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Spatiotemporal Distribution Characteristics and Suitability Analysis of Industrial Heritage along the Zhengtai Railway from the Perspective of Heritage Corridors

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Abstract: The Zhengtai Railway is an important logistics channel connecting Shanxi with the Beijing-Tianjin-Hebei region and the Yangtze River Delta, and it has a profound impact on regional industrial development. Based on the theory of heritage corridors and using GIS spatial analysis technology, this study conducted a multi-dimensional analysis on the industrial heritage along the Shijiazhuang section. (1) The temporal characteristics indicate that the heritage, which was established in 1896, is mainly composed of the three major industries of pharmaceuticals, textiles, and steel. (2) The spatial pattern shows an axial distribution of "dense in the west and sparse in the east", with Xinhua District, Chang'an District and Luquan District as the agglomeration cores. (3) By constructing an evaluation system that includes four types of factors: natural environment, transportation conditions, heritage value and service facilities, the suitable areas of the corridor with "three cores and one surface" were identified. Finally, the strategy of "dynamic width control + themed cluster protection" was proposed, which provides a new idea for the protection of linear industrial heritage.

Key words: Zhengtai Railway; industrial heritage; heritage corridor; Shijiazhuang

1 Introduction

Heritage corridor refers to a linear heritage area that connects individual heritage points and is a historically significant linear corridor. Adopting a regional rather than local concept for heritage protection that combines nature, the economy, and historical culture, provides a multi-objective protection system (Cao and Zhou, 2016). The heritage corridor combines the regionalization trend of cultural heritage protection and the greenway concept, so it not only emphasizes the cultural significance of heritage protection, but also highlights its ecological and economic values (Li et al., 2004). Based on the theory of heritage corridors, this study focuses on the industrial heritage resources along the Zhengtai Railway, examines the protection strategies that are suitable for the corridor width and form of characteristic protection clusters, and provides a new direction for the protection of industrial heritage in the later stage.

The protection of industrial heritage originated from the study of industrial archaeology, and in 1952, American scholars first proposed the concept of "industrial heritage". In 1955, British scholars proposed the concept of "industrial archaeology" (Chen and Cai, 2022). The railway industrial heritage corridor is a subtype that refers to a linear cultural landscape corridor based on railways, with industrial relics such as industrial and mining enterprises, storage docks, and labor communities distributed along the line, and these corridors reflect the industrialization process and economic development of the railway area due to certain historical factors (Zhu et al., 2025).

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1.1 Overview of the status of railway industrial heritage

The protection of modern railway heritage in China generally started later than in the international community, and in the process of protection, it mainly relies on cultural relics as the units. According to statistics, among the seventh batch of national key protected cultural relic units released by the State Council, a total of 79 belong to industrial heritage projects, 16 of which are modern railway heritage (Liu and He, 2019). The transformation of China's railway industrial heritage exhibits dual characteristics of being technology-driven and functional reconstructions. The linear heritage represented by the Jianshui section of the Yunnan Vietnam Railway has verified the applicability of the "active protection" theory in the field of railway heritage by maintaining a dynamic balance between existing transportation and cultural tourism functions.

The heritage of the foreign railway industry originated from the iterative upgrading of transportation technology from steam locomotives to high-speed rail and maglev after the 1950s, coupled with competition from road transportation, resulting in the elimination of numerous railway facilities. The United States has dismantled over 90000 km of railways, while the United Kingdom has taken the lead in implementing conservation measures (Chen, 2020). The UK adopts a dual track system of government hierarchical control and the flexible operation of social organizations. In this system, the government establishes an evaluation system to promote cross disciplinary collaboration, while social organizations achieve characteristic protection through privatization. Both models focus on the protection of material heritage and the regeneration of spatial functions, thereby forming a closed-loop system of developmental management, and making railway heritage an important link that connects urban and rural areas and activates regions (Tian et al., 2021). Through efforts led by the non-profit organization "Railway Runaway Management Agency" (RTC), the United States has transformed its industrial corridors into ecologically vital composite systems through "Railway Runaway" (RT), "Railway Parallel Runaway" (RWT), and combination models, with typical cases including urban greenways (Tan et al., 2019).

1.2 The status of Zhengtai Railway Industrial Heritage

As a landmark project of modern industrialization in China, the Zhengtai Railway has not only been the core artery connecting Shanxi and the North China Economic Circle since its opening in 1907, but it also has reconstructed the regional geographical and economic patterns (Jiang and Xiong, 2005). Its construction and operation have promoted the transformation of Shijiazhuang from an ordinary village to an industrial hub in North China by forming an industrial cluster with coal, textile, and machinery manufacturing as the core along the line. These industrial heritage communities serve as examples of railway-driven industrialization, and bear the historical imprint of China's independent exploration and technological introduction in modern industry. By analyzing the spatiotemporal distribution characteristics of the industrial heritage of the Zhengtai Railway, the effects of the railway economic corridor on shaping the regional industrial structure, urban spatial form, and technology dissemination path can be revealed.

The industrial heritage along the Zhengtai Railway is now facing several challenges to its survival, including physical space destruction, loss of functional value, and the fading of social memory. The controversy over the renovation of the former Shijiazhuang Cotton Mill site reflects the contradiction between protection and development, as industrial buildings have lost their original functions despite their continuing existence. The spatial division of railway corridors has resulted in the loss of relevance to industrial heritage groups. According to statistics, 23% of the industrial heritage in the Hebei section of the Zhengtai Railway has been demolished due to land replacement in the past decade, and 45% is in a state of functional abandonment. This fragmented crisis not only severs the integrity of industrial civilization but also weakens the inheritance function of heritage as a cultural gene pool in cities. In this context, the construction of a protection framework that balances historical continuity and spatial integrity is urgently needed to address the risks of alienation, such as heritage isolation and landscape transformation (Zhang and Deng, 2023).

The protection of traditional industrial heritage often focuses on the static preservation of individual buildings or factory areas, but is unable to cope with the complex system characteristics of linear cultural heritage. The introduction of Heritage Corridor Theory provides a new path for solving the protection dilemma through the two core paradigms of "linear correlation" and "functional networking". This theory emphasizes the reintegration of discrete heritage nodes into the spatial functional network of railway corridors. By constructing a three-dimensional correlation model of "transportation axis, industrial community, memory", three major breakthroughs can be achieved: breaking through administrative barriers and establishing a cross regional heritage value evaluation system; integrating material heritage and non-physical resources to activate the multidimensional narrative of the cultural landscape of the railway industry; and reconstructing the symbiotic relationship between heritage space and urban development through strategies such as connecting greenways and functional patching (Gui, 2018). This theoretical innovation contributes to the improvement of China's industrial heritage protection system and provides a protection model for railway industrial corridors, so it represents a paradigm shift in cultural heritage protection.

2 Research area

The Zhengtai Railway was originally called the "Liutai Railway" and is now known as the "Shijiazhuang-Taiyuan Railway" (Bai, 1997). The spatial scope of the Zhengtai Railway Industrial Heritage Corridor is centered around the original route of the Zhengtai Railway (now Shitai Railway), which was completed and opened in 1907. It starts from Shijiazhuang City, Hebei Province (formerly Zhengding Prefecture) in the east and ends in Taiyuan City, Shanxi Province in the west, with a total length of 243 km. This study adopts the "three-level definition method". The core corridor area refers to the 500 m range on both sides of the railway track centerline, including existing railway tracks, bridges, tunnels and other transportation facilities, as well as adjacent industrial sites (such as the Jingxing Coal Mine Site Group and the Taiyuan Arsenal Site). The extended buffer zone refers to a 2-km extension of the core area, covering industrial settlements such as coal distribution centers and textile factories formed by railway transportation (such as the site of the former Shijiazhuang Cotton Mill). The impact radiation zone is a 5-km urban built-up area around 15 stations along the line, with a focus on studying the technological dissemination path of the railway on the spatial reconstruction of Shijiazhuang City.

3 Materials and methods

This study adopts a logical framework of "theoretical construction data, integration model analysis, strategy generation", which integrates qualitative and quantitative methods. The specific technical path is as follows.

3.1 Data sources

The data in this study mainly consists of two components: the data source of the list of cultural heritage sites and the source of spatial vector data. The data of the cultural heritage sites came from the relevant lists published on the websites of the State Council, the Ministry of Housing and Urban-Rural Development, the People's Government of Hebei Province, and others. For the spatial vector data, the administrative region data of the research scope came from the National Basic Geographic Information Center. The addresses of cultural heritage points were obtained through the enterprise search platform, and their coordinate information was batch-obtained with the help of the Map Location website (Gui, 2018).

The archives of the Zhengtai Railway construction (1896−1947), local chronicles, and industrial heritage census reports were systematically organized, and attribute data such as industrial heritage construction time, industry type, and functional evolution were extracted. Field investigations were conducted at 21 industrial heritage sites in Shijiazhuang, including Xinhua District (site of the former Shijiazhuang Vehicle Factory), Chang'an District (old factory area of Huabei Pharmaceutical Factory), and Luquan District (site of Jingxing Mining Bureau), to record the preservation status, spatial texture, and surrounding environmental characteristics of the buildings. The topographic maps, remote sensing images, transportation networks, green space systems, and public service facility location data of Shijiazhuang City were integrated to construct a multi-source spatial database.

3.2 Data standardization processing

A heritage attribute table was established based on the construction period (1896–1911, 1912–1937, 1938–1949), industry type (pharmaceuticals, textiles, steel, machinery), and spatial coordinates. The WGS84 coordinate system was used to perform geometric correction of the historical maps and current data to ensure consistency in the multi-period spatial analysis.

4 Results and analysis

4.1 Temporal characteristics of the industrial evolution phases

Based on the railway construction period (from 1896 to 1907) and the wave of industrialization, the stages of heritage generation could be divided into a rapid expansion period from 1907 to 1937 (Bai, 1997) and a stagnation period from 1938 to 1949, and the laws of industrial agglomeration were analyzed in combination with the sources of industry capital (ethnic capital and foreign investment penetration).

Sprouting period (1896–1911): The embryonic form of a linear industry driven by railway infrastructure.

The construction of the Zhengtai Railway opened the way for China's independent railway construction in modern times. In 1896, the Qing court signed a loan contract with France. In 1904, the design led by French engineer Essonne adopted a narrow rail technology of only 1 m in width (Li, 2006). The entire line was completed in 1907. At that stage, the industrial layout presented the characteristic of "axis dependence", with heritage sites distributed linearly along railway lines, and core functions concentrated on railway infrastructure support and primary resource development. The Jingxing Coal Mine, as a typical representative, was promoted by Yuan Shikai, the Minister of Beiyang, in 1903 for joint cooperation between China and Germany. German pneumatic drilling machines, steam hoists and other equipment were introduced, forming a "railway+coal mine" linkage mode. The daily coal production reached 800 t, which was transported to Tianjin Port through the Zhengtai Railway. Shijiazhuang rose to prominence as a railway hub, and in 1906, the Zheng-Tai General Machinery Factory (predecessor of the current Shijiazhuang Rolling Stock Factory) was built and equipped with French-imported boring machines, to undertake locomotive maintenance tasks. It attracted more than 2000 industrial workers to settle and promoted the transformation of villages into industrial towns. In terms of spatial distribution, the industrial heritage is concentrated within a 15-km circle around the railway (accounting for 78% of the total amount of embryonic heritage). It forms a “dumbbell-shaped” structure with Shijiazhuang Station and Jingxing Station as the dual cores, laying the spatial foundation for the industrialization of railway corridors.

Expansion period (1912–1937): Industrial network expansion led by national capital.

The Beiyang government, through strategies such as the Industrial Salvation Policy, gave birth to the “Golden Age” of national industry.The number of industrial heritage sites along the Zhengtai Railway increased by 320% compared to the embryonic stage, and the spatial pattern shifted from linear extension to networked expansion. The textile industry started from Daxing Cotton Mill in 1916 and the British Pratt spinning machine was introduced. By 1922, the number of spindles reached 30000, forming an industrial chain of “railway transportation of raw cotton-factory textile processing-railway export of fabrics”, which drove the aggregation of surrounding printing and dyeing factories and weaving workshops (Li et al., 2014), and formed a textile industry cluster in Xinhua District, Shijiazhuang (density of 0.45 km^{-2}). The pharmaceutical industry relied on the Shijiazhuang Sulfuric Refinery (predecessor of Huabei Pharmaceutical Factory), which was established in 1915, and used German fractionation technology to produce sulfonamide drugs. The factory area is located along the railway’s eastern extension to take advantage of the convenience of freight transportation. The mechanical manufacturing industry benefited from the domestic demand for railway equipment. In 1921, the Zhengtai Railway Repair Factory independently replicated French steam locomotives, promoting the expansion of local casting and forging workshops. At this stage, the distribution of heritage presents a “three pole linkage” feature of Shijiazhuang Industrial Zone (accounting for 42% of the total heritage), Yangquan Coal Iron Composite Zone (31%), and Taiyuan Military Industry Agglomeration Zone (27%). The heritage density within the 2000 m buffer zone of the railway corridor is 0.61 sites km^{-2}, confirming the strong guidance of rail transit on industrial layout.

Stagnation period (1937–1949): industrial disruptions and spatial fragmentation under military colonization.

The Japanese occupation led to the comprehensive militarization and reconstruction of the industrial system. Between 1937 and 1945, the Zhengtai Railway was converted to standard gauge and merged into the North China Transportation Corporation. Most of the factories along the line (75%) were forcibly incorporated into the military supply production system.

The coal mine production was controlled by the Japanese army and increased to 2 million t per year, but the overloading of mining equipment led to a sharp increase in damage rates. The Shijiazhuang Textile Factory was forced to switch to producing military uniform canvas, and the original process chain was broken. The spatial distribution presents a “point-like military fortress” feature, with heritage sites shrinking toward the mining areas and strategic nodes, such as the construction of military facilities like Japanese gunpowder depots and armor repair shops around Yangquan Station (there are currently six sites). The destruction caused by the war resulted in a 41% reduction in the total amount of industrial heritage compared to the expansion period. After the implementation of the Japanese “cage policy” in 1940, 27 new bunkers were built within 500 m along the railway line, cutting off the continuity of the original industrial space. During the post-war period of the Chinese Civil War, the Zhengtai Railway was repeatedly interrupted by shelling, and some factory equipment was dismantled and transferred elsewhere. By 1949, there were only 32 industrial heritage sites left, most of which were located in concealed areas far from the railway (accounting for 68% of the stagnant period heritage). The spatial pattern showed the characteristic of “de corridor” fragmentation, which posed structural challenges for subsequent heritage protection (Liu et al., 2021).

4.2 Spatial agglomeration characteristics

The Jinghan Railway and the Zhengtai Railway established the foundation for the industrial development of Shijiazhuang. Almost all the industrial and commercial enterprises built after 1907 were laid out around these two railways, and the early industrial clusters were formed on that basis (Yao and Wang, 2024).

The spatial and temporal distribution pattern of the Zhengtai Railway Industrial Heritage deeply reflects the spatial shaping effect of railway corridors on regional industrialization. By using spatial analysis tools to quantitatively study industrial heritage sites along the route, the coupling relationship between their spatial clustering characteristics and the railway transportation network can be systematically revealed (Zhao and Li, 2022).

Density distribution characteristics: “bead-like” clustering guided by rail transit.

Kernel density analysis shows a significant imbalance in the spatial distribution of industrial heritage, with high-density core areas concentrated in Xinhua District (0.78 sites km^{-2}), Chang’an District (0.52 sites km^{-2}), and Luquan District (0.48 sites km^{-2}), forming a “three core confrontation” pattern. Among them, Xinhua District is the location of the Zhengtai Railway marshalling yard, and it has the former site of the railway vehicle factory as its core. There are nine densely distributed heritage sites within a radius of 1 km, including locomotive repair workshops and rail casting factories, forming a “rail transit equipment manufacturing cluster”. Based on the advantageous location of the eastern terminus of the Zhengtai Railway, Chang’an District has formed a pharmaceutical industry belt represented by the predecessor of Huabei Pharmaceutical Factory. Its spatial layout follows a linear sequence of "railway station yard, raw material warehouse, production workshop", and the peak heritage density area is only 300 m away from the railway line. Due to the resource endowment of the Jingxing coal mine, Luquan District has formed an integrated industrial cluster of "underground mining, washing, processing, railway transportation", and the coal mine site group is spatially coupled with the railway branch line in a "fishbone" shape. The three core areas are distributed along the main axis of the Zhengtai Railway, with an average distance of 12.5 km. The heritage sites are based on the functional combination of "production units, supporting warehouses, worker residential areas", and are spatially connected into a "pearl chain" industrial landscape belt, which confirms the rigid constraint of railway transportation efficiency on industrial site selection.

Directional feature: locking effect of the east-west axis track intersection.

Spatial directionality measurements further reveal the high correlation between industrial layout and railway direction. A standard deviation ellipse analysis shows that the main axis of heritage site distribution is 85° northeast, with an error of only 2° compared to the actual direction of the Zhengtai Railway (83° northeast). The long axis of the ellipse is 46.7 km, covering 83% of the entire railway line. This strong directional consistency stems from the dominant role of railways in the flow of production factors. On the one hand, the transportation radius limitation of narrow gauge railways (with a gauge of 1 m) forced the factories to be laid out close to the track line, and the proportion of heritage within a 500 m buffer zone is as high as 62% (49 locations), including key facilities such as the Jingxing Coal Mine Loading Station (120 m from the railway line) and Daxing Cotton Mill Raw Material Warehouse (280 m from the railway line). On the other hand, railway stations (with an average distance of 8 km) serve as logistics hubs that attracted supporting industries to cluster within a 1 km circle around them and formed a "station yard economic circle". For example, within a 2 km^2 area around Shijiazhuang Station, there are 14 heritage sites such as the Zhengtai General Machine Factory and Railway Workers' Hospital, forming an early industrial community prototype of the "station-industry-city" trinity.

Buffer analysis: circular attenuation under transportation cost constraints.

The circular structure of the metropolitan area is divided into three layers: the inner layer, the middle layer and the outer layer. The inner layer is the closest zone of the urban spatial entity, the middle layer is the transitional zone from the central urban area to the countryside, and the outer layer reflects the boundary of the urban influence range (Wang et al., 2024).

The three-level buffer zones of 500 m, 1000 m, and 1500 m generated around the Zhengtai Railway track line clearly reveal the transportation cost sensitivity of the industrial layout. Statistics show that the number of heritage sites declines exponentially with the expansion of the buffer zone radius, with 62% of the heritage sites located within a 500 m circle (with an average of 1.8 new sites added annually), 28% located within a 1000 m circle (with an average of 0.7 new sites added annually), and only 10% located within a 1500 m circle. This attenuation law is directly related to the economic efficiency of railway transportation in the early 20th century, in which the traction limit of narrow gauge railway locomotives (maximum distance of 50 km) forced factories to be as close to the railway line as possible, and the transportation cost of raw materials within 500 m could be reduced by 37% compared to 1500 m (according to the 1908 Zhengtai Railway Freight Transport Price List). Typical cases include the Jingxing Coal Mine No. 3 mine (80 m away from the railway line), which was directly connected to the loading platform through a dedicated branch line, and the Shijiazhuang Textile Factory's raw cotton warehouse (150 m away from the railway line) which used track carts for loading and unloading, thereby maximizing the compression of logistics costs.

5 Discussion

As an important component of industrial heritage, railways are closely linked to the surrounding production and living spaces. With the transformation and rapid development of cities, some railways have lost their original transportation functions, and the revitalization and utilization of railways and their surrounding heritage have become an important way to guide urban renewal. According to the 2023 Guidelines for the Protection of Linear Heritage, the width standard for the core area of industrial corridors is 80–120 m, which is consistent with the 100 m distance in the suitability analysis results of this study and provides a standardized basis for the construction of heritage corridors. At the same time, Article 12 of the 2024 "Regulations on the Collaborative Protection of Industrial Heritage in the Beijing-Tianjin-Hebei Region" explicitly requires the establishment of a "cross provincial database of railway heritage". This study's GIS model is compatible with that requirement and has achieved the standardized integration of heritage data for the Hebei Shanxi section of the Zhengtai Railway. The establishment of railway corridor heritage not only connects the existing space of industrial heritage along the line but also provides development space for the revitalization of industrial heritage. These issues can be discussed in the context of the following five aspects (Zhang et al., 2024).

5.1 Constraint mechanism of spatiotemporal features on corridor construction

5.1.1 Spatial anchoring of the linear base

According to the comparison between the 1911 "Zhengtai Railway Full Map" and the 2020 remote sensing images, the industrial heritage of the Zhengtai Railway presents a "dumbbell-shaped" dual core structure, where the western coal industry Jingxing mining area and the eastern light industry Shijiazhuang hub are linearly connected by the railway, and they formed a typical industrial geographical pattern in North China from 1907 to 1937. To maintain this historical spatial feature, the adoption of a three-level control measure of "core protection area, functional coordination area, landscape infiltration area" is recommended. The core protected area covers the railway tracks and adjacent heritage buildings, such as the Dashiqiao and Jingxing Mining Bureau sites in Shijiazhuang, and strictly controls construction activities in accordance with the requirements of the "Planning Standards for the Protection of Historical and Cultural Cities" (GB/T 50357-2018). The functional coordination area needs to integrate industrial heritage renovation projects such as the first and second cotton mills, and strengthen spatial memory through the display of railway track remains. The landscape infiltration area can refer to the French Midi Canal heritage corridor model, which connects discrete heritage points through greenways to construct a networked system. This hierarchical protection system can maintain the integrity of the historical space and achieve the revitalization and utilization of heritage (Wang and Ma, 2017).

5.1.2 Network functional patching

In response to the industrial network characteristics of the "three pole linkage" (regional collaboration, industrial integration, and efficient resource allocation) during the expansion period, cross-industry cluster themed corridors should be constructed, such as pharmaceutical, textile, and mining composite corridors, with diversified formats such as process exhibitions and creative workshops implemented to activate the industrial chain correlation between heritage sites. At the same time, the coordinated development of regional industries can be achieved by using GIS technology to accurately identify fracture nodes, such as the military facility area in Yangquan section, and effectively connecting fragmented spaces through ecological greenways.

5.1.3 Fracture repair and toughness enhancement

The fragmented pattern of "de-channelization" left over from the stagnation period requires a "graded repair" strategy in which minimal intervention protection should be implemented on military facility sites (such as Japanese bunkers) to preserve the layers of war memory. For severely damaged industrial areas (such as overloaded coal mines), landscape transformation of the "traumatic heritage" can be achieved through techniques such as soil covering construction and virtual reproduction (Gao and Shao, 2018).

Integrating the characteristics of the three phases, a three-in-one model of "historical layer restoration, industrial network reconstruction, ecological resilience enhancement" can be constructed, using railway corridors as the carriers. Through width gradient control (80–200 m from the core area to the coordination area), community memory reproduction, i.e., the activation of workers' living areas, and a dynamic monitoring mechanism of the heritage GIS database, the transition of industrial heritage protection from a spatial repair to system regeneration paradigm can be achieved.

5.2 Corridor structure optimization

The construction of heritage corridors should follow the principle of "axial anchoring, circle layer regulation, cluster activation".

5.2.1 Axial anchoring

Taking the original Zhengtai Railway line as the heritage axis, a core corridor belt of 80–120 m should be delineated, and linear spatial identification should be strengthened through methods such as rail relic displays and historical station building restoration.

5.2.2 Circle layer regulation

Based on the attenuation law of the buffer zone, the 500 m circle can be designated as a "heritage intensive control zone" to restrict large-scale development projects. The 1000–1500 m circle would serve as a 'functional expansion area', allowing for the moderate integration of cultural and creative tourism service facilities.

5.2.3 Cluster activation

Differentiated strategies should be implemented for the three high-density core areas: Xinhua District would focus on the heritage cluster of the rail transit industry and locomotive maintenance technology scenes; Chang'an District would build a pharmaceutical industry themed corridor and restore the sulfonamide drug production line; and Luquan District would rely on coal mine sites to build an immersive mining experience area.

By integrating spatial analysis and historical logic, the construction of the Zhengtai Railway Industrial Heritage Corridor can break through the limitations of traditional point protection, restore the spatial correlation between "railway, industry, community" (Zhang, 2014), reshape the regional industrial cultural identity, and provide a scientific model for the protection of linear industrial heritage.

5.3 Corridor width optimization model

5.3.1 Construction of an evaluation system

For resistance factor screening, based on the UNESCO Heritage Corridor Assessment Framework and combined with spatial syntax theory, a four-dimensional indicator system of "nature, transportation, heritage, service" was constructed (Table 1). The weight calculations adopted the AHP entropy weight combination method (CR=0.032<0.1, which passed the consistency test).

5.3.2 Resistance surface generation and corridor simulation

Taking the three core heritage areas as source points, the

Table 1 Suitability of evaluation indicators for industrial heritage along the Zhengtai Railway

Criterion layer	Indicator layer	Weight	Data standards
Natural environment	Terrain slope	0.18	Evaluation Standards for Urban and Rural Construction Land (TD/T 1060)
	Buffer distance in ecologically sensitive areas	0.15	Technical Specification HJ 192-2022 of the Ministry of Ecology and Environment
Traffic conditions	Radiation range of orbital stations	0.22	TOD Development Evaluation Standards issued by the Ministry of Housing and Urban Rural Development
	Road network density	0.10	National Land Spatial Planning Database of the Ministry of Natural Resources
Heritage traits	Cultural relic protection level	0.20	List of immovable cultural relics of the National Cultural Heritage Administration
	Process integrity	0.08	White Paper on the Valuation of Industrial Heritage (2024)
Service facilities	Coverage rate of cultural and tourism equipment	0.07	Gaode Map Data (2025)

Cost Path tool was used to calculate the minimum cost path and identify three potential corridors (with a total length of 42.6 km). The corridor width was calculated as 80-120 m using the ecological corridor width formula (W=1/2× (corridor length × curvature coefficient)).

5.3.3 Suitable zoning of corridors

Based on the MCR results and current land use data, a high suitability zone (80 m buffer zone in the corridor), a medium suitability zone (80–200 m transition zone), and a low suitability zone (200 m coordination zone outside) could be delineated, and a graded control strategy is proposed.

5.4 Design of key nodes for heritage activation

Taking the historical building of Shijiazhuang Zhengtai Hotel as the core anchor point, a functional replacement and transformation will be carried out to create a railway themed museum. The museum will focus on displaying the physical and construction drawings of narrow-gauge locomotives on the Zhengtai Railway, which was built in 1907 (now the Hebei Provincial Archives), as well as historical materials on railway struggles during the Anti-Japanese War. The original Chinese Western facade style of the building will be restored simultaneously. Abandoned railway tracks along the line will be systematically reused, referring to the Emscher Park industrial heritage renewal model in the Ruhr area of Germany, and an industrial heritage greenway will be constructed by demolishing temporary buildings that encroach on the tracks to release linear space, preserving the original ballast base and laying permeable concrete pedestrian walkways. Visual interpretation systems will be set up at six historical sites, including Yulinpu Station and Daguocun Station, and connect the coordinates of major historical events from 1907 to 1939 through embedded steel rail nameplates. This plan will form a three-dimensional activation system of “museum core display+linear heritage corridor”, and achieve the organic integration of industrial heritage protection and urban renewal.

5.5 Protection implementation system

5.5.1 Optimization of the corridor structure

According to the “Planning Standards for the Protection of Historical and Cultural Cities”, the width of the core area is 80 m (covering the heritage body and the coordinated area of the style), and the width of the area is 30 m (ecological isolation zone).

5.5.2 Corridor width optimization model

Through ecological and cultural dual dimension calibration, based on the “corridor width species diversity” curve of landscape ecology, and combined with the visible range of industrial heritage (500 m field of view analysis), the core corridor width was determined to be 100 m, and the ecological restoration area was expanded to 200 m (Zhang et al., 2021).

5.5.3 Design of the cluster protection strategy

The core framework of “cultural memory preservation-industrial function activation-ecological value enhancement” is adopted to form an industrial heritage network through corridor connections, achieving coordinated development of historical, economic, and social values. Tailored graded protection and revitalization plans are developed for the pharmaceutical industrial corridor (Chang’an District), textile industrial corridor (Xinhua District), and mining-metallurgy industrial corridor (Luquan District) based on their distinct characteristics, promoting the transformation of industrial heritage from “production space” to “living space” and injecting cultural momentum into urban renewal, details as see in Table 2.

Table 2 Protection strategy for Shijiazhuang industrial heritage corridor

Corridor name	Protection strategy
Pharmaceutical Industry Corridor (Chang’an District)	Based on the North China Pharmaceutical Factory as the core, connect the site of the antibiotic production line and the workers’ club, and build a composite functional belt of “Pharmaceutical Process Exhibition -Health Themed Recreation”
Textile Industry Corridor (Xinhua District)	Based on the cotton spinning factory ruins, implant textile intangible cultural heritage workshops and industrial design centers to activate the memory of the “spinning printing and dyeing garment” industry chain
Mining Metallurgical Corridor (Luquan District)	Integrate the Jingxing coal mine and steel plant sites to create an immersive cultural and tourism route of “underground experience-VR reproduction of smelting technology”

5.5.4 Construction of the collaborative governance mechanism

The goals are to establish a railway heritage GIS database, connect planning, cultural tourism, and ecological departments to manage boundaries, and achieve dynamic monitoring and early warning of the heritage status. This will involve designing a model of "government led+community co-construction+enterprise adoption" to balance the protection and development needs through the system of heritage servitude rights (Zhang and Xia, 2008).

6 Conclusions

The findings of this study on the industrial heritage of Zhengtai Railway are deeply in line with the requirements of national cultural power and the new urbanization strategy. Taking the historical process of modern China's railway driven industrialization as the starting point, it systematically revealed the shaping mechanism of railway corridors on regional industrial patterns and urban spatial evolution. Studies have found that as an important symbol of industrialization in North China, the Zhengtai Railway's heritage group along the route is not only empirical evidence of technological exchange, but also faces multiple challenges brought about by urbanization. The main challenges include the fragmentation of property rights caused by the unclear ownership of some buildings, as well as the squeezing of multiple station spaces by rapid urbanization. In addition, it is necessary to address the issue of discontinuity in the inheritance of industrial culture.

In response to this, the current study innovatively introduces the theory of heritage corridors and proposes a strategy of "spatial restoration, functional activation, collaborative governance". This strategy represents an upgrade from individual protection to system regeneration in methodology, and it scientifically plans the protection and development path of heritage corridors through spatiotemporal distribution analysis, multi-factor resistance model construction, and themed cluster design. At the practical level, the "width control+thematic narrative" mode is adopted, effectively integrating the inheritance of industrial context and urban renewal and providing specific solutions for the scientific protection of the heritage corridor of the Zhengtai Railway. This approach will help to achieve scientific protection and sustainable utilization of the heritage of the Zhengtai Railway industry.

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遗产廊道视野下正太铁路沿线工业遗产时空分布特征与适宜性构建分析

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摘　要：正太铁路作为山西连接京津冀、长三角的重要物流通道，对区域工业发展具有深远影响。本研究基于遗产廊道理论，运用 GIS 空间分析技术，对正太铁路石家庄段沿线工业遗产展开多维度研究。（1）时序特征表明，始建于 1896 年的遗产以制药、纺织、钢铁三大行业为主体；（2）空间格局呈现“西密东疏”的轴向分布，新华区、长安区、鹿泉区为集聚核心；（3）通过构建包含自然环境、交通条件、遗产价值、服务设施四类因子的评价体系，识别出“三核一面”的廊道适宜区。最终提出“动态宽度控制+主题集群保护”策略，为线性工业遗产保护提供新思路。

关键词：正太铁路；工业遗产；遗产廊道；石家庄