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Spatial–temporal distribution and evolution of the socialist built heritage in China, 1949–1978

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Abstract

As the material product of socialist construction activities, the socialist built heritage (SBH) represents socialist-era achievements and has unique cultural value. However, political controversy and inadequate conservation awareness have produced an unprecedented crisis. The aim of this study was to draw worldwide attention to the value of SBH to promote future conservation. Taking the socialist country of China as a representative example, the spatial distribution and spatial–temporal evolution of SBH during the Socialist Revolution and Construction Period (1949–1978) were explored using GIS analysis tools from typological and holistic perspectives. A geographic detector was also applied to reveal the driving factors that affected the distribution. The results indicate that (1) from both perspectives, the SBH presented uneven and clustering distributions compared with other heritages. High-density areas varied by heritage type but were virtually nonexistent in western and northwestern China. (2) Growth stages existed to different degrees for most types and the holistic SBH, primarily from 1953 to 1965. The centers of military heritage, industrial heritage, transport heritage, and the holistic SBH all exhibited north-to-south migration with narrowing and clustering of range areas. Cities such as Beijing were identified as hotspots. (3) GDP, financial revenue and capital investment constituted the major positive driving factors for the SBH distribution and interacted with other factors, with average altitude ∩ GDP having the strongest interpretation. These findings reveal the spatial–temporal distribution characteristics of Chinese SBH and provide concrete guidance and positive foundations for future conservation in China and the world.

Keywords Driving factors, GIS-based analysis, Socialist built heritage, Socialist China, Socialist period, Spatial distribution, Spatial–temporal evolution

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Introduction

The socialist system, which sprang from Thomas More's Utopian socialism in 1516, has been in development for over five hundred years [1]. This system has been in practice for over a hundred years, since the Russian Soviet Federative Socialist Republic was established in 1917. In its heyday, there were more than fifty socialist countries in the world. China was founded in 1949 and is currently recognized as the largest and most powerful socialist country in the world [2, 3]. Similar to other socialist countries, China underwent nationwide reforms of the socialist system after its foundation, breeding a series of socialist construction activities. The socialist built heritage (SBH) is considered to be the material products created by these activities. It covers a wide range of political, economic, cultural, military, diplomatic, scientific, technological, educational and other fields and presents an integral legacy at various scales, including landscape, architecture and facilities. Related concepts can be found in the socialist heritage [4], Soviet heritage [5, 6] and socialist modernism architecture [7, 8], as proposed by scholars in Russia and Georgia. However, it should be noted that with the collapse of the Soviet Union in 1991, many socialist regimes were overthrown, and capitalist systems were established. The new governments and the population considered the SBH formed by the construction of the war-aggressive Soviet Union a symbol of the past socialist era that needed to be dismantled or not utilized [9, 10]. As a result, the SBH has been politicized as a controversial heritage without widespread conservation recognition, and countries such as Ukraine, Poland and Armenia are facing the dilemma of its destruction and disappearance [11, 12]. Therefore, using China as an example, this study calls for the world society to focus on the pure value of SBH and to prepare for the future development of related conservation work.

A number of socialist or former socialist countries have created conservation legislation for their own SBH, such as the Revolutionary Monument Model of the Soviet Union [13], the Cultural Heritage Law of the Russian Federation (2012) [14], and the Cultural Heritage Protection Law of North Korea (1994) [15]. These countries have explicitly incorporated SBH into their conservation systems. They have emphasized heritage elements related to revolutionary movements, important historical figures and major events and integrated them with national culture and patriotic education. There are also some Central and Eastern European countries that, despite having built their national identities on anti-communist foundations, still discuss the cultural values of the SBH and have made policy recommendations accordingly [16]. Belarus has refrained from considering anti-communism a component of the national narrative and has even developed a World Heritage proposal for the socialist architectural ensemble of the Minsk city center [17]. International organizations, such as ICOMOS and the UNESCO World Heritage Committee, have continued to promote diverse heritage protection policies. In particular, through initiatives for new heritage types such as contemporary monuments [18] and rural heritage [19], a small proportion of SBHs have been protected legally but without specific regulations.

Although a more comprehensive heritage protection system has been formed in China through the National Key Cultural Relics Protection Unit [20], no specific regulations for SBH have been enacted. The National Cultural Heritage Administration has launched successive selections of twentieth century heritage [21] and national industrial heritage [22] in the present century, enabling small amounts of the SBH to be registered, but legal protection has yet to be achieved.

Additionally, several countries have developed multi-conservation utilization for SBH with significant value. For example, the Ministry of Highway Construction office (1975) in Tbilisi, Georgia, which was listed on the Russian National Heritage List (2007), was acquired by the Bank of Georgia Headquarters and continued to be an office building after simple interior restoration [23]. The landmark National Television Tower (1966) located on the top of Ještěd Hill in the Czech Republic was transformed into a hotel by real estate developers after a short absence during the Eastern European upheaval, making it once again a famous local tourist attraction [24]. There are many similar cases, such as the House of Soviet (Russia, 1970) [25], Druzhba Sanatorium (Ukraine, 1985) [26], Grodno Drama Theater (Belarus, 1984) [27], and Zhengzhou No. 2 Grinding Wheel Factory (China, 1964) [28]. Through proper preservation and reuse, the value of these SBHs has been recreated, effectively contributing to the industrial revitalization, residential activities, and cultural and educational development of heritage sites.

In addition to the abovementioned policies and practices, many scholars have conducted rich theoretical studies on SBH with a focus on the following five areas. First, based on examinations of traditional literature, overview studies of conceptual identification [29–31], development history [32, 33] and conservation policy trends of SBH [14, 34, 35] have been conducted. Most of them concentrated on Eastern European countries such as Romania, Yugoslavia and Poland with the aim of advancing the socialist politicization of World Heritage. Second, from the perspective of heritage value and implications, the identity attributes [36–38], conservation dilemmas [39, 40] and public perception of SBH [41, 42] have been discussed. These studies note that political controversies should be put aside to pay attention to the historical and cultural value of SBH. Third, urban development potential [43, 44], tourism mutual promotion [45–48] and future policies [49, 50] have also been studied in terms of conservation utilization and development. Strategies including target transformation [51], cultural marketing [52], functional replacement [53], adaptive reuse [7], and green renovation [54] have been proposed. Fourth, case studies of SBHs have been conducted from the single-type perspective involving industrial enterprises [55], collective farms [56], the iconic Institutes of Marx-Engels-Lenin [57], collective residences [58], housing construction cooperatives [59], and socialist train stations [60] in relation to organizational management [61], sustainable development [62], and stylistic features [63, 64]. Fifth, based on GIS analysis, the spatial distribution of SBHs has been examined from macroregional views, mostly at the national [65, 66] and provincial scales [67, 68]. Compared to the other four areas, few studies have been conducted in this area, which is dominated by the current distribution of individual types. Few references from a temporal evolutionary perspective have been integrated.

Studies on SBH in China with international influence have gradually been undertaken but are still very limited in number. Among them, studies on single types account for a high proportion, such as industrial plants of the first Five-Year Plan [69], factories of the Third Front [70, 71] and people's communes [72–74]. However, no studies have examined the overall spatial–temporal distribution by combining multiple SBH types.

Global efforts have been made for SBH conservation in terms of policy, practice, and theoretical research, but these studies have centered on the historical development of and dedicated research on single types. Since the SBH is a holistic heritage that incorporates various types and periods, it is not adequately studied from single-type perspectives only, and interpretation from a multitype view is urgently needed. Therefore, to better identify and conserve SBHs, this study considered SBHs in the Socialist Revolution and Construction Period (SRCP, 1949–1978) of China as an example and explored their spatial distribution, spatial–temporal evolution, and driving factors across both typological and holistic perspectives. Based on current Chinese heritage conservation lists, heritage data points were extracted to create a GIS-based database. Then, several GIS analysis tools were applied to assess the spatial–temporal distribution of SBH and its evolutionary process. Finally, the distribution numbers of SBH were statistically analyzed with social environmental data to clarify the driving factors. The results can provide an innovative and systematic picture of the distribution and evolutionary patterns of this young heritage, laying the scientific basis for future conservation.

The main objectives of this study include the following three points:

(1) To analyze the spatial distribution and spatial–temporal evolutionary characteristics of SBH from both typological and holistic perspectives;
(2) To reveal the driving factors of the spatial distribution of SBH combined with statistical analysis of social environmental data;
(3) To propose preliminary future conservation methods for SBH based on the spatial distribution.

The paper is structured as follows. This "Introduction" section provides an overview of current issues, conservation policies, practical projects, and theoretical studies related to SBH. In the "Materials and Methods" section, the SBH database setup process and GIS analysis tools are described. In the "Results" section, the analysis results of spatial distribution, spatial–temporal evolution and driving factors are presented from both typological and holistic perspectives. In the "Discussion" section, the three results mentioned above are discussed along with preliminary proposals and limitations. Finally, in the "Conclusions" section, the main findings are summarized.

Materials and methods

Database set-up

Data resources

This study was limited to SBHs in the SRCP of China given the typicality and the urgency of their protection. The SRCP is officially regarded as the period of the most rapid development and extensive construction activities in socialist China and set the firm foundation for today's growth and prosperity [3]. Nevertheless, due to restricted conditions, many SBHs of that period are being replaced by present-day construction. Accordingly, this type of heritage is becoming increasingly valuable and endangered in current China.

As there is not yet an equivalent conservation list for SBH in China, this study selected data from existing acknowledged and authoritative lists to construct the point database (Accessed on 1 May 2023). In particular, the Chinese Key Cultural Heritage Units were used as the core source for the most comprehensive conservation legislation. This source contains both national and provincial levels (excluding Taiwan, Hong Kong and Macau), with information on the former obtained from the National Cultural Heritage Administration [75] and the latter from local cultural and tourism departments. To complement this, national industrial heritage and twentieth century heritage were considered additional sources using information accessed from government websites [76, 77]. According to the definition of SBH, two selection principles were established: (1) construction or renovation after 1 October 1949 and (2) strong relevance to the socialist construction practice. A total of 861 heritage sites were finally identified, as listed in Table 1. In addition to information on the title, construction date, usage, and other attributes of these SBHs, the geographical location (latitude and longitude) was searched using the coordinate extraction function of Baidu Maps. All information was sorted into Excel 2016 and then point datasets were created in ArcGIS 10.8, resulting in spatial distribution maps of SBHs in China. The base map was produced from the 1:22 million map of China (review

Table 1 Source-specific information on the database

Protection list	Number of sites protected	Number of SBH included
National key cultural relics protection units	5058	78
Provincial key cultural relics protection units	Anhui (708); Beijing (255); Fujian (942); Gansu (532); Guangdong (884); Guangxi (465); Guizhou (654); Hainan (208); Hebei (963); Henan (1521); Heilongjiang (348); Hubei (920); Hunan (1004); Jilin (56); Jiangsu (952); Jiangxi (920); Liaoning (673); Inner Mongolia (561); Ningxia (156); Qinghai (466); Shandong (1968); Shanxi (779); Shaanxi (1097); Shanghai (228); Sichuan (1519); Tianjin (220); Tibet (417); Xinjiang (620); Yunnan (389); Zhejiang (910); Chongqing (444)	Anhui (17); Beijing (7); Fujian (10); Gansu (8); Guangdong (10); Guangxi (11); Guizhou (27); Hainan (9); Hebei (7); Henan (49); Heilongjiang (15); Hubei (19); Hunan (44); Jilin (13); Jiangsu (12); Jiangxi (20); Liaoning (19); Inner Mongolia (22); Ningxia (5); Qinghai (13); Shandong (53); Shanxi (11); Shaanxi (23); Shanghai (5); Sichuan (40); Tianjin (6); Tibet (20); Xinjiang (34); Yunnan (11); Zhejiang (17); Chongqing (20)
National industrial heritage	197	80
20th century heritage	697	128
Total	27731[a]	861[b]

[a] Repeated appearances of the same site have not been excluded

[b] Repeated appearances of the same site have been excluded. All heritage data were accessed as of 1 May 2023

number GS(2020)4619) from the National Standard Map Service website.

The *Comprehensive Statistical Data and Materials on 50 Years of New China* [78], which is relatively well documented and authoritative, was chosen as the source of social environmental information. Corresponding to the area in which the SBH was located (precisely, the prefecture level), annual average data (30 years) of the social environment, such as natural geography (including average altitude, terrain undulation, mineral reserves, and arable area), transportation (including railway mileage and road mileage), economy and population (including total population, population density, gross domestic product (GDP), and GDP per capita), and policy support (including financial revenue and capital investment), i.e., potential driving factors, were screened and incorporated into the database. It was assumed that these variables were relatively stable in their changes over the time range of the study.

Type classification

It is universally accepted that the content and purpose of socialist construction activities change and that the areas and types of SBH dynamically evolve with them. To classify the SBH typology more comprehensively and objectively, this study referred to descriptions of socialist construction in the literature, such as *The History of the People's Republic of China (2nd ed.)* [79], *Reconstruire la Chine: trente ans d'urbanisme (1949–1979)* [80], *A History of Chinese Modern Architecture* [81], and *Modernism in China: Architectural Visions and Revolutions* [82]. Nine main types were identified for the entire study period using the following codes:

- Type A: Municipal heritage;
- Type B: Military heritage;
- Type C: Industrial heritage;
- Type D: Agroforestry heritage;
- Type E: Hydraulic heritage;
- Type F: Transport heritage;
- Type G: Science, education, culture, health and sports heritage;
- Type H: Diplomatic heritage;
- Type I: Others.

Development stage division

As the product of socialist construction activities, the development paths of SBH correspond to the periods of Chinese socialist history. Therefore, by referring mainly to the phasing criteria of *The History of the People's Republic of China (2nd edition)* [79] supplemented by *A History of Chinese Modern Architecture* [81], the development of SBH in the SRCP was divided into four stages as follows:

- Stage I (1949–1952): the rehabilitation period of the national economy;
- Stage II (1953–1957): the implementation period of the first Five-Year Plan;
- Stage III (1958–1965): the Great Leaps Forward and Adjustment period of the national economy;
- Stage IV (1966–1978): the Great Proletarian Cultural Revolution period.

Analysis tools

On a national geographical scale, all SBHs can be considered one-point elements whose geographical information and numbers constitute the basic analysis parameters. After the data were transformed in ArcGIS 10.8, built-in analysis techniques were applied to further explore the evolutionary features. This process involved the following three steps: (1) kernel density estimation and average nearest neighbor were used to determine the spatial distribution and pattern; (2) kernel density estimation, standard deviation ellipse and mean centering were employed to explore the spatial–temporal evolution, including changes in number, center and range, and Getis-Ord Gi* was used to identify hotspot areas; (3) a geographical detector was utilized to determine and assess the driving factors of the SBH evolution [83, 84]. The first two steps were performed based on typological and holistic perspectives, whereas the last step considered only holistic perspectives.

Kernel density estimation

Kernel density estimation was used to evaluate the density of SBH elements around each output raster image unit to judge the degree of aggregation and spatial distribution characteristics under different conditions (including holistic, type and stage). According to Eqs. 1 and 2, the density of each SBH element within the distance range to the center was calculated and superimposed on the same locations to obtain an overall density distribution map. The continuous smoothing surface indicated where SBH was more concentrated, with lighter to darker colors corresponding to smaller to larger values [85].

$$f(x) = \sum_{i=1}^{n} \frac{1}{h^2} \cdot \lambda \cdot \left(\frac{x - x_i}{h}\right) \tag{1}$$

$$h = 0.9 \times \min\left(SD, \sqrt{\frac{1}{\ln(2)} \cdot Dm}\right) \cdot n^{-2} \tag{2}$$

f(x) is the kernel density at the x-th SBH element, n is the number of SBH elements whose distance from x is equal to or less than h, h is the distance decay threshold (kernel density bandwidth value), λ is the spatial weight function, D_m is the median distance from the mean center to each SBH, and SD is the standard deviation distance from the mean center to each SBH.

Average nearest neighbor

To adopt both a typological and a holistic perspective, the average nearest neighbor was applied to identify the distribution patterns of SBH, including clustered, discrete and random, and its associated attributes across the region. The nearest neighbor index R, z score and p value were the main rubrics of the tool. R was the ratio of average nearest neighbor distance and expected nearest neighbor distance, and the other two were measures of statistical significance. When z and p were statistically significant, an R value less than 1.0 characterized clustering trends, a value greater than 1.0 characterized discrete trends, and a value of 0.0 characterized random trends [86], calculated as in Eqs. 3–5.

$$R = \frac{\overline{D}O}{\overline{D}E} \tag{3}$$

$$\overline{D}O = \frac{\sum_{i=1}^{n} di}{n} \tag{4}$$

$$\overline{D}E = \frac{0.5}{\sqrt{n/A}} \tag{5}$$

R is the average nearest neighbor index, $\overline{D}O$ is the average nearest neighbor distance between each SBH and its nearest neighbor SBH, $\overline{D}E$ is the expected nearest neighbor distance between each SBH and its nearest neighbor SBH, n is the total number of SBH elements, d_i is the distance between the i-th SBH and its nearest neighbor SBH, and A is the total study area.

Standard deviation ellipse

The standard deviation ellipse, also known as directional distribution, was chosen to separately measure the standard distances of SBH elements in the X and Y directions from a global spatial perspective for different stages to form the axis of an ellipse containing all elements. In detail, the main trend direction of the SBH distribution was judged by elliptical azimuth, with the long axis showing the direction of maximum diffusion and its dispersion degree and the short axis showing the direction of minimum diffusion [87], as computed in Eqs. 6–8. By overlaying the four stages of the ellipse, the evolutionary trend of the spatial distribution of SBH could be investigated in terms of both extent and direction.

$$RAz = \tan^{-1}\left[\frac{\sum_1^n xi^2 - \sum_1^n yi^2 + \sqrt{\left(\sum_1^n xi^2 - \sum_1^n yi^2\right)^2 + 4 \cdot \sum_1^n xiyi}}{2 \cdot \sum_1^n xiyi}\right] \tag{6}$$

$$D = \sqrt{\frac{\sum_1^n \left(xi \cos RAz - yi \sin RAz\right)^2}{\sum_1^n \left(xi \sin RAz - yi \cos RAz\right)^2}} \quad (7)$$

$$S = \sqrt{\frac{\sum_1^n \left(xi \sin RAz - yi \cos RAz\right)^2}{n}} \quad (8)$$

n is the total number of SBH elements, x_i and y_i are the spatial coordinates of the i-th SBH element, Az is the azimuth of the standard deviation ellipse, D is directionality, and S is dispersion.

Mean center

Using the mean center in this study, the geographical centers of the SBH distribution at different stages could be identified. As shown in Eq. 9, by calculating the mean x and y coordinates of all SBHs in the study area, it is possible to track the trajectory of the SBH distribution after superposition and cascade and thus compare the distribution characteristics at each stage [85].

$$\overline{X} = \frac{\sum_{i=1}^{n} xi}{n}, \overline{Y} = \frac{\sum_{i=1}^{n} yi}{n} \quad (9)$$

n is the total number of SBH elements, $\overline{X}$ is the mean central horizontal coordinate, $\overline{Y}$ is the mean central vertical coordinate, x_i and y_i are the coordinates of the i-th SBH element.

Getis-Ord Gi*

By calculating the Getis-Ord Gi* index for each prefecture-level city, hotspot analysis was performed from a two-dimensional spatial perspective to identify where clusters of high values (hotspot areas) and low values (coldspot areas) of SBH occurred [87], as shown in Eq. 10. A positive GiZScore score with p presenting statistical significance meant that region i and its surroundings were hot areas for SBH and vice versa. This tool is able to present the results of the holistic evolution of SBH to propose further protection strategies.

$$Gi* = \frac{\sum_{j=1}^{n} wi,jxj - \frac{\sum_{j=1}^{n} xj}{n} \sum_{j=1}^{n} wi,j}{\sqrt{\frac{\sum_{j=1}^{n} xj^2}{n} - \left(\frac{\sum_{j=1}^{n} xj}{n}\right)^2} \cdot \sqrt{\frac{\left[n \sum_{j=1}^{n} wi,j^2 - \left(\sum_{j=1}^{n} wi,j\right)^2\right]}{n-1}}} \quad (10)$$

n is the total number of SBH elements, x_j is the attribute value of the j-th SBH element j, and $w_{i,j}$ is the spatial weight between the i-th and j-th SBH elements.

Geographical detector

A geographical detector was ultimately selected to examine the driving factors of the spatial distribution of SBH. The working principle assumed that the underlying condition for the independent variables to have significant effects on their dependent variable was similarity in spatial distribution [88]. Concretely, as illustrated in Eq. 11, the q value and p value were set to identify this coupling in the single-factor detector, with the former showing the coupling strength (range 0–1.0) and the latter indicating significance. When the q value was larger and significant, it indicated that the independent variable had a stronger effect on the dependent variable. In the interaction detector, the presence or absence of an interaction (strength, direction and whether it is linear) between two factors was determined by calculating and comparing the q values of the respective variables and the superimposed values [89]. In this study, the distribution numbers of SBH (prefecture-level cities) were considered the dependent variable, while the social environmental data acted as the independent variables.

$$q = \left(n\sigma^2 - \sum_{i=1}^{L} ni\sigma i^2\right)/n\sigma^2 \quad (11)$$

n is the total number of SBH elements, σ^2 is the variance of SBH elements, n_i and σ_i^2 are the sample size and variance of the social environmental variable i, and L is the total number of independent variables (nine in this study).

Results

Structural characteristics

Figure 1a displays the quantitative structure of the nine types of SBH that are currently entered into the conservation lists. Specifically, type G was the largest heritage type in total at 29.62%, while type C followed with 17.89%, both maintaining absolute dominance. The totals for types A, B, D, E, G, and H remained similar, all at approximately 9.00%, which was one half of the total for type C. Types F and I, with the smallest totals, accounted for 5.11% and 3.14%, respectively. There were large differences between the various types, with an overall trapezoidal composition.

For the chronological structure, as shown in Fig. 1b, the total amount of heritage was similar across the stages.

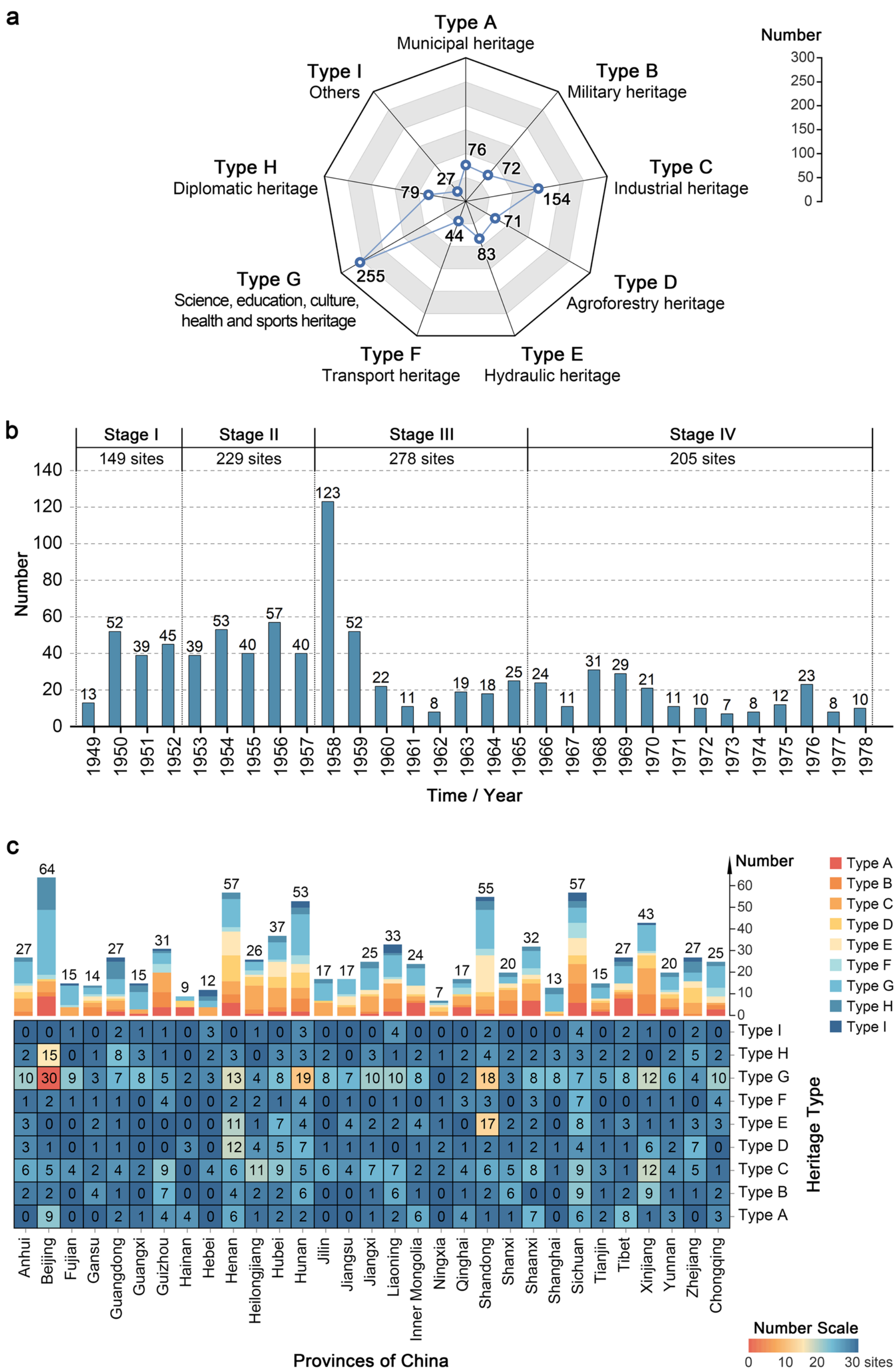

Fig. 1 Structural Characteristics of SBH. **a** Proportion of different types; **b** Number per year; **c** Number of each type in different provinces

However, there were differences in annual numbers, with a general trend of growth → decline → fluctuation. Stage I, with the least heritage (17.31%), exhibited a trend of rapid growth → stability. With the second highest number (26.60%), stage II had relatively little variation annually, remaining at approximately 5.00%. Stage III held the largest heritage number (32.29%), with a trend of rapid decrease → stability. The year 1958 was the peak of this stage and of the 30-year period, accounting for 14.29%. The proportion of stage IV was 23.81%, showing multiple fluctuations with a low annual average (1.83%).

The number distribution of each SBH type in different provinces was also counted, as illustrated in Fig. 1c. In terms of provinces, Beijing, Henan, Sichuan, Shandong, and Hunan had the largest total number, all greater than 50 (5.81%), while Xinjiang, Hubei, Liaoning, Shaanxi, and Guizhou came next, all maintaining proportions above 3.48%. Ningxia and Hainan were the only two provinces with a total of less than 10 sites, making up 0.08% and 1.05%, respectively. Focusing on heritage type, types C and G covered the most provinces with 30 and 29 in each, while type I was the lowest with only 13. The other types were spread over 22 to 29 provinces. Among them, Beijing, Anhui, Guangxi, Henan, Hunan, Jiangsu, Jiangxi, Liaoning, Shandong, Shanghai, and Chongqing were all dominated by type G, with numbers ranging from 7 to 30, whereas Guizhou, Heilongjiang, Sichuan and Xinjiang were dominated by type C, all greater than 9. Compared to other provinces, Beijing had higher proportions of types A and H, while Henan and Shandong had relatively high proportions of types D and E.

Spatial distribution characteristics

Distribution characteristics from the typological perspective

Spatial distribution characteristics, including density and pattern, were calculated by kernel density estimation and average nearest neighbor. The results are presented in Fig. 2 and Table 2.

Across the different types, the spatial distribution of SBH varied enormously with different high-density areas. First, type A was mainly distributed in northern and central China, with Beijing as the high-density area (mean kernel density $<KD_M>=0.000055$) and southern Shaanxi ($KD_M=0.000035$) and western Chongqing-eastern Sichuan ($KD_M=0.000032$) as the medium-density areas (Fig. 2a).

Second, the high-density areas of types B and F were both concentrated in southwest China, i.e. east Sichuan-west Chongqing-northwest Guizhou and east Hunan, but the former had higher KD_M values of 0.000042 and 0.000028, respectively. They occupied a medium-density area in west China together but differed due to type B in northwest Xinjiang ($KD_M=0.000019$) and type F in central Qinghai ($KD_M=0.000010$). A number of these two types were also found in Shandong, Shaanxi and Henan (Fig. 2b and f).

Third, type C was more abundant and widely distributed in two high-density areas, namely, south Anhui-west Hubei-north Jiangxi ($KD_M=0.000083$) and Tianjin-east Hebei ($KD_M=0.000072$), as well as several medium-density areas in central Shaanxi, east Heilongjiang, northwest Xinjiang, east Sichuan, central Guizhou and other areas (Fig. 2c).

Fourth, west Henan in central China was the only high-density area for type D ($KD_M=0.000065$), while north Zhejiang ($KD_M=0.000048$) and north Xinjiang ($KD_M=0.000029$) were medium-density areas. Furthermore, a few heritages existed in provinces such as Heilongjiang, Hunan and Sichuan (Fig. 2d).

Fifth, the distribution structures of types E, G and H were quite similar with small but concentrated scales, although the total for type G was greater. Both of these had high-density areas centered in Beijing, with KD_M values of 0.000390 and 0.000121, respectively, except for type E, where the area was located in southwest Shandong ($KD_M=0.000186$). All three had a minor distribution in northern Henan, western Chongqing, and northwestern Jiangxi-northeastern Hunan, but types G and H also encompassed northern Zhejiang-southern Jiangsu-Shanghai (Fig. 2e, g and h).

Sixth, type I, which had the lowest heritage number, covered a wider region with the high-density area concentrated in south Liaoning-Tianjin-east Hebei-northeast Shanxi (also known as the Bohai Bay Rim, $KD_M=0.000012$) and two medium-density areas in western Sichuan and east Guizhou-west Hunan-northwest Guangxi (Fig. 2i). In combination, types C and F showed comparatively more widespread spatial distributions, i.e., multiple medium- and high-density areas, while types E, G and H had only one medium- or high-density area. All SBH types presented a clear imbalance and were mainly distributed in areas other than western and northwestern China.

Furthermore, all types exhibited varying degrees of clustering, apart from type I, which lacked statistical significance. Type G held the highest z score (− 18.2051) with the strongest clustering, while type F had the weakest clustering with a z score of only − 1.7446, which was

(See figure on next page.)

Fig. 2 Kernel density distribution for each SBH type. **a** Type A (*N* = 76); **b** Type B (*N* = 72); **c** Type C (*N* = 154); **d** Type D (*N* = 71); **e** Type E (*N* = 83); **f** Type F (*N* = 44); **g** Type G (*N* = 255); **h** Type H (*N* = 79); **i** Type I (*N* = 27)

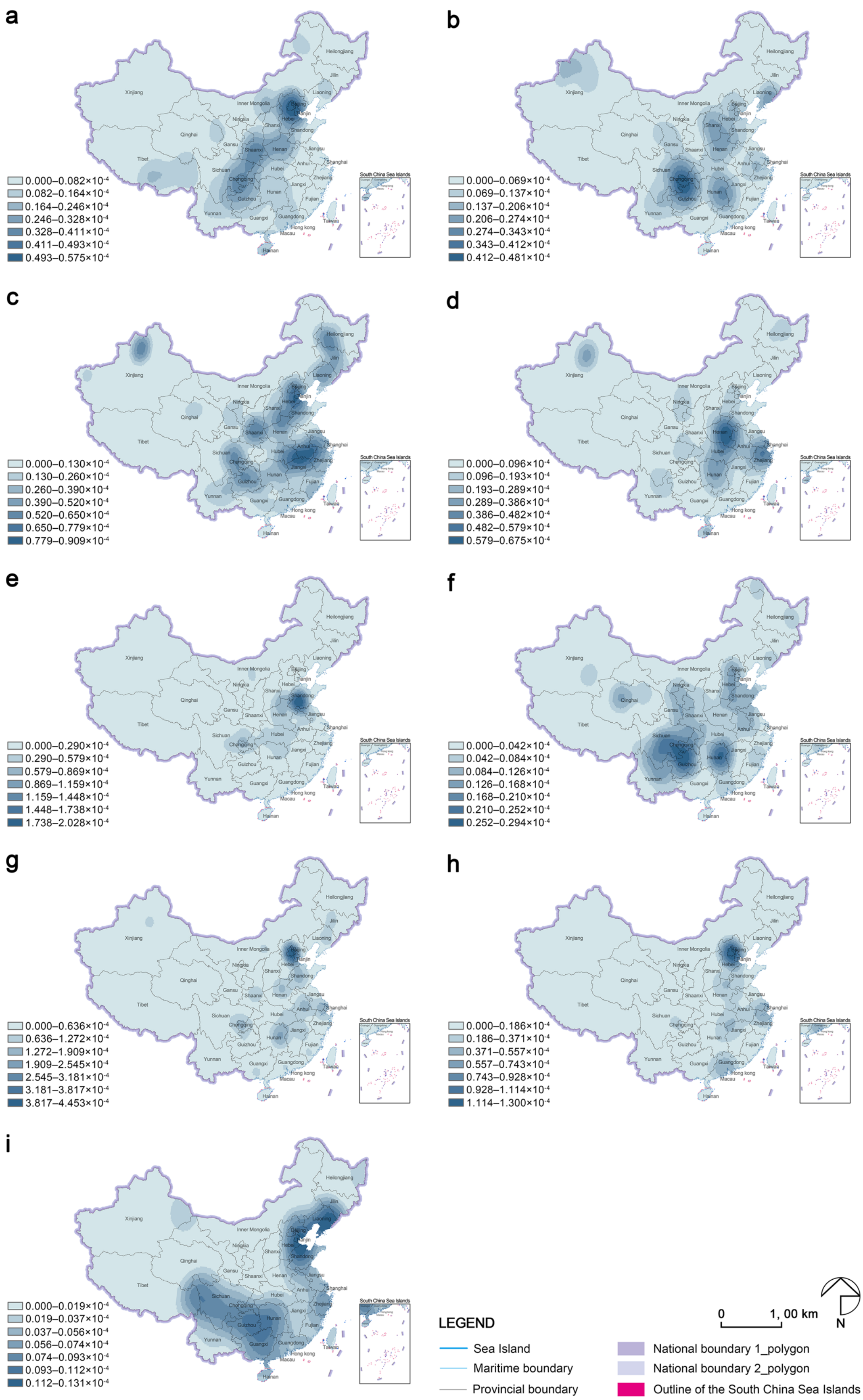

Fig. 2 (See legend on previous page.)

Table 2 Global Moran's I results for typological and holistic conditions

Type	R	Average nearest neighbor distance (m)	Expected nearest neighbor distance (m)	z score	*p* value	Distribution pattern
A	0.6362	129068.3145	202885.3068	− 6.0680	0.0000	Significant clustered
B	0.6270	127680.4795	203639.7227	− 6.0550	0.0000	Significant clustered
C	0.5648	82413.5344	145907.2163	− 10.3311	0.0000	Significant clustered
D	0.7096	150970.8374	212758.8832	− 4.6814	0.0000	Significant clustered
E	0.7320	131879.6611	180174.2345	− 4.6717	0.0000	Significant clustered
F	0.8625	197882.9831	229424.8868	− 1.7446	0.0810	Weaker clustered
G	0.4041	47915.6798	118581.2723	− 18.2051	0.0000	Significant clustered
H	0.3749	57199.8984	152560.2972	− 10.6285	0.0000	Significant clustered
I	0.8778	252810.9089	287995.5078	− 1.2145	0.2246	Random
Holistic	0.4040	28694.6582	71027.8633	− 33.4568	0.0000	Significant clustered

not particularly statistically significant ($p = 0.08 > 0.05$). The remaining types all featured significant clustering, with z scores from −10.6285 to −4.6717.

Distribution characteristics from the holistic perspective

As indicated in Fig. 3, the SBH was widely and unevenly distributed in general, with high-density areas mainly in north, central, east, and south China ($KD_M > 0.000072$) and fewer in the west and northeast. A spatial distribution structure was formed in which Beijing was the high-density area, followed by five medium-density areas in north Henan-southwest Shandong, east Hunan, north Zhejiang-south Jiangsu-west Shanghai, west Chongqing, and northwest Xinjiang. The former had a KD_M value of 0.001152, while the latter had KD_M values of 0.000571, 0.000559, 0.000462, 0.000456, and 0.000214, respectively. The average nearest neighbor result for the holistic condition indicated that SBH was extremely clustered (z score = − 33.4568)

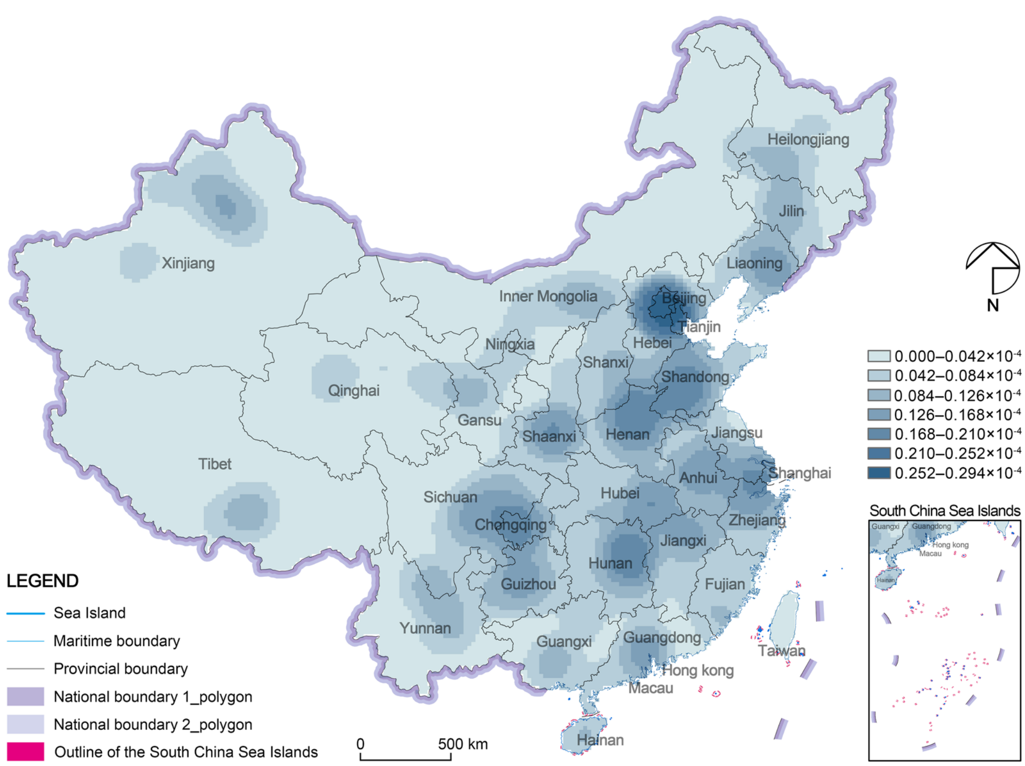

Fig. 3 Holistic kernel density distribution of SBH ($N = 861$)

and characterized by widespread distribution and high concentration.

Spatial–temporal evolution characteristics

Evolutionary characteristics from the typological perspective

Due to limitations of the number of each SBH type at each stage, a numerical distribution method was employed to explore the evolutionary characteristics for different types, as visualized in Figs. 4 and 5. Notable differences were revealed in the spatial–temporal evolutionary characteristics from the typological perspective in both quantity and geographical distribution. Broadly, they can be classified into three situations.

In the first situation, some heritage types featured a growth → decline evolution, including types A, C, G, and H. All of them maintained a relatively small number in stage I and expanded rapidly in stage II or III but contracted again in stage IV. With regard to quantity, type A had the weakest trend of growth (0.35%), while type G had the strongest trend (4.18%). Type H experienced the weakest contraction trend (0.46%), while types C and G had the strongest trends (all at 4.30%). For geographical distribution, the high-value area for type C displayed a north-to-south migration, while the other types showed insignificant changes. In particular, types A, C and G were all more clustered in stage I, situated in Beijing-Sichuan, Xinjiang and Beijing-Guangxi, respectively, while type H was dispersed. During the growth stage, there was extensive expansion of types C and G with new high-value areas such as Hunan, Shandong, Hunan, Henan, and Heilongjiang, while the increase in types A and H was focused on Beijing with 7 and 12 sites, respectively. However, in the contraction stage, the four types differed considerably in the high-value areas, which, in numbered order, were Shaanxi, Guizhou-Sichuan, Beijing-Hunan-Jiangxi, and Guangdong-Jiangxi-Shandong.

In the second situation, types B, D, E and F were characterized by continuous growth over the study period. With regard to quantity, type E increased the most at 4.18%, followed by type D (2.67%), while type F was the smallest at 1.27%. With regard to geographical distribution, the high-value areas of types B and F in stage I were

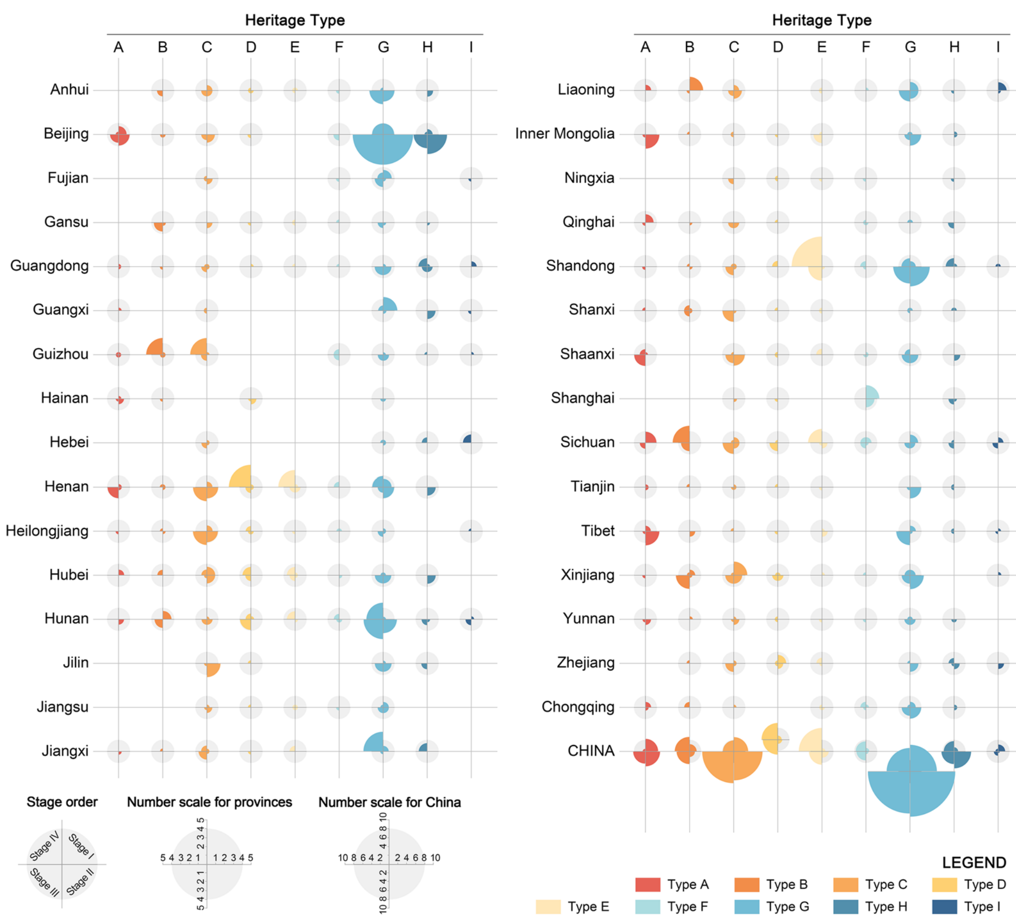

Fig. 4 Evolutionary scale of each heritage type in different provinces

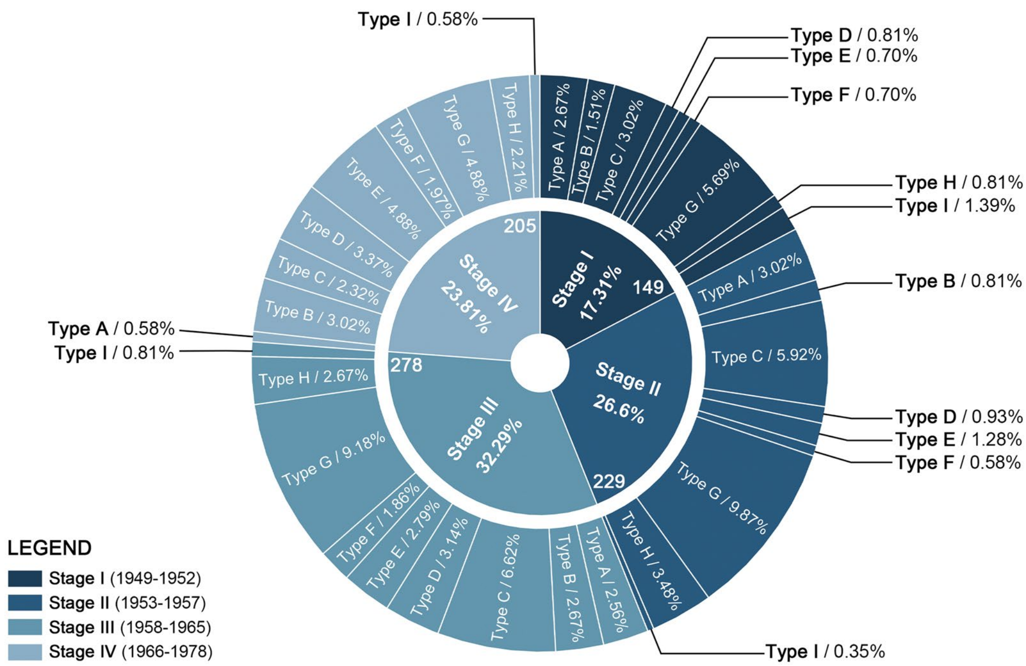

Fig. 5 Percentage change in the SBH number of each type at different stages

both in north China, i.e., Liaoning and Shandong, respectively, while type D was positioned in Zhejiang and type E was insignificant. In the next three stages, the high-value areas of types B and F started to shift to the southwest, mainly Sichuan and Chongqing, while type D moved to the central areas of Henan and Hunan. In contrast, type E appeared in both Shandong and Henan, two high-value areas, without significant migration.

In the third situation, only type I presented a fluctuating and decreasing evolutionary feature. With regard to quantity, it contracted at stages II and IV with decreases of 1.04% and 0.23% each and increased at stage III (0.46%). With regard to geographical distribution, the high-value areas of type I in stage I were clustered in Liaoning and Sichuan, whereas in the last three stages, high-value areas such as Zhejiang, Hunan and Hebei appeared in sequence with no obvious migration characteristics.

Evolutionary characteristics from the holistic perspective

The kernel density distribution for each development stage was also calculated to investigate the changing characteristics of the spatial–temporal distribution from a holistic perspective, as shown in Fig. 6. There were many differences in the distribution structure of SBH at different stages.

Stage I, which contained the fewest heritage sites, was the most extensive with medium and high value areas in all provinces. South Liaoning and west Chongqing-east Sichuan were the most dominant high-density areas with KD_M values of 0.000084 and 0.000074, respectively, accompanied by medium-density areas such as Beijing-Tianjin-north Hebei, north Zhejiang-south Jiangsu-Shanghai, north Henan and north Xinjiang (Fig. 6a).

For stage II, the total number grew somewhat (80 sites) with a clear tendency to cluster in Beijing. The distribution structure was established with Beijing as the high-density center ($KD_M = 0.000311$), containing three major medium-density areas in north Henan, northwest Hunan-southwest Hunan and north Zhejiang-south Jiangsu-Shanghai-west Anhui. The densities in Liaoning, Chongqing, Sichuan, and Henan were relatively weakened, representing the high-density areas moving closer to Beijing (Fig. 6b).

In stage III, which included the largest heritage number, the distribution structure of SBH was reinforced from the previous stage with a slightly more pronounced trend toward Beijing and central and eastern China. The distribution densities in northern Xinjiang, northern Inner Mongolia and south-central Tibet were relatively reduced, but the ranges were almost invariable (Fig. 6c).

During stage IV, which included the most years, the total number of SBHs decreased (73 sites). The distribution has also begun to shrink toward central China and all of the former medium-density areas were weakened, including Beijing, Zhejiang, Jiangsu, Shanghai, and Shaanxi. Ultimately, the distribution structure was developed with southwest Shandong-northwest Henan as the

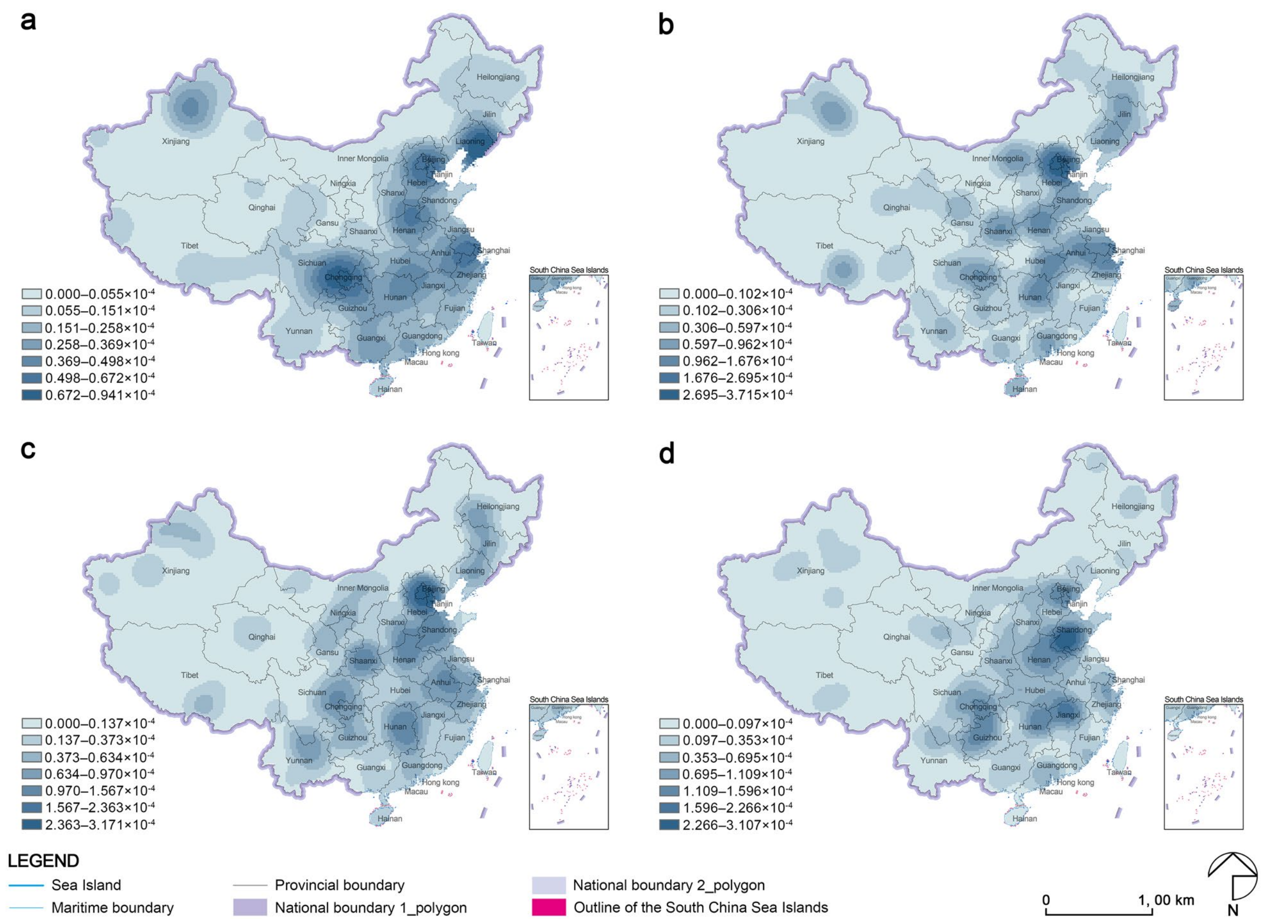

Fig. 6 Kernel density distribution of SBH at different stages. **a** Stage I (*N* = 149); **b** Stage II (*N* = 229); **c** Stage III (*N* = 278); **d** Stage IV (*N* = 205)

high-density area ($KD_M = 0.000283$) and north Jiangxi-northwest Hunan and west Chongqing-central Guizhou as the medium-density areas (Fig. 6d). The distribution range of SBH tended to narrow and converge over time, while its high-density areas showed the evolutionary characteristics of convergence from the north and south to Beijing, then intensifying and finally developing toward the center.

Alternatively, the standard deviation ellipse and mean center of each stage were calculated and plotted superimposed, as depicted in Fig. 7 and Table 3. First, the ellipse areas of the former three stages were similar, approximately 4.00×10^5 km^2, but the area of stage IV varied dramatically by approximately 1.53×10^5 km^2 compared to the previous stage. This result suggested that the SBH distribution range showed a contracting evolutionary trend, especially in the final stage (Fig. 7b). Second, in terms of azimuth, there were two angular deflections in the distribution from horizontal to northeast–southwest. Nevertheless, all oblateness values were similar and converged to 0.00 (i.e., the difference between the long and short axes was not significant), indicating that the directionality of the SBH distribution was not clear in all stages. Finally, the mean center generally presented a weak northeast → southwest → southeast historical migration (Fig. 7c) but was always located within Henan in central China, denoting insignificant distances. Thus, the overall range variation and migration trend of SBH correspond to the geographical location change of the high-density area.

As a complement, the hotspot areas of the holistic SBH were also measured and identified as marked by the black circles in Fig. 8. Beijing, Chongqing, Jining, Xian, Changsha, Guangzhou and Tianjin were specified as the main high hotspot cities with GiZScore values greater than 2.807745, especially Beijing (13.656557). In addition, Shanghai, Wuhan, Dandong, Hangzhou, Hefei, Zunyi, Haixi, Jinan, Kaifeng, Lasa, and Changchun were identified as medium hotspots, all of which had GiZScore values between 1.7008 and 2.364994. The

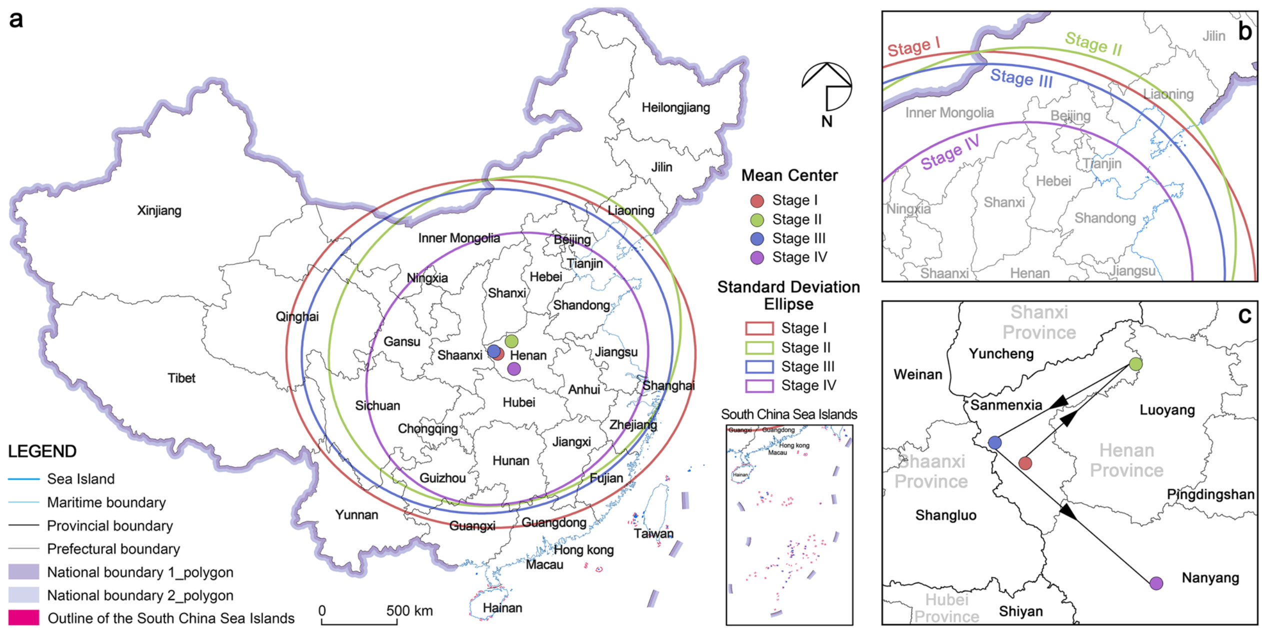

Fig. 7 Migration trend of standard deviation ellipse with mean center for the four stages after superimposition. **a** National scale; **b** Variation in the ellipse; **c** Trajectory of the mean center

Table 3 Parameters of the standard deviation ellipse of the SBH distribution for each stage

Stage	Long axis of ellipse (m)	Short axis of ellipse (m)	Area (m^2)	Azimuth angle	Oblateness
Stage I	1357304.0492	1154847.0751	4924119416059.7891	90.9034°	0.1492
Stage II	1199126.0225	1058539.2692	3987485421909.6538	61.0185°	0.1172
Stage III	1232591.2545	1073670.6478	4157357306947.1958	82.9763°	0.1289
Stage IV	976833.3721	857523.0171	2631440371628.0352	52.8292°	0.1221

results demonstrate that these cities were potential areas of SBH distribution enrichment as eventual products of the staged evolution.

Driving factors of spatial distribution

Single-factor detection results

Based on the geographical detector and natural breaks approach (five tiers), four social environment categories with a total of twelve potential driving factors were analyzed in combination with the holistic SBH distribution. The results are presented in Table 4. Clearly, not all potential factors were validated, and only seven were considered statistically significant driving factors ($p < 0.05$). They were fitted linearly to the distribution numbers to determine the positivity or negativity of the relationship and the fit degree, as illustrated in Fig. 9.

First, with regard to category, policy support (sum of q values = 0.921935) had the strongest coupling, followed by economy and population (sum of q values = 0.729679). Natural geography had the lowest coupling (sum of q values = 0.123365), while transportation had no role. Second, for individual factors, the most significant and strongest coupling was GDP. Two factors of policy support, namely, financial revenue and capital investment, ranked second. Q values were approximately 0.500 and positive for all three. The detection results were also supported by the fitted data for these three factors, which had relatively higher R^2 values of 0.276, 0.167, and 0.411, respectively. Population density (positive) and GDP per capita (positive) in the economy and population together with average altitude (negative) and terrain undulation (negative) in natural geography were similarly coupled, albeit weakly (q values approximately 0.100, $0.01 < p < 0.05$). Their R^2 fit coefficients also showed slight influence relationships, which were all less than 0.005. Third, with regard to distribution, the hotspot cities pinpointed were mostly located to the right of the famous Heihe-Tengchong Line (red dotted line), which is a demarcation line representing the distribution differences in the

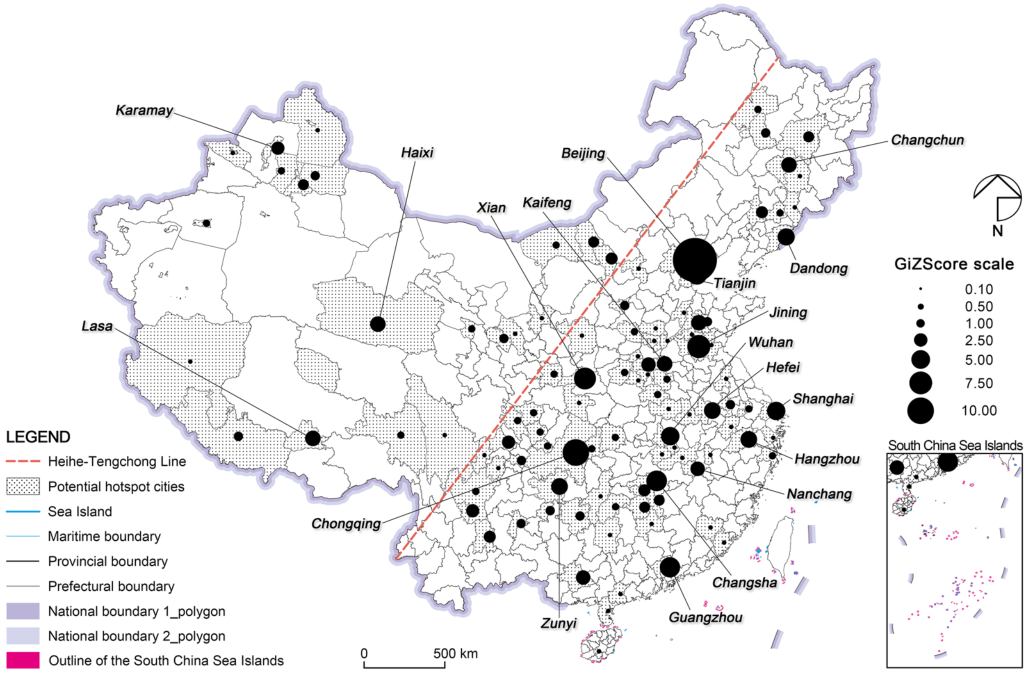

Fig. 8 Potential hotspots cities for SBH in China

Table 4 Potential social environmental driving factors and their coupling strength

Category	Potential social environmental driving factors	q value	*p* value	Rank
Natural geography	Average altitude	0.05447568	0.0234*	6
	Terrain undulation	0.06888942	0.0457*	5
	Mineral reserves	0.05203214	0.9246	N/A
	Arable area	0.02007033	0.4117	N/A
Transportation	Railway mileage	0.40463443	0.1040	N/A
	Road mileage	0.28437056	0.2855	N/A
Economy and Population	Total population	0.03028148	0.3018	N/A
	Population density	0.02853553	0.0466*	7
	GDP	0.58121540	0.0000*	1
	GDP per capita	0.11992840	0.0001*	4
Policy support	Financial revenue	0.46686251	0.0000*	2
	Capital investment	0.45507251	0.0000*	3

*indicates significance, i.e., the driving factor is effective

population and resources of China, as Fig. 8 highlights. This result indicates that the potential enrichment areas of SBH were mostly located in central and southeastern China, which have higher population density and better economic development, validating the significant correlation between the distribution of SBH and policy support, economy and population.

Consequently, as confirmed above, policy support and economy and population were the main driving categories affecting the holistic spatial distribution of SBH, while GDP, financial revenue and capital investment were the most dominant and positive factors.

Interaction detection results

After the significant driving factors were clarified, they were extracted separately for interaction analysis. The results are summarized in Table 5, including

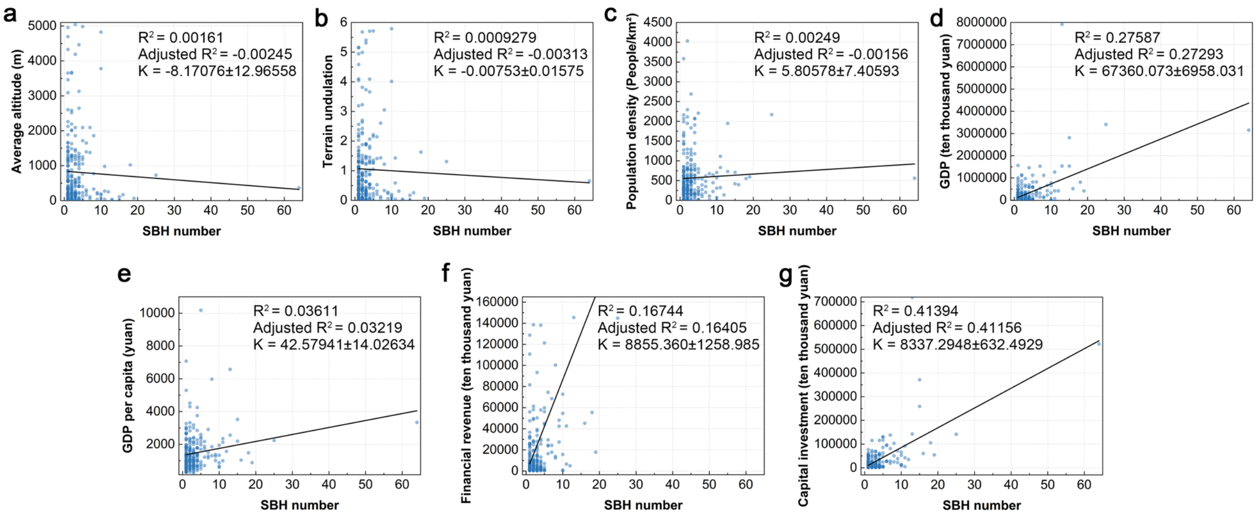

Fig. 9 Fitted relationships between effective driving factors and spatially distributed quantities. **a** Average altitude; **b** Terrain undulation; **c** Population density; **d** GDP; **e** GDP per capita; **f** Financial revenue; **g** Capital investment

Table 5 Interaction results of social environmental driving factors

Driving Factor	Average altitude	Terrain undulation	Population density	GDP	GDP per capita	Financial revenue	Capital investment
Average altitude	0.0545						
Terrain undulation	0.3105[a]	0.0689					
Population density	0.1831[a]	0.2193[a]	0.0285				
GDP	0.6292[b]	0.2678[c]	0.3175[c]	0.5812			
GDP per capita	0.3755[a]	0.0917[c]	0.1227[a]	0.2710[c]	0.1199		
Financial revenue	0.2351[c]	0.2421[c]	0.2377[c]	0.2430[d]	0.4807[b]	0.4669	
Capital investment	0.3575[c]	0.3245[c]	0.2954[c]	0.3434[d]	0.5126[b]	0.5063[b]	0.4551

[a] Nonlinear enhancement

[b] Double-factor enhancement

[c] Single-factor nonlinear reduction

[d] Nonlinear reduction

double-factor enhancement, nonlinear enhancement, nonlinear reduction, and single-factor nonlinear reduction.

Nine sets (42.86%) were enhancements, indicating that their two-by-two combinations could enhance the interpretation of the SBH distribution. In particular, the combination of average altitude and GDP had the greatest effect, i.e., average altitude ∩ GDP had the strongest explanatory power for distribution (q = 0.6292), followed by GDP per capita ∩ capital investment (q = 0.5126), financial revenue ∩ capital investment (q = 0.5063), and GDP per capita ∩ financial revenue (q = 0.4807). In addition, these four interaction sets were double-factor enhancements, showing that they had complementary effects on SBH distribution, while the remaining five were nonlinear enhancements. However, some sets were reduced (57.14%), indicating that their interpretations were all less than those of each single factor or the sum. Among them, the combinations of GDP with financial revenue and capital investment showed the strongest nonlinear reduction with q values of 0.2430 and 0.3434, respectively, while the remaining ten sets were single-factor nonlinear reductions. These sets did not have high interpretation for the SBH distribution; for example, the q value of average altitude ∩ capital investment was only 0.3575 (highest), suggesting that the overall reduction effect was smaller than the enhancement effect.

Comparative observations showed that there were simultaneous increases or decreases in the interaction results for each factor, which demonstrated that there was not a complete promoting or weakening relationship. In other words, because the geographical distribution of the driving factors was not uniform, multiple influences that reinforced or limited each other arose when confronted with the same SBH distribution. Thus, the SBH distribution within the study area was not affected by a single factor but was the result of a multifactorial approach.

Discussion

Spatial distribution of SBH

The SBH distribution in all conditions was widespread and covered several areas of China. The exceptions were types E, G and H, which were closely related to the extensive nature of socialist construction. In the SRCP, to restore the national economy and complete the socialist transformation as quickly as possible, China embarked on profound and comprehensive socialist construction countrywide. This involved the administrative, military, industrial, agroforestry, and transportation sectors [79, 82, 90], resulting in the existence of these SBH types in almost every province, i.e., multiple high-density areas. The holistic SBH also exhibited wide distribution, as these types of heritage occupied 51.57% of the total sample (444 sites). There was a distribution relationship between type E and water resources, mainly around two major Chinese water systems [82, 91], the Yellow River and the Yangtze River, especially in the middle and lower reaches, such as southwest Shandong. The distribution of types G and H was associated with the urban administrative hierarchy. High-ranking cities often had more SBHs to radiate corresponding service coverage and demonstrate administrative status [92]. For example, type H was concentrated in the capital, Beijing, due to its symbolic role as the national center and an important window for external communication [93].

Judging from the distribution pattern, the SBH under all conditions showed various degrees of clustering, except for type I, which was random and directly related to the reason for its formation. Most heritage sites of this type were historical sites affected by uncontrollable factors such as war or disaster. Specifically, in stage I, China took part in the War to Resist US Aggression and Aid Korea as well as several liberation wars, leaving many SBHs in the Bohai Bay Rim and the border areas [79, 94]. In stages II and III, foreign wars were almost nonexistent, but there were struggles against bandits (e.g., Hunan) or earthquakes (e.g., Hebei) in various areas, creating some relics [95]. However, for other types, socialist construction in different sectors was significantly clustered by controllable environmental conditions [80, 82, 93], such as types G and H, which were affected by administrative hierarchy, and type C, which was affected by population and construction investment.

Spatial–temporal evolution of SBH

Integrating both typological and holistic perspectives, the social environment and reasons for the spatial–temporal evolution of SBH are also discussed. First, at the early stage of the establishment of new China, the country underwent restoration construction and liberation wars, including government formation and production development [79, 90, 91]. This was the widest distribution in the study period, so the area of the standard deviation ellipse was the largest. Additionally, the various SBH types were generated in varying quantities, but the main type was type G, which served the residents' livelihoods.

The number of SBH began to climb from 1953 (stage II), when the first Five-Year Plan was implemented in a systematic manner, and included most types. Of these, the inclination of socialist construction toward industry to quickly achieve industrialization led to the rapid growth of types B and C in this stage [69, 91, 96]. Constrained by construction costs, most of these industry projects revolved around cities in northeast and north China with industrial bases, so these types were mainly centered on those areas [97, 98]. To set up and improve the urban function, many public constructions highlighting the national image and achievements were built [92, 93], generating a large number of type G and focusing on the capital, Beijing. Other types were present in different areas due to the prevalence of construction needs. Since the more dominant types B and G were concentrated in north China, the mean center in this stage shifted toward the northeast.

Furthermore, at the end of the first Five-Year Plan, China began to enter a period of the Great Leaps Forward. This period was marked by high targets, which caused the expansion of socialist construction in all fields, especially in the first year of the movement's outbreak (1958) [79, 99]. During the movement, industrial and agricultural production took the lead in leapfrogging, and the numbers of types C and D grew dramatically [73]. This was followed by leaps in transportation, culture, education, and health, resulting in high numbers of types F and G [100]. Conversely, municipality and diplomatic construction were somewhat negatively impacted by the movement, with reductions in the numbers of types A and H [101]. In general, the holistic number and range of SBH were expanded, as evidenced by the area of the standard deviation ellipse. In addition, as the Great Leap Forward movement was developed on the basis of the first Five-Year Plan, the high-value areas for each SBH type remained broadly consistent with the previous stage, mainly in Beijing and some provincial capitals.

Finally, in stage IV, the political movement entitled the Great Proletarian Cultural Revolution emerged, which had an adverse influence on socialist construction [79, 102]. Both the quantity and range of heritage were reduced, especially types A and G, which were related to culture and education. However, against the backdrop of the Sino-Soviet split, the Third Front, which was implemented to prepare for war and drought, began to be fully constructed in 1970. This construction drove the development of military and heavy industry [71, 103, 104], making it possible to sustain or increase the numbers of types B and C. Accordingly, hydraulic engineering and transport facilities were built to support the Third Front [82], giving rise to numerous large-scale sites of types E and F. In particular, these major SBH types were required to be built in accordance with guidelines such as large decentralization, small concentration, and leaning, dispersal and concealment [80, 105]. As a result, a large number of SBHs appeared in central and western China, far from the coastal and northeastern industrial bases, including Guizhou, Sichuan and Henan. This contributed to the migration of the mean center to the southeast during this stage.

After four evolutionary stages, it is evident that socialist construction tended to concentrate on the past capitals of each province to highlight urban hierarchies and enhance production. Consequently, the hotspots that eventually formed are now mostly municipalities or provincial capitals, such as Chongqing, Hangzhou, Xian and Changsha.

Driving factors of the spatial distribution of SBH

Through a geographical detector, all social environment categories were found to have significant effects on the SBH distribution, except transportation. First, for natural geography, areas with low average altitude and low terrain undulation often have a relatively easy construction process and cheap construction costs as the transportation of construction materials, production materials and products is more accessible [65, 67, 79, 97]. Whereas mineral reserves and arable area may have some influence on industrial and agricultural production (i.e., types C and D), this potential relationship was not apparent since the dependent variable was the holistic SBH spatial distribution. This is because the construction of most SBHs, such as types A, E, F, G, F, and I, would hardly suffer from these two factors, as determined by the extensive nature of socialist construction at the time [80, 82].

Second, both factors of transportation were excluded similar to the two mentioned above, since socialism is built to achieve the common development of all regions [90, 106]. Despite the low mileage of roads and railways in some regions, many SBHs have still been generated due to government, economic and other construction, such as Lasa and Karamay located in western China.

Third, all factors of the economy and population were related to SBH distribution except for the total population. Because a larger total population does not mean a sufficient amount of productivity, population density can reflect this characteristic. More densely populated regions indicate more productivity for the same area conditions and contribute more to socialist construction [91, 96]. GDP and GDP per capita represent the production capacity of the region and the standard of residents' livelihoods, respectively. GDP is the gross product of industry, agriculture, etc. By default, more production units contribute to a higher GDP provided that the economic efficiency of each unit is similar. GDP per capita reveals the affluence of a region. Often, the more affluent a region is, the greater people's demands are for living standards and the more comprehensive facilities such as culture, education and health are in addition to having more productive units [80, 93].

Fourth, both factors of policy support were successfully identified. Given that most SBHs were newly built and required significant capital investment, areas with higher investment tended to have a higher number of SBHs as well. Similar to GDP, financial revenue is linked to taxation, meaning that the more productive units such as factories and farms there are, the higher the financial revenue [78]. Furthermore, as the interaction detection results indicate, cities with higher GDP, which usually provide greater financial revenues and capital investments, have more SBHs. This can be explained by the fact that the hotspots are distributed to the east of the Heihe-Tengchong Line, the demarcation line for national resources.

Preliminary proposals for future SBH protection

This study not only revealed the characteristics of the spatial distribution and spatial–temporal evolution of SBH but also provided strong application value for future conservation work. First, the SBH distribution at different protection levels is guided by changes in the density distribution of SBHs at different stages. This is because SBHs of different ages face various conservation dilemmas, such as the fact that the older the heritage is, the more vulnerable it is to structural failure and destruction [20, 70]. Therefore, by identifying high-density areas of SBH distribution in earlier stages, it is possible to detect regions in need of urgent conservation attention to salvage the heritage.

Second, combined with the evolutionary characteristics of SBHs that have been registered on conservation lists and the identification results of hotspot cities, the areas and cities where SBHs are relatively abundant can be roughly ascertained. This is helpful for future work, such as conducting pilot censuses and field surveys. Furthermore, according to the evolutionary characteristics of each SBH type, it is feasible to identify the corresponding hotspot cities; for example, Beijing is a major city of type G, and Shandong is a major city of type E.

Third, based on the judgment of the current spatial distribution and its driving factors, potential areas of SBH can be predicted. For instance, areas with higher GDP, financial revenue and capital investment should have greater and more extensive socialist construction activities and larger SBH stocks. In conjunction with the interaction factor analysis, potential areas for SBH may be found around regions with relatively low terrain undulation and average altitude.

Limitations

First, because there is no specific conservation list for SBH in China, the heritage counted in this study was taken from the current major lists. Constrained by the heritage numbers, the quantity of SBH included in the count remains negligible for the potential total with some error. Nevertheless, from the perspective of protected SBH (i.e., SBH with typical values that can broadly reveal the spatial distribution and spatial–temporal evolutionary trends), it is of reference value. Nevertheless, in the future, there is a need for more comprehensive heritage data using extensive and numerous surveys to produce more detailed distribution maps to guide conservation efforts.

Next, when identifying the driving factors of the spatial distribution, these social environmental data were replaced with annual averages of the study area, which is an unavoidable error. In reality, however, the gross product, population and other development conditions of the various regions changed considerably in the intervening period. In this study, the development process was synchronized across regions by default, and the use of averages would also be a measure to reduce mistakes [107, 108].

In addition to the quantifiable environmental conditions discussed above, there are numerous nonquantifiable social factors that have not been explored, such as political callings and historical events [79, 105]. These require more research and evaluation studies. Additionally, the driving factors for different SBH types should differ, but this was not analyzed in this study due to sample size limitations. This information could be discovered using censuses to obtain a larger sample.

Conclusions

The SBH represents the socialist era achievements of some countries and is an essential part of the young heritage that deserves to be preserved. However, it has not yet received the attention it deserves and faces a serious crisis of survival. Currently, studies on SBH mainly focus on heritage values, utilization and development, and discussions of the holistic spatial–temporal distribution evolution are lacking. Consequently, to attract consideration and protection of SBHs, this study took the representative country of China as an example and selected its 861 SBHs in the SCRP to establish a database. Through GIS analysis tools and geographical detectors, the spatial–temporal evolutionary features and driving factors were explored from typological and holistic perspectives. Despite unavoidable errors such as limited samples and fluctuating social environments, this study was able to broadly reveal the distribution and evolution of SBH, with the following findings.

(1) The distribution of kernel densities showed uneven characteristics for each type as well as for holistic SBH, demonstrating a clear east–west difference; that is, there was little heritage in the west and northwest areas. Additionally, there were significant differences in each type of clustering area, but the holistic area of high density was around Beijing. For all conditions, SBH presented varying degrees of clustering, except for type I, which was randomly distributed.
(2) Different types of SBH were characterized by an increase in numbers at different stages, especially in stages II and III, with type G having the largest increase. In terms of distributional variation, there was no clear trend of migration for most types, except for types B, C and F, which were from north to south. At the same time, the holistic distribution of SBH narrowed and concentrated over time but with no apparent directionality. The distribution center showed a northeast → southwest → southeast migratory trend, albeit faint. Furthermore, cities represented by Beijing, Chongqing and Jining were identified as hotspots for SBH evolutionary results.
(3) GDP, financial revenue and capital investment were found to be the main driving factors affecting the spatial distribution of SBH, all with positive relationships. The interaction of these factors exhibited varying degrees of double-factor enhancement, particularly the average altitude ∩ GDP, which provided favorable explanations for the SBH distribution.

These research findings possess considerable value. On the one hand, they can provide a scientific basis for the future conservation of SBH, including the identification of critical conservation areas, the selection of pilot census cities, and the prediction of potential heritage sites, with extensive application value and guidance. On the other hand, beyond the traditional concept, these findings hold invaluable documentary value, demonstrating to the world the preservation of Chinese heritage in a broader sense and revealing attitudes toward socialist heritage in contemporary Chinese cultural policy.

Nevertheless, this study is preliminary, and future efforts for SBH are needed. Faced with the situation of continuous destruction, it is necessary not only to innovate census and forecasting methods to fully understand the preservation status and general distribution of SBH but also to conduct adequate studies on the historical background to promote the exploration of relevant holistic conservation strategies. Finally, we hope that this study will draw worldwide attention and concern to SBH.

Abbreviations

SBH Socialist built heritage
SRCP the Socialist Revolution and Construction Period
KD_M Mean kernel density
GDP Gross domestic product

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