

Article

Construction of the Chinese Route of Industrial Heritage Based on Spatial and Temporal Distribution Analysis

Jiahao Zhang ^{1,2,*} , Lingchen Zhuo ^{1,2}, Hao Sun ³, Yuanling Wang ¹, Hanbin Wei ¹, Subin Xu ^{4,*} and Nobuo Aoki ⁴¹ School of Architecture, Huaqiao University, Xiamen 361021, China² Urban and Rural Architectural Heritage Protection Technology Key Laboratory of Fujian Province, Xiamen 361021, China³ Tianjin Municipal Engineering Design & Research Institute, Tianjin 300072, China⁴ School of Architecture, Tianjin University, Tianjin 300072, China

* Correspondence: zhangjh@hqu.edu.cn (J.Z.); xusubin@tju.edu.cn (S.X.); Tel.: +86-1862-2768-003 (J.Z.); +86-1311-6182-845 (S.X.)

Abstract: In the context of cultural routes, in order to achieve overall protection of industrial heritage, the European Route of Industrial Heritage (ERIH) was established to organize and promote the entire European industrial heritage. The conservation and utilization of Chinese industrial heritage are currently dominated by individual cases, which limits their potential to contribute to regional sustainable development. There is an urgent need of a conservation system at the regional or national level, to ensure that Chinese industrial heritage conservation effectively contributes to regional sustainable development. This study considers the industrial heritage of China built between 1840 and 1978 to establish the Chinese Industrial Heritage GIS Database (CIHGD). The analysis shows that the distribution of China's industrial heritage is mainly concentrated in the eastern and southern coastal areas, and the industrial heritage has formed three key regions, 14 key cities, and important railway and water systems located in eastern China. The CRIH facilitates the holistic conservation of China's industrial heritage and provides basic data for future research on China's industrial heritage. The objective of this study is to promote the establishment of an information-based management system for industrial heritage in China, and to explore the value evaluation, protection system, and regional tourism of industrial heritage from a national perspective in China.



Citation: Zhang, J.; Zhuo, L.; Sun, H.; Wang, Y.; Wei, H.; Xu, S.; Aoki, N.

Construction of the Chinese Route of Industrial Heritage Based on Spatial and Temporal Distribution Analysis. *Buildings* **2024**, *14*, 1065. <https://doi.org/10.3390/buildings14041065>

Academic Editor: Marco Di Ludovico

Received: 8 February 2024

Revised: 31 March 2024

Accepted: 2 April 2024

Published: 11 April 2024



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Keywords: China; industrial heritage; GIS database; route of cultural heritage; conservation

1. Introduction

The concept of industrial heritage was born out of industrial archaeology, which originated in the UK in the 1950s, and was added to the World Heritage List in 1986 [1,2]. The concept of cultural routes, first proposed by the European Union in 1987, was added to the World Heritage List in 2005 [3], reflecting an innovation and breakthrough in the concept of cultural heritage conservation. Cultural heritage no longer represents separate “heritage sites” in terms of the historical and natural environment [4]. Cultural routes are geographical journeys through a territory and through plural local identities, gather different territorial systems, and, finally, are a tourism product to connect cultural heritage from different regions [5]. The European Route of Industrial Heritage (ERIH), established in Germany in 1999, comprises a cultural route system of 100 important industrial heritage anchor points, 20 regional industrial routes, and 13 European industry thematic routes, which play a very important role in preserving industrial heritage conservation, as well as in the organization and promotion of industrial tourism routes throughout Europe [6]. In China, the start of national research and conservation of industrial heritage began with the *Wuxi Recommendations* in 2006 [7–9]. However, in terms of development status, the existing legal system and institutional framework related to industrial heritage has remained the same [10,11], and in practice, industrial heritage case studies are the main

form of expression [12–14]. In related studies, research on Chinese industrial heritage at the regional level has focused on industrial heritage of a certain type, in a certain region, or in a certain conservation system [15–17]. There is a dearth of research on the spatial and temporal distribution of Chinese industrial heritage using the whole country as the spatial scope.

The mature application of geographic information technology (GIS) in the field of cultural heritage preservation has opened up new opportunities for industrial heritage preservation and research. This includes the integrated management of heritage resources [18–20], the monitoring of heritage status [21–23], and the digital conservation of heritage [24,25]. In addition, GIS technology has been widely used to analyze the spatial and temporal analysis of cultural heritage [26–29], but most of these studies have analyzed the spatial distribution characteristics of heritage, and have not performed further research based on the analysis results. Yan, M. et al. also utilized GIS to explore the spatial distribution characteristics and influencing factors of European industrial heritage, and arrived at conclusions regarding its temporal and spatial distribution [30]. Fan, X. and Sun, L. utilized GIS to analyze the geographical distribution characteristics and influencing factors of Italian industrial heritage, and proposed a series of recommendations aimed at the sustainable protection and management of Italian industrial heritage [31]. Therefore, it is of great significance to analyze the spatial and temporal distribution of China's industrial heritage based on GIS database, and to clarify the current situation of China's industrial heritage protection on this basis, which is of great significance for future protection and value assessment.

China's industrial development has had a long and tortuous history [32–50]. After the First Opium War in 1840, the invasion of foreign powers forced China to begin the process of early modernization; by the 1860s, the Westernization Movement initiated the development of national industry [51]. In 1894, the Qing government was defeated in the Sino-Japanese War, resulting in the geographical division of China and the introduction of a certain degree of industrialization. The Qing government implemented the “New Deal” in 1901 to promote the development of China's early modern national industry [52]. From the outbreak of World War I in 1914 until 1921, the turbulent external environment provided abundant opportunities for the development of national industry [51]. The establishment of the Nanjing National Government in 1927 promoted further development of national industry [53], and the Anti-Japanese War and the Liberation War, which spanned 1937 to 1949, wreaked havoc on early modern industrial development. After the founding of the PRC in 1949, China's industrial development entered a new stage [54]; during the First Five-Year Plan period from 1953 to 1957, the Soviet-aided Project 156 became the focus of industrial construction. From 1958 to 1963, Project 156 continued, while heavy industry remained the focus of industrial construction [55]. Thereafter, in the face of the unstable external environment, the “Third Line Construction” was proposed in 1964 and industry began to move to the inland Third Line areas, which is basically the central and western interior of China excluding Xinjiang, Tibet, and Inner Mongolia [56]. By 1978, China had initially established an independent and relatively complete industrial system and national economic system [36].

The industrial construction that occurred during these historical periods has left China with a rich variety of industrial heritage resources [57]. As China enters a period of rapid urbanization, the protection of industrial heritage has faced great challenges. Currently, the overall quantity and protection status of industrial heritage in China are still weak, and the value and significance of industrial heritage protection need to be further promoted among the public. This study aims to establish a GIS database to comprehensively review the protection status and distribution of China's industrial heritage.

This paper focuses on Chinese industrial heritage built between 1840 and 1978, and is based on the development of the Chinese industrial heritage GIS database (CIHGD), and coupled spatial and temporal analysis of Chinese industrial heritage using GIS tools. Drawing on the experience of the ERIH, a preliminary concept for the Chinese Route of Industrial Heritage (CRIH) is proposed to provide ideas for the overall regional conservation

of Chinese industrial heritage and to promote the coordinated and sustainable development of industrial heritage in various regions of China.

2. Data Sources and Research Methodology

2.1. Data Sources

Based on the history of China's industrial development, before 1840, China's industry was still at the stage of traditional handicrafts and workshop production. The invasion of imperial powers led to the introduction of new energy, new technologies, and new equipment, and China's industrial development was "forced" into the early modernization stage [54]. By 1978, an independent and relatively complete industrial system and national economic system was initially established [58]. Following that same year, a major restructuring of the industrial structure was produced, and, thereafter, a huge number of industrial constructions began, and all in a relatively short period of time. This study, therefore, focuses on the existing Chinese industrial heritage built between 1840 and 1978. As China has not yet conducted a national industrial heritage census campaign, the amount of industrial heritage in China is currently unknown. In order to provide as comprehensive a picture of Chinese industrial heritage as possible, this study conducted data collection efforts based on the following sources: (1) lists of Chinese cultural relic protection units; (2) lists of local industrial heritage; (3) industrial heritage lists of other Chinese government and authoritative academic institutions; (4) academic works and related academic papers; and (5) field investigation. As of 31 December 2020, 1681 industrial heritage sites were recognized throughout China, as shown in Table S1. This article analyzes the spatial and temporal distribution of China's industrial heritage using the collected data in ArcGIS. The workflow is illustrated in Figure 1.

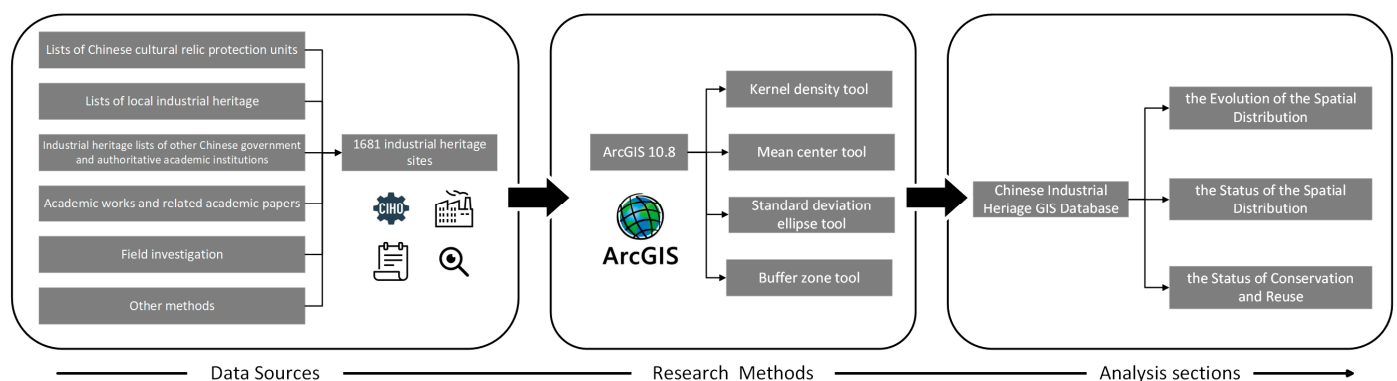


Figure 1. Workflow for analyzing China's industrial heritage based on GIS.

2.2. Research Methods

The Chinese Industrial Heritage Database was based on ArcGIS 10.8. The data include China's national, provincial, and municipal boundaries; important railroads, waterways, and highways; and coordinate point data for industrial heritage sites. The GIS software included the following tools for analysis, which were used to generate the corresponding analysis maps: kernel density, mean center, standard ellipse, and buffer zone et al.

2.2.1. Kernel Density Analysis

The kernel density estimation method focuses on the estimation of the density of point, line, or surface element layouts with the help of moving cells. The Parzen–Rosenblatt kernel density estimation formula is commonly used [59,60]. This paper utilizes the kernel density function to predict the spatial distribution of industrial heritage in China.

$$R(x) = \frac{1}{nh} \sum_{i=1}^n k\left(\frac{x - x_i}{h}\right) \quad (1)$$

In Formula (1), $R(x)$ is the probability value of the element R at x . In this paper, R is the industrial heritage site; $k\left(\frac{x - x_i}{h}\right)$ is the kernel function, where $(x - x_i)$ is the distance from the estimated value point x to the certain type of spatial element site x_i ; and h is the bandwidth that is greater than 0. The results show that the kernel function has a small effect on the results, while the effect of h is larger. In practice, the value of h has a certain degree of flexibility depending on the object of analysis. In this study, the value of h was determined to be 1 km based on several comparative analyses.

2.2.2. Mean Center and Standard Ellipse Analysis

The standard ellipse was first proposed by Lefever as a spatial statistical method to quantify the characteristics of the spatial distribution of geographical elements [61]. The relevant parameters of the ellipse can characterize the center, direction, and shape of the distribution of elements. The area of the standard ellipse reflects the size of the distribution range of the elements, and the spatial coordinate migration of the standard centers in different periods can characterize the spatial distribution trend of the industrial heritage in China. The direction of the long axis characterizes the directional trend of element distribution, the length of the short axis characterizes the aggregation pattern of elements, and the flatness value reflects the degree of spatial aggregation of elements. The formula is as follows:

$$C = \frac{1}{n} \left(\begin{matrix} \sum_{i=1}^n \bar{x}_i^2 & \sum_{i=1}^n \bar{x}_i \bar{y}_i \\ \sum_{i=1}^n \bar{x}_i \bar{y}_i & \sum_{i=1}^n \bar{y}_i^2 \end{matrix} \right), \left\{ \begin{matrix} (x_i - \bar{x}') \\ (y_i - \bar{y}') \end{matrix} \right\} \quad (2)$$

In Formula (2), \bar{x} , \bar{y} is the mean centroid coordinate value, x_i , y_i are the spatial coordinate values of the i element, and n is the total number of elements in the set.

2.2.3. Buffer Zone Analysis

This paper determines the width of the 1 km double-sided buffer zone after several trials based on the principle of accessibility of excursions, with important river systems, railways, and other traffic line elements as the main focus. On the basis of the generated buffer zones, the total number of industrial heritage sites within each buffer zone was determined by overlaying the distribution analysis with China's industrial heritage elements [62]. The number of industrial heritage sites per unit length of buffer was then calculated and the transportation routes were graded accordingly.

3. Analysis

According to the above data sources, the CIHGD was established (Figure 2), using the territory of China as the base map, and overlaying elements such as provincial and municipal boundaries, important transport routes, and Chinese industrial heritage sites.

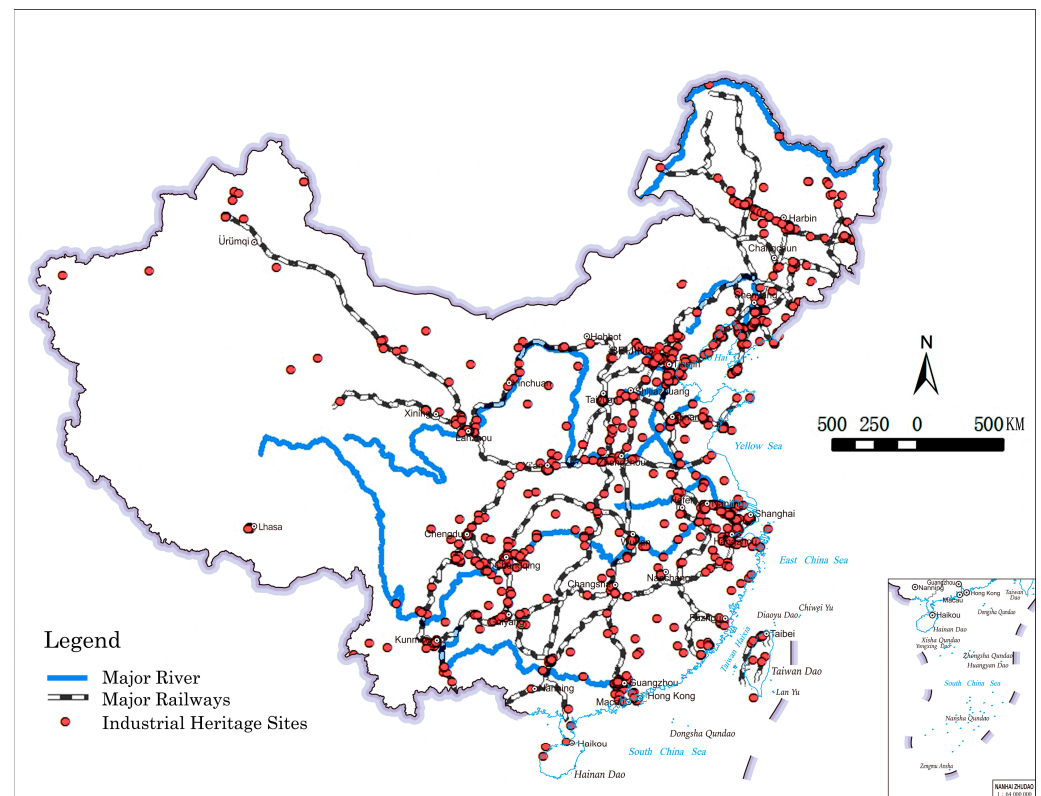


Figure 2. CIHGD map (source of base map: National Standard Map Service, Revision No. GS (2019) 1682, national boundaries unchanged).

3.1. Analysis of the Evolution of the Spatial Distribution of Industrial Heritage

The development process of China's modern industry can be divided into the early modern industrial development period from 1840 to 1949, and the modern industrial development period from 1949 to 1978. The key regions, development laws, and leading forces of industrial development in the two periods are considerably different. According to the history of Chinese industry and related studies [54], the development of modern Chinese industry can be divided into seven stages: (1) the 1840–1894 period, (2) the 1895–1913 period, (3) the 1914–1936 period, (4) the 1937–1948 period, (5) the 1949–1957 period, (6) the 1958–1963 period, and (7) the 1964–1978 period. The 1949–1957 period included the period of national economic recovery (1949–1952) and the period of industrial construction in the First Five-Year Plan (1953–1957), which were, respectively, the recovery period and the starting period of industrial construction in the PRC.

The kernel density analysis method was used to obtain a map of the kernel density distribution of each period and all Chinese industrial heritage (Figure 3). In the seven historical periods of China's modern industrial development, with the founding of the PRC as the nodal point, China's industrial construction has shown a development trend characterized by a build-up along the coast to dispersal into the interior. However, three regions have always been the focus of industrial construction: the Beijing–Tianjin–Hebei region, the Yangtze River Delta region, and the Pearl River Delta region. However, industrial construction in the Pearl River Delta region is mainly concentrated in Guangzhou, and is, therefore, discussed at the city level. In addition, the northeast region, although not an area of build-up during all periods of modern industrial construction in China, played an important role in four historical periods: 1895–1913, 1914–1936, 1937–1948, and 1949–1957. To summarize, at the regional level, the Beijing–Tianjin–Hebei region, the Yangtze River Delta region, and the northeast were crucial to China's industrial development.

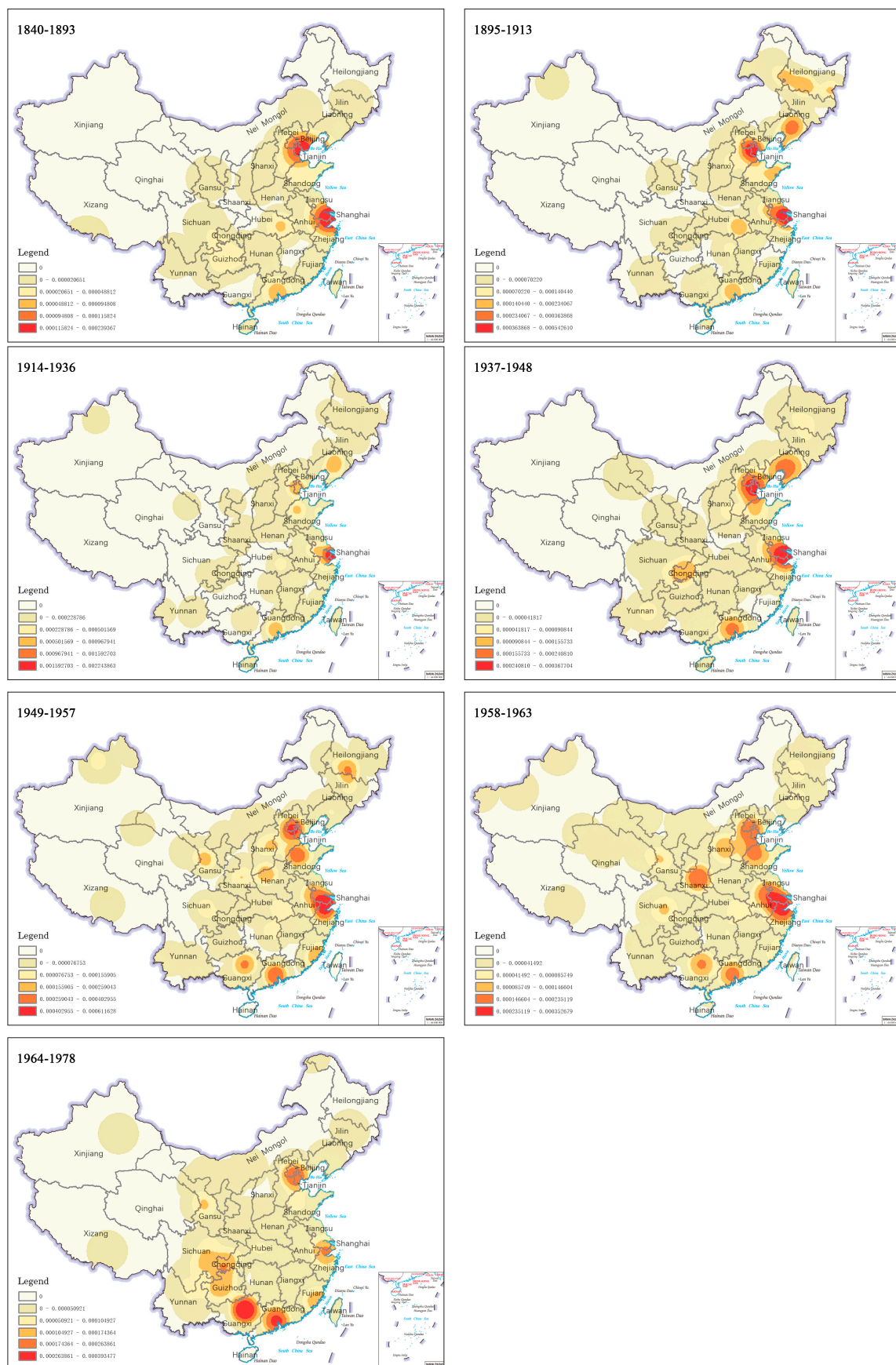


Figure 3. Distribution of industrial heritage kernel density in China by period.

Through the mean center analysis and standard ellipse analysis, the mean centers and standard ellipses of the spatial distribution of industrial heritage in China in different periods were calculated (Figure 4). Overall, the mean center of industrial heritage distribution in the seven periods is roughly located in the coastal region of central China. Among the changes in each period, the mean center of industrial heritage distribution in the five periods after 1914 shows an overall trend of moving towards the southwest. In addition, the mean center of industrial construction was relatively concentrated during the six periods from 1840 to 1963, while the mean center of industrial construction deviated from this concentrated area during the Third Front Construction period from 1964 to 1978.

The standard ellipses for each period were analyzed (Figure 3). In general, the rotation angle of the long axis of the ellipse mostly lies within the range of 15° – 35° , which shows that the distribution of industrial construction is relatively uniform across the periods. Based on the parameters such as the rotation angle of the long axis, the length of the short axis, and the flatness of the standard ellipse, the spatial distribution of industrial heritage can be divided into two intervals across the seven periods (Table 1). In the first interval, in the periods from 1840 to 1948, the ellipse's long axis rotated at an angle of 19° – 35° , the short axis length ranged from 550–690 km, and the flatness values ranged from 0.31–0.52. In the second interval, in the periods from 1948 to 1978, the ellipse's long axis rotated at a more variable angle, the short axis length ranged from 790–970 km, and the flatness values ranged from 0.02–0.16. Overall, compared with the four periods before 1949, the three periods post-1949 show a greater variation in the elliptical long-axis rotation angle, a longer short-axis length, and a smaller flatness value. This shows that the trend in the direction of industrial construction in China after 1949 is more variable, with a decreasing degree of aggregation of the distribution and a widening distribution.

Table 1. Mean center and standard ellipse parameters by period.

Historic Stage	Mean Center Coordinates	Directional Angle	Long Axis (km)	Short Axis (km)	Oblateness	Shape Area (km ²)	Moving Direction	Moving Distance (km)
1840–1894	102.13° E, 36.64° N	33.16°	995.95	685.70	0.31	2,145,333.29	-	-
1895–1913	117.03° E, 40.32° N	23.10°	1178.05	566.01	0.52	2,094,592.36	Northeast	397.69
1914–1936	117.48° E, 37.98° N	19.40°	1031.57	549.47	0.47	1,780,557.33	Southeast	233.79
1937–1948	98.48° E, 38.30° N	32.35°	1194.72	660.75	0.45	2,479,783.44	Northwest	192.57
1949–1957	84.41° E, 37.94° N	8.62°	1116.01	963.35	0.14	3,377,385.80	Southwest	145.12
1958–1963	73.50° E, 37.01° N	90.01°	974.36	955.00	0.02	2,923,143.34	Southwest	143.57
1964–1978	54.94° E, 30.38° N	23.75°	947.74	795.47	0.16	2,368,318.73	Southwest	407.74

The distribution characteristics of Chinese industrial heritage in various periods are closely related to the history of China's modern development. After the First Opium War in 1840, more than 100 treaty ports were opened nationwide, mainly along the eastern and southeastern coasts and a few inland areas. Concessions were also established in cities such as Guangzhou, Shanghai, Tianjin, and Chongqing, which objectively contributed to the industrial development of these areas [54,63]. From the 1860s to 1890s, the Qing government's westernization group launched the Westernization Movement to save the country. Industrial construction during the Westernization Movement primarily consisted of military industry, supplemented by civilian industry, and was mainly located in Tianjin and the surrounding areas, Shanghai, Nanjing, Fuzhou, and other provincial capitals [54]. In 1894, the Qing government was defeated in the Sino-Japanese War. The imperialist countries were given the right to operate factories in China through the principle of "equalization of interests", and took the liberty of dividing their spheres of influence in China [64]. At the same time, the Qing government introduced the "New Deal" in 1901, promulgating a series of regulations to encourage the development of industry and commerce, which objectively promoted the development of China's modern national industry [52]. During the period from 1895 to 1913, the railways built by foreigners without permission and borrowed by the Qing Government became the focus of industrial construction. The industrial heritage built during this period showed a clear tendency to be distributed

along the railways, mainly in the Beijing–Tianjin–Hebei region, Yangtze River Delta region, Liaoning province, Heilongjiang province, and Guangzhou city, etc. Between 1914 and 1921, during the First World War and the early post-war period, the weakening of commodity dumping by the British, French, and Germans, and the reliance of Tsarist Russia and other countries on China for military supplies, contributed to the “golden period” of China’s national industry [54]. From 1927 to 1936, the establishment of the Republican Government in Nanjing led to another period of rapid development of early modern industry in China; great progress was made in transport and the economy, hence the name “Golden Decade” [53,65]. The period 1914–1936 was similar to the previous period in terms of the distribution of industrial construction. The Anti-Japanese War and the War of Liberation between 1937 and 1949 caused significant damage to China’s modern industry. Industrial losses in the eastern and southern regions of China during the Anti-Japanese War between 1937 and 1945 accounted for about 36% of the total losses [54]. In addition, when the National Government moved its capital to Chongqing in 1937, industrial construction was carried out in the southwestern and northwestern regions, which formed the backbone of the war effort, to develop a large rear area and ensure military supplies. Japan also carried out industrial construction in the occupied northeast and north China to plunder China’s resources [66]. In the above four periods, industrial construction was mainly concentrated in the Beijing–Tianjin–Hebei region and Yangtze River Delta region, as well as in the three northeastern Provinces, Shandong Province, Hubei Province, and cities such as Guangzhou and Chongqing.

In 1949, when the People’s Republic of China was founded, China’s industrial development entered a brand-new period [54]. During the three-year period of national economic recovery, the People’s Government made adjustments to the nature of China’s industrial capital. During the First Five-Year Plan period (1953–1957), the Soviet Union’s support for China’s 156 projects was the focus of industrial construction, mainly concentrated in the northwest, southwest, and the central part of China, except for the northeast, which was originally a relatively weak industrial area [55]. Industrial construction, thus, began to show a trend of dispersal from the coast to the interior. During the Second Five-Year Plan period (1958–1963), Soviet aid to China continued, with most of the 156 projects completed around 1958 [55]; in addition, industrial construction centered on heavy industry was continued, and railways were built for the northwestern region, where industrial development was lagging behind, and industrial construction was carried out accordingly. In 1964, the Party Central Committee put forward the policy of “Third Line Construction” in the face of the turbulent international situation in the early 1960s, including the escalation of the US–Vietnam war, the breakdown of relations with the Soviet Union, and the armed conflict on the Sino-Indian border; accelerating the industrial construction behind the Third Line strategy became one of the main elements of policy [56]. The Third Line referred to the vast area “south of the Great Wall, north of Shaoguan, west of the Beijing–Guangzhou Railway, and east of the Wuyinling Mountains”, and the actual construction was mainly situated in the “eight provinces and one city” of Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Henan, Hubei, Hunan, and Shanghai City [67]. The construction of the Third Line had a significant impact on China’s central and western regions. It was of great significance to the industrial development of central and western China, and to a certain extent changed the spatial distribution structure of China’s industry, further promoting the dispersal of industrial construction throughout the country.

In summary, the spatial distribution of China’s industrial heritage during the period from 1840 to 1978, with the founding of the PRC in 1949 as the nodal point, shows the evolutionary characteristics of accumulation along the coast to inland dispersal. The industrial heritage built between 1840 and 1948 was mainly concentrated in the Beijing–Tianjin–Hebei region, the Yangtze River Delta region, the northeast region, and Guangzhou city, which are located along the coast. Due to state regulation of industrial construction, the industrial heritage built between 1949 and 1978 began to gradually disperse to the inland provinces of Sichuan, Guizhou, Henan, Shaanxi, Gansu, and Shanxi.

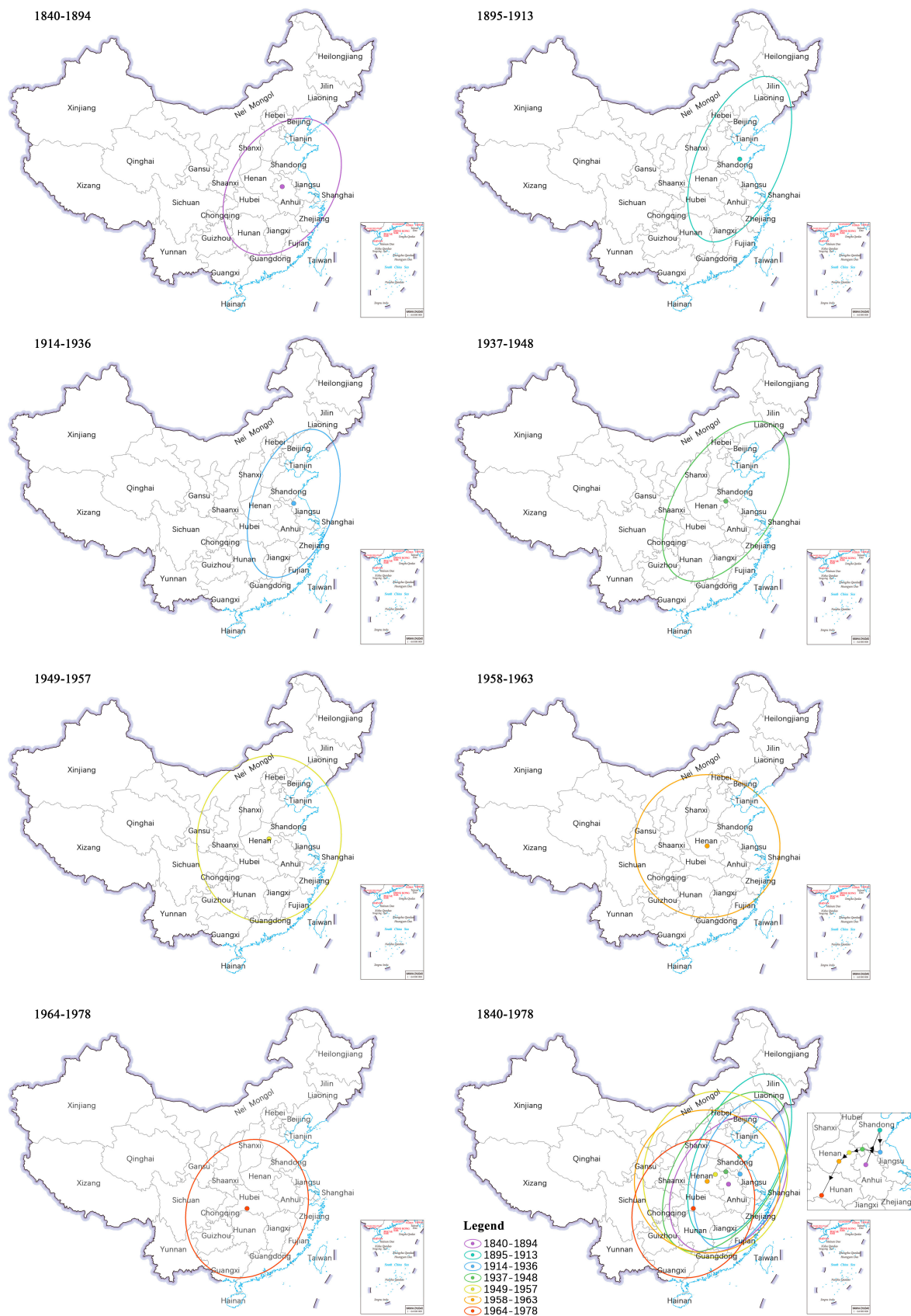


Figure 4. Mean centers and standard ellipse of Chinese industrial heritage by period.

3.2. Analysis of the Status of the Spatial Distribution of Chinese Industrial Heritage

The current distribution of China's industrial heritage is analyzed at three levels: the distribution of industrial heritage by province and city, by region, and along transportation routes. The distribution of industrial heritage by province (Figure 5) shows that the provinces with more than 50 industrial heritage items are located in the northeast and southeast coastal regions of China, except for Fujian and Jilin. The provinces with 20 to 50 industrial heritage items are mainly concentrated in the inland provinces of China. These provinces are located inland and far from the national border. The provinces with less than 25 industrial heritage items are located in regions bordering other countries. Based on this background, the spatial distribution of Chinese industrial heritage can be divided into three distinct categories. The first is Category I, where the total number of industrial heritage items in the northeast–southeast coastal region of mainland China is 1203, accounting for 71.78% of the national total. The easternmost region of mainland China is the most concentrated and important Industrial Heritage Agglomeration Zone in China. The Gathering Zone includes three key clusters: Jingnjnjinji Region centered in Tianjin and Beijing, with 225 items of industrial heritage; the Yangtze River Delta Region centered in Shanghai, including Jiangsu and Zhejiang, with a total of 272 items of industrial heritage; and the northeast region, including Heilongjiang, Jilin, and Liaoning, with 250 items of industrial heritage. The zone also includes Guangdong Province, where the industrial heritage is mainly located in Guangzhou; Guangxi Province, where the industrial heritage is mainly located in Liuzhou; Fujian Province, where the industrial heritage is mainly located in Quanzhou and Fuzhou; and Shandong Province, where the industrial heritage is mainly located in Jinan and Qingdao. Category II, where the total number of industrial heritage items in the inland region is 377, accounts for 22.49% of the national total. Category III, where the total number of industrial heritage items in the border region is 69, accounts for 4.12% of the national total.



Figure 5. Statistics on industrial heritage quantity of Chinese provinces.

The number of industrial heritage items of all cities in China was counted using GIS technology (Figure 6). National industrial heritage items are distributed in 185 cities, accounting for 54.73% of the total number of cities in China. Thirty-five cities have more than 10 industrial heritage items, and 26 of these cities are located in the Class I distribution region. The other nine inland cities are Wuhan, Chongqing, Lanzhou, Xi'an, Taiyuan, Changsha, Chengdu, Luoyang, and Kunming. Among the nine cities, seven are provincial capitals, and one is a municipality directly under the jurisdiction of the central government. Only Luoyang is a prefecture level city; however, it was also one of the construction centers of the 156 project during the Soviet Union's period of assistance after the founding of the People's Republic of China.

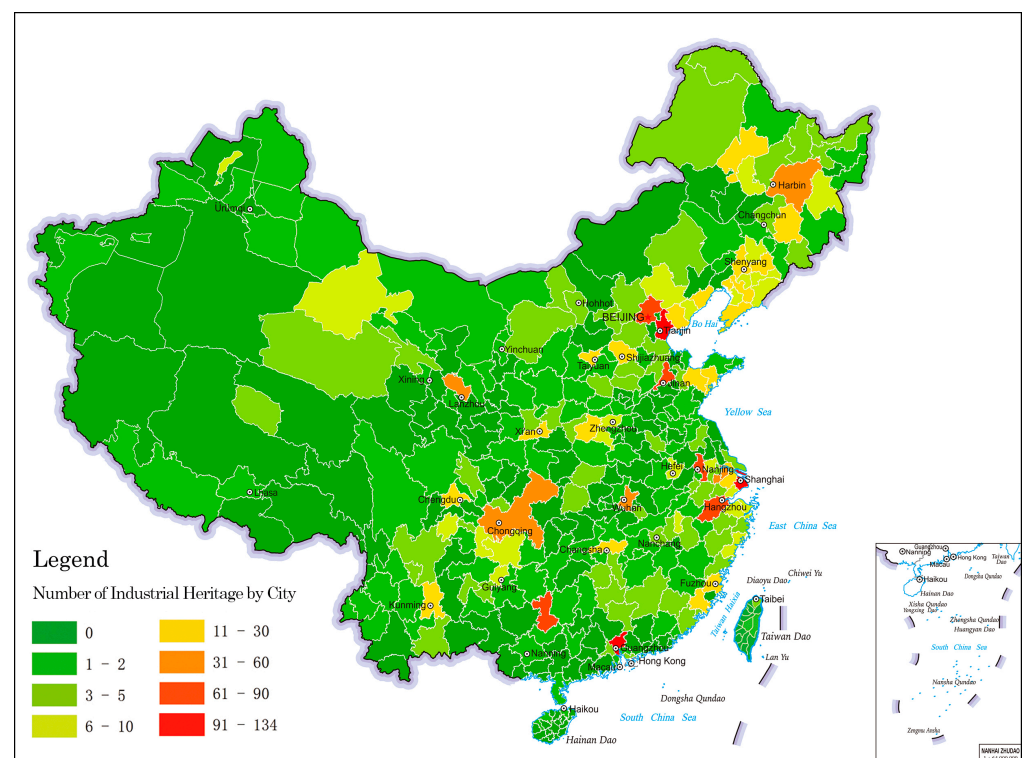


Figure 6. Statistics on the quantity of industrial heritage of Chinese cities.

On this basis, combined with the kernel density distribution map of the existing industrial heritage as a whole (Figure 7), the key areas of industrial heritage distribution in China can be summarized. At the regional level, the main provinces and cities constitute the three priority regions for the distribution of industrial heritage: Beijing, Tianjin, and Hebei as the Beijing–Tianjin–Hebei region; Jiangsu, Zhejiang, and Shanghai as the Yangtze River Delta region; and Heilongjiang, Jilin, and Liaoning as the northeast region. By combining the above-mentioned distribution of industrial heritage in the provinces and cities, it is possible to obtain 14 key cities in addition to those classified as key regions: Jinan, Qingdao, Taiyuan, Xi'an, Lanzhou, Wuhan, Changsha, Chongqing, Chengdu, Kunming, Fuzhou, Quanzhou, Liuzhou, and Guangzhou.

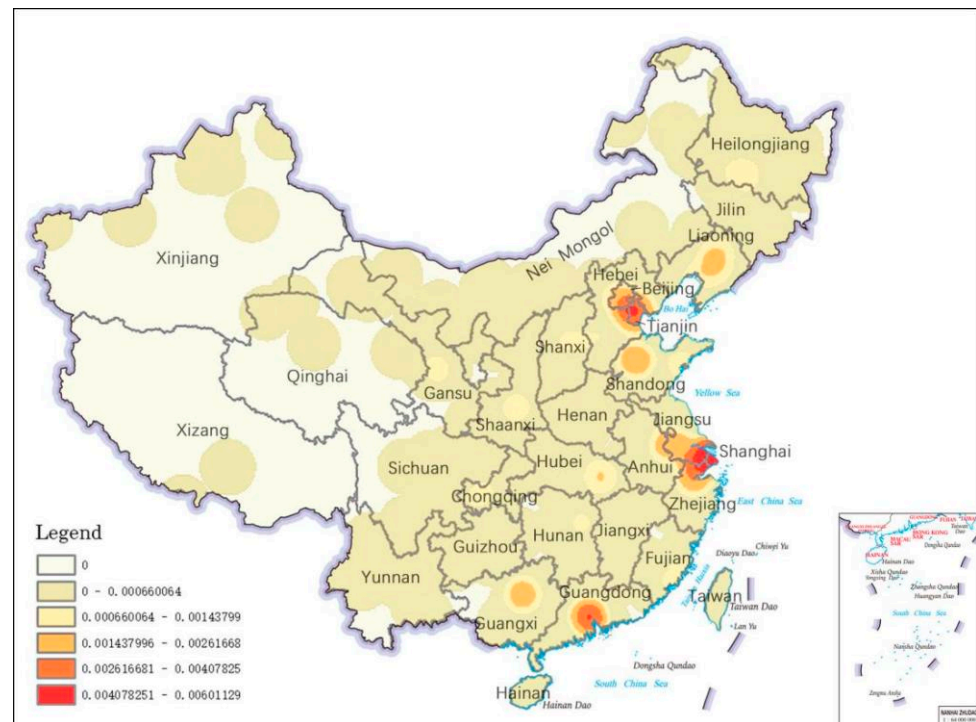


Figure 7. Distribution of kernel density of Chinese industrial heritage status.

The GIS buffer zone tool was used to analyze the distribution of industrial heritage along important railways and water systems. Chinese railways are divided into regional and national railways, and the longer length national railways require pre-segmentation. On this basis, a 5 km buffer zone for each section of railway was established, the number of industrial heritage sites within the buffer zone was counted, and the number of industrial heritage sites within each kilometer of the buffer zone was calculated. This was used to classify each section of railway, the results of which are shown in Figure 8. For important water systems, the longer rivers were segmented according to the upper, middle, and lower reaches, and were analyzed in the same way the railways above were analyzed (Figure 9). Overall, the distribution of China's industrial heritage along important transport routes shows a decreasing trend from coastal to inland, and the trend is more pronounced along railways than along rivers. For railways, the 2.0–10.0 and 10.0–25.0 classes are mostly located in the north-eastern region and the south-eastern coast, with the 10.0–25.0 class directly adjacent to the sea. In terms of water systems, the Beijing–Hangzhou Grand Canal, the Haihe River, the middle and lower reaches of the Yangtze River, and the lower reaches of the Yellow River, which border the eastern and southern coasts, are areas of intense industrial heritage, all at the 0.5–2.0 and 2.0–10.0 levels. Among them, the Beijing–Hangzhou Grand Canal is important in linking the two key regions of industrial heritage—the Beijing–Tianjin–Hebei and Yangtze River Delta regions. In summary, the railways at the 2.0–10.0 and 10.0–25.0 levels and the rivers at the 0.5–2.0 and 2.0–10.0 levels can be considered key routes for industrial heritage, while the other levels will be selected on the basis of the connectivity and integrity of the industrial heritage routes.

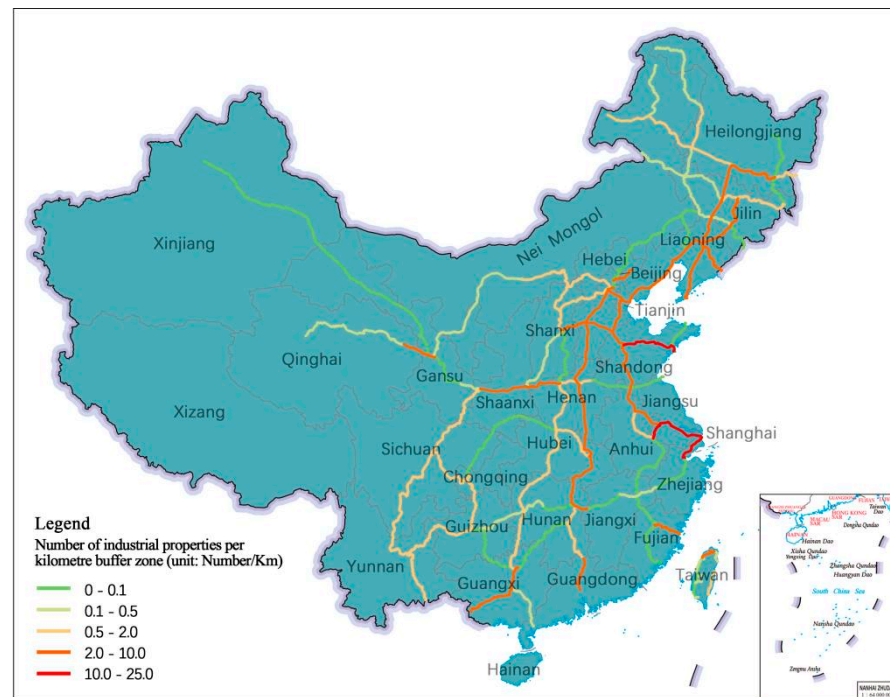


Figure 8. Major railway classification.

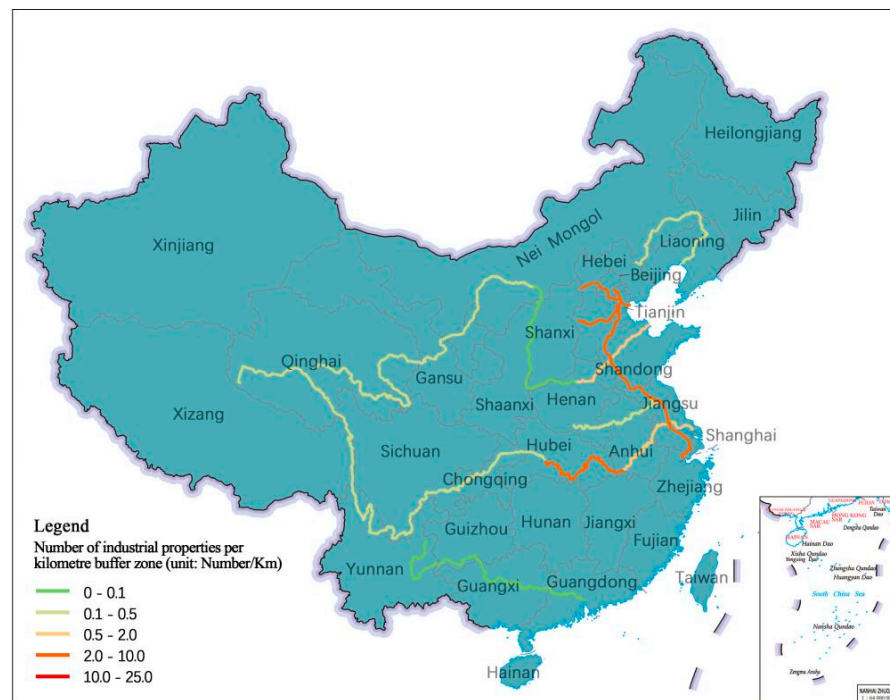


Figure 9. Major river classification.

3.3. Analysis of the Status of Conservation and Reuse of Industrial Heritage

Statistically analyzed, the current situation of the protection and reuse of China's industrial heritage mainly includes the following four types: conservation and reuse, conservation only, reuse only, and not conserved and not reused (Figure 10a). Approximately 57% of the industrial heritage is not conserved and not reused, which represents a large proportion. In conservation and reuse projects, the statistical objects of conservation includes the cultural conservation units above the municipal level and the historical buildings

of each city, totaling 479 items. The statistical objects of reuse include various types of industrial heritage transformation and reuse projects. The types of reuse mainly include cultural creation parks, museums, city parks, mine parks, residential areas, shopping malls, and office buildings, totaling 292 items (Figure 10b). Cultural creation parks are the main mode of reuse, followed by mine parks and museums. However, being conserved by the government and being reused are mutually exclusive. Less than 3% of industrial heritage is both conserved and reused by the government. This may be due to the government's exclusive power in the decision-making process of heritage conservation and use, lack of public participation, and reliance on a top-down management process [68–70].

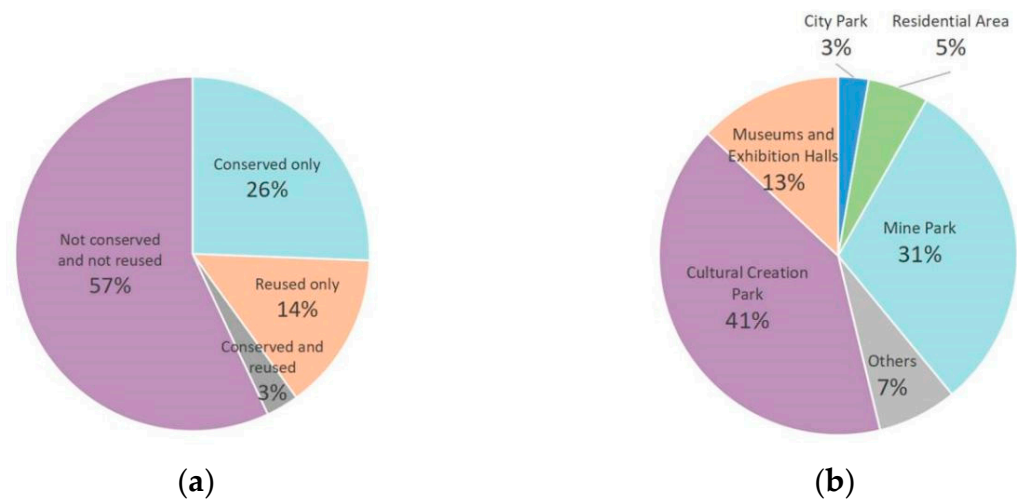


Figure 10. Statistics on the status of conservation and reuse of Chinese industrial heritage: (a) proportion of industrial heritage conservation and reuse in China; (b) proportion of industrial heritage reuse models in China.

Using GIS kernel density analysis, the spatial distribution of industrial heritage conservation and reuse in China was studied (Figure 11). Overall, the spatial distribution of conservation and reuse is similar to that of known industrial heritage, but the dominance of the east over the west becomes more pronounced. The conserved industrial heritage in China is mainly concentrated in the eastern part of the country, with less conserved industrial heritage in the northwest and southwest. In the eastern region, the best protected areas are Guangzhou and Shanghai. Reuse projects in China are mainly concentrated in important cities, such as municipalities or provincial capitals in northern, eastern, and southern China, with fewer industrial heritage reuse projects in other regions. The cities with the most projects are Shanghai and Beijing. It is also worth noting that although the status of conservation is relatively good in the north-eastern region, which is a key region for industrial heritage, there is still room for the development of reuse models.

In summary, the status of conservation and reuse of industrial heritage in China is poor, with large disparities in the status of different regions and a low degree of integration of conservation and reuse. There is, therefore, an urgent need to propose holistic conservation strategies, to balance the status of conservation and reuse in different regions, to make flexible and scientific decisions on the conservation and reuse of industrial heritage, and to promote the development of industrial heritage conservation.

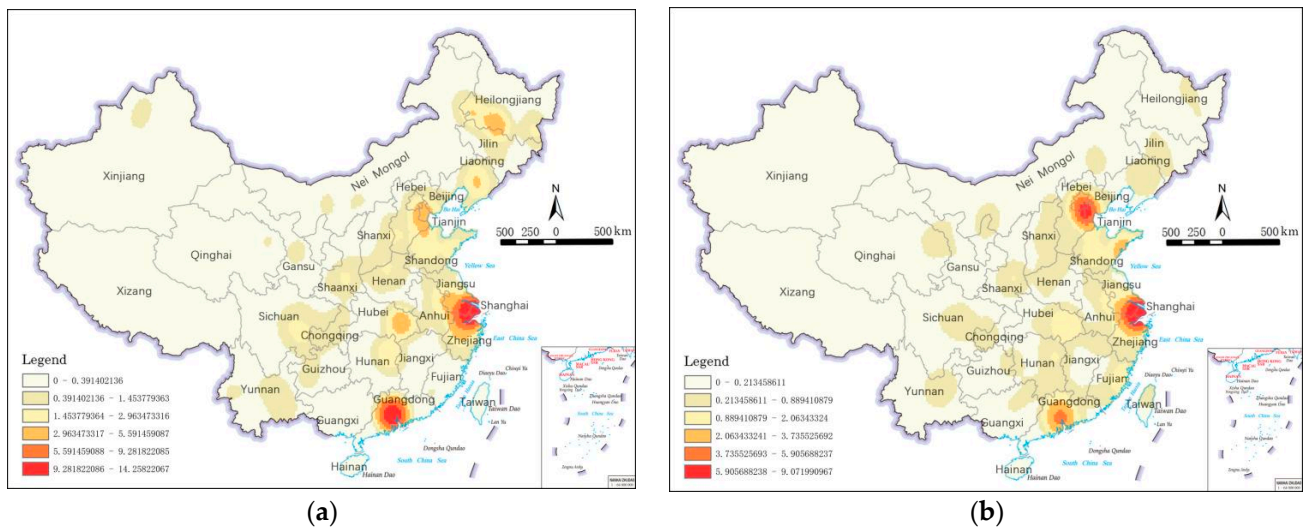


Figure 11. (a) Kernel density distribution of conserved Chinese industrial heritage; (b) kernel density distribution of reused Chinese industrial heritage.

4. Results

4.1. Construction of the Chinese Route of Industrial Heritage (CRIH)

Based on the CIHGD, the concept of cultural routes, and the experience of the ERIH, and in combination with China's industrial development process and regional differences, this study explored the development of the CRIH. The CRIH can be summarized according to site, region, line, and series (Figure 12), each of which is detailed below.



Figure 12. Composition of the Chinese Route of Industrial Heritage (CRIH).

4.1.1. CRIH Key Sites (Point Elements)

Sites refer to important industrial heritage sites. An important industrial heritage site has an important position and representation in China's industrial development at all stages, plays an important role in the industrialization process of the country or regions, and has special significance in industrial development. In this study, the selection scope included China's key cultural relic protection units (eight batches in total), the national industrial heritage list (three batches in total), China industrial heritage protection list (two batches in total), and the National Mine Park list (four batches in total).

Important industrial heritage sites were divided into Class 1 and Class 2. The selection scope comprised mainly the major historical and cultural sites protected at the national level, the national industrial heritage list, the China industrial heritage protection list, and the National Mine Park list. The selection criteria for Class 1 important industrial heritage sites were those included in three or more categories of the above-mentioned list; the selection criteria for Class 2 important industrial heritage sites were those included in two categories of the above-mentioned list. The statistics based on the GIS database demonstrated that 21 sites were selected as Class 1 important industrial heritage sites, and 79 as Class 2 important industrial heritage sites (Table S2).

4.1.2. CRIH Key Areas (Surface Elements)

Area refers to industrial heritage key regions and cities, which were defined as regions and cities with a high number of industrial heritage items at the national or regional level. Region and city were divided because Chinese industrial heritage generally presents a pattern of greater distribution in the east than in the west. The industrial foundation was more developed in the east and north. In the Beijing–Tianjin–Hebei Region, the Yangtze River Delta Region, Shandong, and Guangdong, the phenomenon of industrial heritage accumulation and dispersal occurred in many cities, creating an industrial heritage key region. However, in the central, northwest, and southwest regions of China, the number of industrial heritage items was relatively small, and the distribution characteristics of industrial heritage items were mainly concentrated in key cities, such as provincial capitals. Therefore, the distribution pattern of industrial heritage items concentrated in a single city was formed in the provinces of central and western regions; that is, major industrial heritage cities.

Thirty-three cities with more than 10 items of industrial heritage were defined as industrial heritage key cities (Table 2). The spatial distribution characteristics of these cities were analyzed, and 18 key cities and regions were concentrated in the northeast, Beijing–Tianjin–Hebei, and Yangtze River Delta Regions, which were defined as industrial heritage key regions.

Table 2. List of CRIH key areas.

Categories	Specific Items
Industrial heritage key regions (3)	Northeast Region (Heilongjiang, Jilin, Liaoning) 249 items, major cities: Harbin (38 items), Dalian (26 items), Shenyang (19 items), etc.
	Beijing–Tianjin–Hebei Region (Beijing, Tianjin, Hebei) 226 items, major cities: Tianjin (109 items), Beijing (62 items), Shijiazhuang (18 items), etc.
	Yangtze River Delta Region (Shanghai, Jiangsu, Zhejiang) 272 items, major cities: Shanghai (134 items), Hangzhou (71 items), Nanjing (60 items), Wuxi (31 items), Suzhou (24 items), etc.
Industrial heritage key cities (15)	Guangzhou (116 items), Jinan (70 items), Liuzhou (65 items), Wuhan (41 items), Chongqing (36 items), Lanzhou (29 items), Qingdao (29 items), Xi'an (27 items), Quanzhou (27 items), Taiyuan (23 items), Changsha (15 items), Fuzhou (14 items), Kunming (14 items), Chengdu (13 items), and Luoyang (12 items).

4.1.3. CRIH Key Routes (Line Elements)

Line represents an important industrial heritage line. Raw material input and product output of industrial production both depend on transportation. The spatial distribution of industrial heritage has a strong dependence on transportation lines. An important industrial heritage line is defined as an industrial heritage cultural line system that connects important industrial heritage sites and important regions and cities with China's important railways, highways, ancient post roads, and waterway transportation as the trunk lines.

The important industrial heritage lines are a corridor system linking key cities and regions with important railroads, highways, ancient post roads, and waterways as corridor axes in China. In this study, buffer zones were established at 5 km on both sides of important railways and rivers, and route grades were determined according to the number of industrial heritage sites per unit length of the buffer zone. Railways with 2.0–10.0 and 10.0–25.0 industrial heritage sites per km and rivers with 0.5–2.0 and 2.0–10.0 sites per km, as well as some other route grades, were selected as CRIH key routes (Table 3). These routes are similar to the heritage corridors proposed in the USA in the 1980s, and are the product of combining the greenway concept with the development of heritage conservation areas. This is of great significance to the overall conservation, development, and utilization of China's industrial heritage and cultural landscape.

Table 3. List of CRIH Key Routes.

Categories	Specific Items
Important railways	National railways: Middle East railway, Jingguang railway, Jiaoji railway, Jinpu railway, Jingfeng railway, Longhai railway, JiaoLiu railway, Southwest Third Line railway; Regional railways: Shenji railway, Shendan railway, Beijing–Bao railway, Shide railway, Shitai railway, Huning railway, Huhang railway, Ningwu railway
Important rivers	Haihe River, Beijing–Hangzhou Grand Canal, Lower Yellow River, Yangtze River

5. Discussion

5.1. Thematic Heritage Series of CRIH

Construction of the CRIH system is based on the concept of serial heritage. In this study, serial industrial heritage included development history series and industry type series. The development history series selected the industrial heritage preserved during the period important to the development of China's national industry. This selected industrial heritage was used to construct the industrial heritage series. The industry type series was based on the analysis and statistics of the industry types of Chinese industrial heritage. The corresponding industrial heritage series were established by selecting those types representing a large proportion and industry characteristics in the development of China's industry.

5.1.1. Development History Thematic Heritage Series

Based on the development of Chinese industry as described above, six heritage series have been selected to represent the development during each historical period. These include the following: (1) the Westernization Movement series (1861–1894): a total of 97 items, including two categories of government-run or government-supervised commercial industries established under the auspices of the Qing government, and traditional handicraft industries established purely by private individuals, with military industries as the main type of industry and civilian industries as the secondary one; (2) the late Qing New Deal series (1901–1911): a total of 167 items, in which the Qing government was forced to start the “late Qing New Deal” in order to save the country, objectively contributing to the initial development of national industry; the surviving heritage is mainly the industrial heritage of railways and their routes, and also includes the mining, textile, smelting, food, and tobacco industries; (3) the national industry development series (1914–1936): a total of 376 items, the demand for materials from various countries during World War I and

the stable situation under the Nanjing National Government objectively contributed to the development of national industry, with the main industry types being textiles, foodstuffs, railway transport, and warehousing; (4) the Anti-Japanese War series (1937–1945): 134 items in total, including the industrial heritage of the KMT-ruled areas, the Japanese-occupied areas, and the industrial heritage of the base areas, including military industries, machine manufacturing, and military supply-related industries, which are of great historical, cultural, and patriotic educational value; (5) the Soviet aid series (1953–1960): a total of 399 projects, 156 of which were built with Soviet aid and were the focus of industrial construction, including machine building, light manufacturing, textiles, chemicals, electrical manufacturing, and other industries; and (6) the Third Line construction series (1964–1978): a total of 219 projects, during which industrial construction was centered on the “Great Third Line” in the central and western inland areas and the “Small Third Line” in the inland areas of the border provinces.

5.1.2. Industrial Type Thematic Heritage Series

The progress of industrial development brought continuous changes in industry types. The classification of industry types in this study was based on historical documents such as “Materials of Modern Industrial History of China” [52] and “National Economic Industry Classification GBT4753-1984” [71]. These documents divide the known industrial heritage in China into 36 categories (Figure 13). We believe that based on the future development of industrial heritage research, a series of industry types with Chinese characteristics should be established as an industrial heritage protection system. In this study, due to space limitations, we selected the textile and mining industries for preliminary exploration.

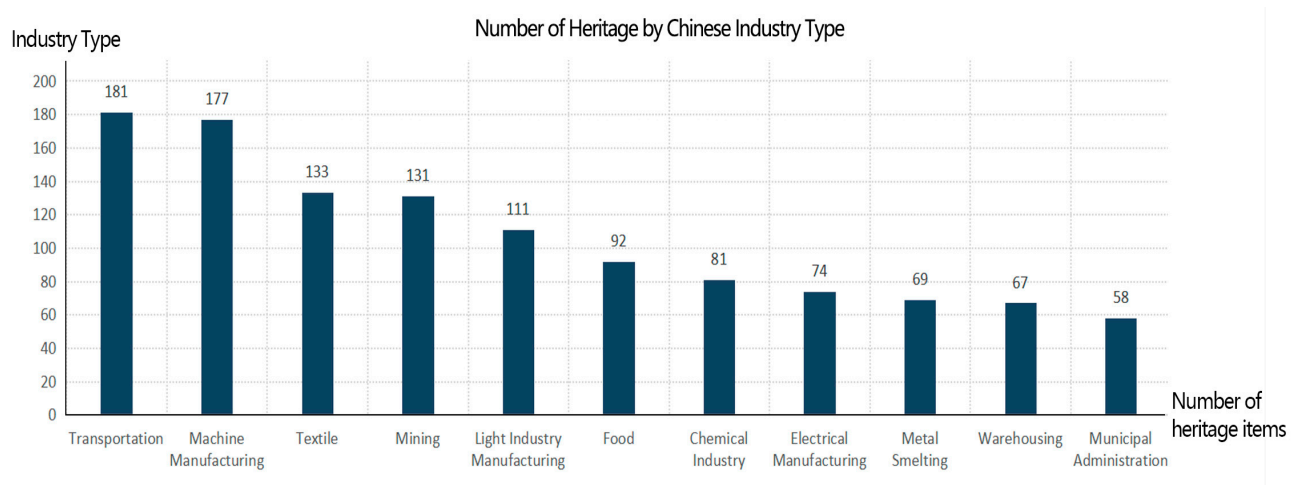


Figure 13. Number of heritage items by Chinese industry type.

Textile heritage series. China’s textile industry has a long history and has been an important export commodity in China since ancient times. The machine textile industry is an important type of light industry in China in modern times, and the textile industry has always accounted for more than 50% of the economy until the founding of the PRC [72]. Textile heritage was mainly concentrated in Jiangsu, Shanghai, Zhejiang, Qingdao, and Tianjin provinces and cities. Some of the more important textile heritage sites were Nantong Dasheng Yarn Factory founded by Zhang Jian in 1895; the former site of Hangzhou Tongyigong Yarn Factory founded by Pang Yuanji, Ding Bing, and Wang Zhenyuan in 1896; Qingdao National Cotton Factory No. 5 (now Qingdao Textile Valley Cultural and Creative District) founded in 1934; and Baoji Shenxin Yarn Factory founded in 1941.

Mining (mine park) heritage series. The database included 200 mining heritage sites, of which the largest number (72) were coal mines. Several oil and iron ore mines were also represented. Mining heritage comprised 88 national mine parks, among which the more important ones included Hubei Huangshi National Mine Park and Jiangxi Pingxiang

Anyuan National Mine Park (Daye Iron Mine of Hanye Ping Company), Guizhou Wanshan Mercury Mine National Mine Park, Zhejiang Cangnan Alum Mountain Mine Park, Shanxi Datong Jinhuaogong Mine National Mine Park, and Heilongjiang Province Daqing Oilfield National Mine Park. The construction of mine parks solved the contradiction between mine landscape protection and urban development and injected new vitality into urban renewal [73].

5.2. Multiple Values of CIHGD and CRIH

This study established the CIHGD and developed the Chinese Route of Industrial Heritage (CRIH) based on the CIHGD. The development and updating of the CIHGD is a dynamic and sustainable process. The CIHGD will be continuously enriched in the future by publishing information sharing and information requests through an online platform. Expanding social awareness of industrial heritage conservation will help the government include more industrial heritage within the statutory cultural heritage protection system, and develop detailed policies and standards to guide the conservation and reuse of industrial heritage.

The establishment of the CRIH is important for the holistic conservation and industrial tourism development of China's industrial heritage. In 2018, China's State Council called for the promotion of "all-area tourism" [4.1] with distinctive and differentiated characteristics; the establishment of the CRIH will help promote the construction of an all-area and regional tourism framework for industrial heritage. Combined with the above background, using CRIH as the basis for the study will help to integrate industrial heritage elements throughout China into regional planning and development, and contribute to the sustainable development of each province and city.

5.3. Areas for Improvement

Research on the valuation of industrial heritage in China is weak and the proportion of protected industrial heritage is low. Therefore, the cultural value of industrial heritage with statutory cultural heritage status is not necessarily higher than that of "potential" industrial heritage not currently protected. In the analysis of this study, no weighting was applied to the level of protection and other elements to differentiate the importance of industrial heritage. As the value assessment and conservation and use of industrial heritage in China develops, the group will follow up and update the study in the future when industrial heritage becomes more widely known and protected. As relevant research in China develops, cases of industrial heritage will continue to emerge. The CIHGD data will need to be continuously updated, and the data framework will be adjusted in the future according to the actual situation.

6. Conclusions

1. The CIHGD was established through extensive data collection. It was used to analyze the changes in the spatial distribution of industrial heritage in China, as well as the current status of conservation and reuse. In the temporal dimension, with the founding of the PRC as the node, China's industrial construction shows a development trend from accumulation along the coast to dispersal inland; in the spatial dimension, the recent development history of Chinese industry has created the current spatial distribution of industrial heritage, forming three key regions of industrial heritage, 14 key cities of industrial heritage, and important railway and water systems located in eastern China. In addition, as the proportion of both conservation and reuse of China's industrial heritage is low, there is an urgent need to develop a conservation system at the regional or national level.
2. Drawing on the ERIH system framework and based on the results of the CIHGD analysis, the Chinese Route of Industrial Heritage (CRIH) system was established. The system consists of three types of elements: points, surfaces, and routes, which represent important points of industrial heritage, important areas of industrial her-

itage, and important routes of industrial heritage. Among them, important routes of industrial heritage are both the heritage itself and the connecting bodies of other elements; all three together constitute China's Route of Industrial Heritage. In addition, based on the relevant attributes of industrial heritage, heritage routes series, such as "development history theme" and "industry type theme", were derived to expand the dimensions of heritage routes.

3. Development of the CRIH is conducive to the holistic conservation of the country's industrial heritage overall, to harmonize the gaps between different regions, and establish a mutual learning mechanism for conservation. In order to adapt to the national strategy for the protection of cultural heritage and industrial heritage, CRIH connects industrial heritage regionally, forming areas and routes, with the aim of establishing a national-scale system for the protection of industrial heritage in China. Applying the CRIH to tourism planning will help to break down the limitations of administrative divisions, to provide support and basis for the establishment of tourism routes for China's industrial heritage, allowing visitors to focus more on the different types of industrial heritage and to gain a comprehensive understanding of the unique value of China's industrial heritage.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/buildings14041065/s1>, Table S1: Data sources for Chinese Industrial Heritage GIS database (as of 2022). Table S2: List of CRIH Key Sites.

Author Contributions: Conceptualization, J.Z.; methodology, J.Z., H.S. and H.W.; software, J.Z., L.Z. and H.S.; validation, J.Z., L.Z. and H.S.; formal analysis, J.Z., L.Z. and H.S.; investigation, J.Z., L.Z. and Y.W.; resources, J.Z., S.X. and N.A.; data curation, J.Z. and Y.W.; writing—original draft preparation, J.Z., L.Z. and H.S.; writing—review and editing, J.Z., L.Z. and H.S.; visualization, J.Z., L.Z. and H.S.; supervision, H.W., S.X. and N.A.; project administration, S.X. and N.A.; funding acquisition, J.Z. All authors have read and agreed to the published version of the manuscript.

Funding: The project is supported by the National Natural Science Foundation of China (52008175), the National Social Science Foundation Art Major Project of China (21ZD01), the Project of Xiamen Science and Technology Bureau (3502Z20206014), and the Fundamental Research Funds for the Central Universities of Huaqiao University (ZQN-919).

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Acknowledgments: The authors thank Wu Onion, Zheng Ying, Hu Lian, Zhang Lei, and Zhang Tianjie from the School of Architecture, Tianjin University, and He Jie from the Tianjin Planning Institute, Liu Jing Harbin Institute of Technology for their help on the project.

Conflicts of Interest: The authors declare no conflicts of interest.

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