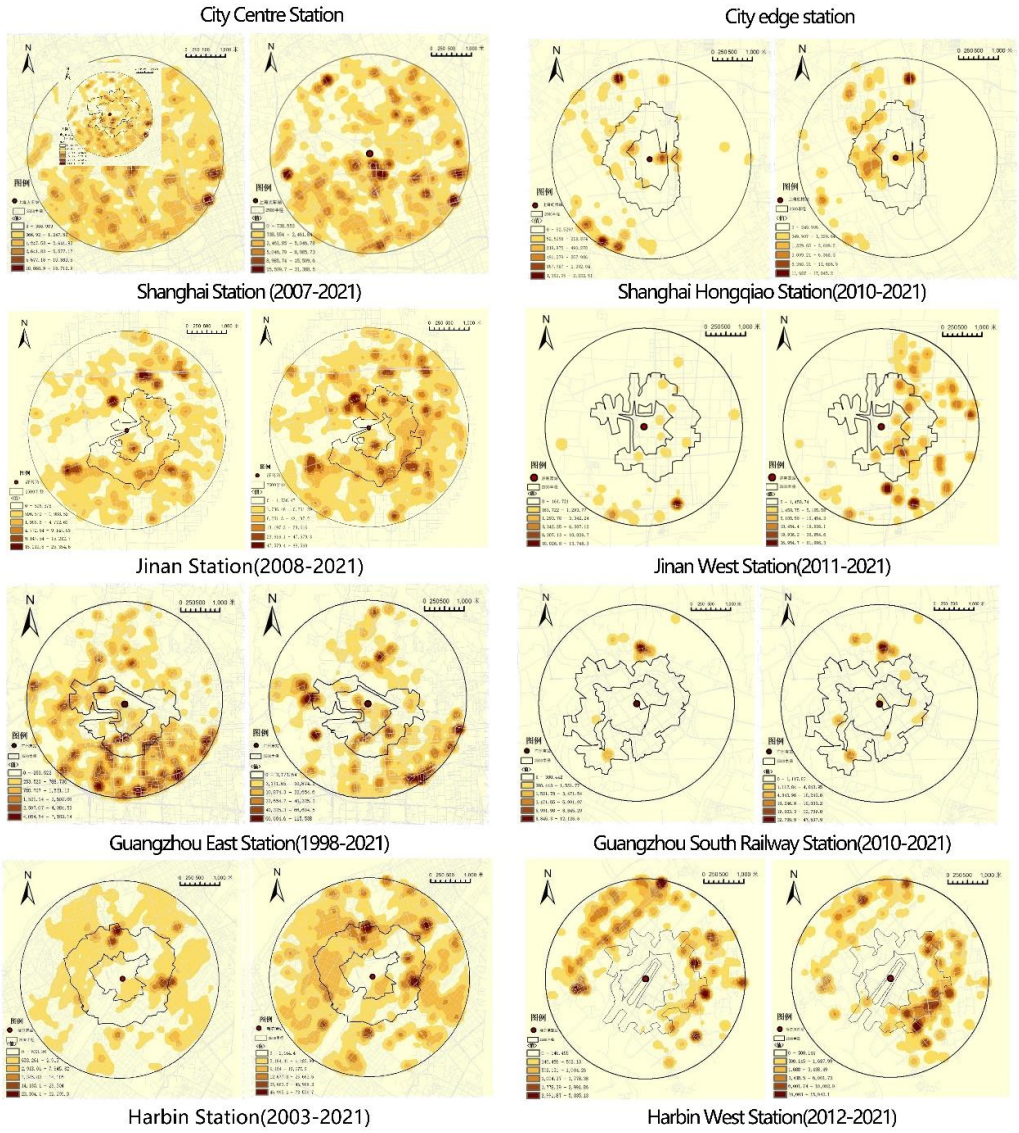

Figure 4: Evolutionary characteristics of industrial spatial agglomeration at the city centre and edge stations (Source: Author's drawing)

4. Conclusions and recommendations

This paper analyses the characteristics of the evolution of the industrial structure of the station areas of city centre stations and edge stations in terms of the increase in the number of enterprises and changes in the industrial structure. Firstly, by comparing the structural evolution characteristics of urban central stations and urban fringe stations, the following three points are concluded: (1) The service industry system in the station area of urban central stations is more complete than that in the station area of urban fringe stations in the early years of the opening of the HSR. (2) After the opening of the HSR until the end of 2021, the industrial structure of the urban fringe station area has changed significantly compared to the central station area. (3) The economic impact of HSR passenger flow on the urban fringe station area is greater than that of the urban central station area. Secondly, the industrial agglomeration characteristics and evolution of the HSR station area were analysed by the grid density analysis method and the kernel density analysis method, and the following conclusions were drawn: (1) The increase in the number of enterprises in the urban central station and edge station area is directional in space. (2) The overall pattern of industrial spatial agglomeration in the station areas of city centre stations and fringe stations shows an opposite trend.

Based on this conclusion, this paper makes the following recommendations on how to make the station areas of different zones of HSR stations play a good role in the HSR effect, optimize the industrial

ISSN 2663-1563 Vol. 4, Issue 2: 60-67, DOI: 10.25236/AJAGE.2022.040210

institutions and promote the integration of the station cities.

At the policy level, the central station area of the city should establish a regional image of "convenience, labelling and modern service industry" and create a public centre of the city with complex functions; the positioning of the peripheral stations of the city should tend to be a sub-centre or professional centre of the city, with differentiated positioning and development from the central station area and reflecting regional characteristics.

In terms of industrial layout, planning guidance should be strengthened. The spatial layout of the station area in the city centre should avoid a single function, promote the linked development of production and consumer services, upgrade industries and renew business patterns; while the peripheral stations should develop new economies according to their location and establish spatial links and industrial linkages with the main urban areas of the city.

In terms of urban design, the design should be centred on spatial development and place optimisation. City centre stations should improve spatial quality through spatial transformation and optimisation, promote urban regeneration in the centre and enhance attractiveness to industry; while urban fringe stations should strengthen the concept of smart city construction and sustainable development, meet the needs of rapid development of the station area through functional optimisation and improvement of public service facilities, and promote the transformation of the fringe station area from a transport node to a quality urban place.

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