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How to achieve a balance between functional improvement and heritage conservation? A case study on the renewal of old Beijing city

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ABSTRACT

Historic city centers require function optimization, while simultaneously being pressured to maintain their heritage conservation and utilization. How to reconcile the two is currently a challenge for the regeneration of many old cities. With old Beijing city as the study area, this study innovatively interpreted the value of heritage from the perspective of urban functions, showing the multiple roles and identities of heritage in modern adaptation. In past 40 years, the gradual improvement of urban functions and more even distribution of facilities in old Beijing city comes at the expense of 51.6% of the historic architectural district. Modern urban heritage exists as several types of functions, mainly tourism-attractive heritage as ancient capital's explicit carrier of history and culture, urban-functional heritage as a stock resource for rational use, combined tourism-attractive and urban functional heritage. Compared with other zones, historic areas have more mixed functional units, predominantly residential mixed with cultural, scientific and educational, and administrative functions. A case study was conducted on nine types of typical heritage sites and their surrounding functional organization patterns, providing references for balancing urban function optimization and heritage conservation and utilization for sustainability.

1. Introduction
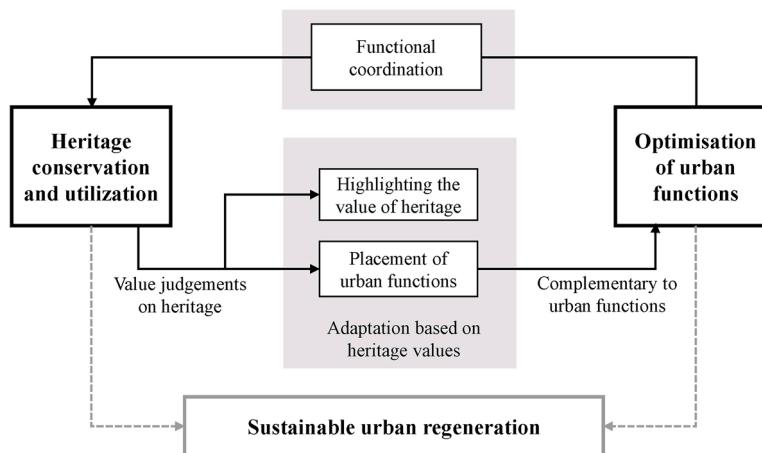
As the urbanization rate of China increases from 17.9% in 1978 to 65.22% by 2022 (Chinese National Bureau of Statistics, 2023), urban planners are faced with the dilemma of accommodating a growing urban population with limited resources, including energy, space, and land (Bai, Chen & Shi, 2012; Shi et al., 2014). Urban development patterns have shifted from sprawl to renewal (Pérez, Laprise & Rey, 2018). Urban renewal is widely recognized as a policy aligned with the sustainable development paradigm (Opoku & Akotia, 2020), whose main objective is to not only improve the physical conditions of the cities in terms of economy, space, and facilities but to also achieve multiple objectives, such as social relations, living environment, and culture (Tomczyk & Basiasi, 2022; Zhang, Deng, Wang & Yuan, 2021). In the current globalization process, the central role of culture in urban development is becoming increasingly prominent (Niu, Lau, Shen & Lau, 2018), and heritage, as an important component of urban culture, is increasingly being incorporated into urban regeneration plans, injecting vitality and

competitiveness into urban regeneration and receiving considerable attention from scholars and policymakers as an element of and tool for socioeconomic development (Yao & Jiang, 2020).

Urban heritage is the valuable historical, cultural, scientific, and artistic remnants in cities, including historic buildings, areas, and environments, as well as intangible elements, such as customs and beliefs (Steinberg, 1996). UNESCO defines heritage as "our legacy from the past, what we live with today, and what we pass on to future generations" (http://whc.unesco.org/en/about/). It is an integral part of the current urban landscape, embodying temporally cumulative and spatially local attributes that are subject to socioeconomic influences and experience a dynamic process of continuous change (Soini & Birkeland, 2014; UNESCO, 2011; Guzmán, Roders & Colenbrander, 2017). In this process, apart from being a carrier of culture and memory, heritage also plays an important role as a tourist attraction and social asset (UNESCO, 2009), contributing to the revitalization of historic urban centers, development of tourism (Zhao, Ponzini & Zhang, 2020; Wu, Wang, Zhang, Zhang & Xia, 2019), and usage of stock resources


Fig. 1. The "Conservation–Value–Function" framework for sustainable urban regeneration.

(Havinga, Colenbrander & Schellen, 2020). The value potential of heritage sites is also realized through adaptive reuse (Wang & Wong, 2020).

Historic areas have more complex and diverse efficiency and equity issues than the general urban region (Liu, Wang & Wang, 2019). They are often the heart of cities, facing decline but with a high demand for functional renewal. They are the most densely populated areas in terms of factors and land resources, and have high requirements for land efficiency (Micelli & Pellegrini, 2018). Numerous heritage sites are spread throughout historic areas, and their land development potential is often considered to conflict with heritage conservation (Yung & Chan, 2012; Yung, Zhang & Chan, 2017). In recent years, the perception of the transformation of old cities from mere physical space improvement to comprehensive development that includes physical, economic, cultural, and social aspects has gradually shifted. However, urban regeneration and heritage conservation are often seen as opposing and require reconciliation; current regeneration plans take less account of the specificity of the nature and function of land in historic areas, leading to heritage isolation and homogenization (Keitumetse, 2009; Wang, Mao, Dong & Zhu, 2018). Balancing urban development, functional improvement, and heritage conservation is one of the biggest challenges in historic city management (Höftberger, 2023).

Many scholars have focused on the issue of heritage conservation in urban regeneration and explored strategies with different dimensions. At the subject level, most scholars have focused on stakeholders, arguing that the key to urban regeneration lies in revitalizing the resources of historic urban areas and realizing the interests and goals of stakeholders (Wang, Li, Zhang, Li & Asare, 2017; Chen, Chiu & Tsai, 2018) and achieving collaborative sharing between heritage and different groups and communities in the surrounding area (Matilainen, Suutari, Lähdesmäki & Koski, 2018; Wang, Hu, Li & Liu, 2016). At the object level, Yıldız, Kıvrak, Gültekin and Arslan (2020) incorporated the conservation of historic buildings into sustainable development models for urban regeneration projects, Wang, Shen, Tang and Skitmore (2013) proposed holistic control tools at the planning level to ensure that urban land redevelopment was compatible with existing neighboring land uses. At the practical level of subject-object interaction, research has extensively applied the historic urban landscape approach, a value-based participatory methodological model (Çatalbaş & Kiliç, 2022), recognizing cities as multiple layers formed in a geographic context and advocating for inclusive management of heritage resources in a dynamic and changing environment (UNESCO, 2016). In general, existing studies are aware of the importance of heritage conservation in the evolution of iterative urban functions and development, and increasingly consider heritage and other elements of the city as a whole. However, current studies have primarily discussed heritage as an individual entity from a land-use perspective (Donaldson & Du Plessis,
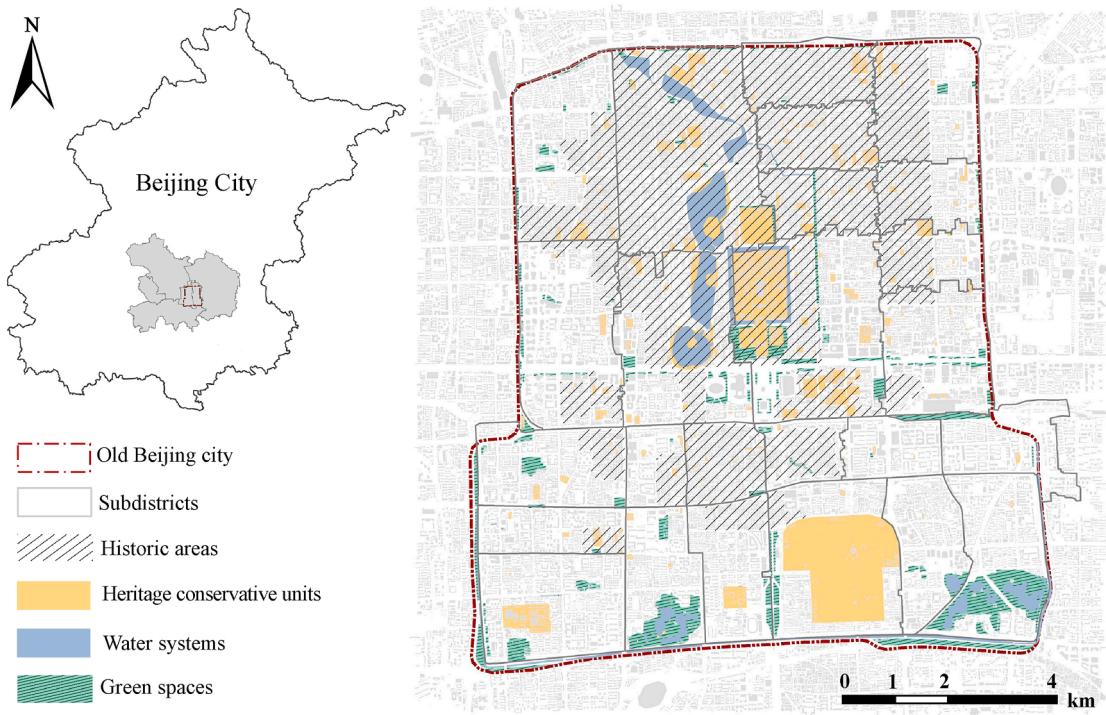
2013) and have focus more on the interaction between heritage and urban space in terms of subject behavior, thus limited discussion of the dynamic relationship between the diverse functions of the city and heritage (Zheng, Shen & Wang, 2014; Wang, Zhao, Gao & Gao, 2021). However, in the context of the functional renewal of the historic city, the contradiction between heritage conservation and functional improvement is highlighted, the need to consider land use and heritage conservation in the regeneration of old cities (AdrianaTisca, Istrat, Dumitrescu & Cornu, 2016), assess the dynamic evolution and modern adaptation of heritage functions, and explore the balance between functional improvement and heritage conservation in old city regeneration in terms of spatial association and temporal dynamics is urgent.

Old Beijing city is a typical example of a city that has undergone a full life cycle from historical capital to modern metropolises, with a large amount of historical and cultural heritage and carries the daily lives of two million inhabitants as well as many political, cultural, and economic functions. However, for various reasons, the renovation of some historic areas has weakened the original social connections (Shin, 2010; Zhang & Lu, 2016), and tourism development has led to the excessive consumption of heritage sites (Zhang, Zhang & Wu, 2021). The problems of adapting historic buildings and cultural heritage to the needs of contemporary urban development and choosing between conservation and development have become important issues that are faced by many historic cities. As a complex and representative case site, old Beijing city can serve as a model for other cities. Therefore, this paper discusses the dynamic relationship and balancing strategies between urban function regeneration and heritage preservation, using Beijing's old city as the study area, with the aim of promoting sustainable urban design oriented to cultural revitalization.

2. Study design

2.1. Research framework

Sustainable urban regeneration requires a balance between the conservation of heritage and functional improvement of the city. Heritage, as an important urban element, is dynamic in its significance and value (Micelli & Pellegrini, 2018), and is embedded in the urban fabric and functions (Couch, Sykes & Börstinghaus, 2011). While urban heritage has its own historical and cultural value, much of it has evolved in the process of urban development, integrating and evolving with the needs of modern society and diverse urban functions and taking on a more concrete and practical value, manifesting itself in the insertion of different functions and becoming complementary to urban functions on a meso-micro scale. In addition to the optimization of urban facilities, the conservation and use of heritage has been increasingly addressed,

Fig. 2. Map of the study area, old Beijing city.

with resources being allocated based on harmonization and functional compatibility, thus achieving a sustainable balance between functional improvement and heritage conservation (Fig. 1). With a view to future sustainable development, this study attempts to answer: (1) What are the merits and drawbacks of the regeneration of old Beijing city in the past 40 years? (2) What is the current relationship between urban functions and heritage? and (3) What patterns of functional combination contribute to heritage sustainability?

The research process is as follows: First, a review of the past 40 years of urban regeneration in old Beijing city was conducted to identify the urban regeneration phases and sustainability issues that have emerged to answer question (1). Focusing on contemporary cities, the functional evolution of urban heritage was examined, and the adaptation of heritage to urban functions was revealed. Furthermore, the functional configuration of old Beijing city was analyzed, and typical patterns of the functional mix in the heritage zones were extracted to answer question (2). Finally, typical sustainability cases were selected for analysis to propose sustainable strategies for reconciling heritage conservation and improving urban functions to answer question (3).

2.2. Study area

The old city of Beijing lies at the heart of the functional area of the capital, within the city walls of the Ming and Qing dynasties; that is, the area within the Beijing Second Ring Road. The political and cultural center of China is also located here and contains many complex functional types. The old city of Beijing has undergone more than 40 years of urban regeneration since the reform and opening up of the country and has faced a continuous demand for urban renewal as society develops and the population migrates. According to the Beijing Core Functional Area Plan, within Beijing's old cities are 30 historical areas, of which 350 national-, municipal-, and district-level heritage units were selected as representatives of the city's heritage sites (Fig. 2).

2.3. Data collection

Urban functions are spatially and directly manifested in land use. According to the current *Code for classification of urban land use and planning standards of development land* of China, urban functions include eight major categories: residential, administrative, and public services; commercial and business facilities; green spaces; industrial, street, and transportation; municipal utilities; logistics; and warehouses. Of the further subdivisions of the functions, 17 types were selected (Table 1).

To portray the changes in urban functions over the past 40 years, land use data between 1981 and 2021 were compiled at five-year intervals. Data for 1981 was referenced from the land status survey map in the *Draft Beijing Master Plan 1982*. The data for 1986 referred to the map of the central city of Beijing in 1984. Data for 1991 was based on the current land use map in *Beijing Urban Master Plan 1991–2020*. The data for 1996 was obtained from the *Beijing Urban Area Map* of that year. Data for 2001 to 2021 were based on satellite images of old Beijing city from Google Earth.

Points of Interest (POI) portray a more refined distribution of urban functions and are widely used in urban function studies (Zheng, Wang, Shang & Zheng, 2023; He, Larkham & Wu, 2021). The data were obtained from the Gaode Map (https://www.amap.com) in 2022, and the attributes of the POI contained latitude and longitude coordinates and facility categories, which were converted into point elements using the coordinates in ArcGIS.

A list of heritage conservation units was obtained from the government websites of the Beijing, Dongcheng, and Xicheng districts. The locations of the heritage conservation units were identified through their profiles, and the boundaries were traced using ArcGIS based on satellite imagery. The original and current functions of the heritage sites were identified through web searches and field surveys. The number of visitors to each heritage site was obtained from Sina Weibo (https://weibo.com/), which is the social networking site with the largest number of users in China.

Table 1
Types of functions selected in this study.

Types of function		No.	Explanation
Residential services		1	Residential and related services;
Administration and public services	Administration and office	2	Offices of government, social groups, institutions, etc. and their related facilities;
	Cultural facilities	3	Facilities for public cultural activities such as books, exhibitions, theatres and concert halls;
	Education and research	4	Universities, secondary schools, primary schools, research establishments, including student living facilities on separate lots allocated to schools;
	Sports facilities	5	Sites such as sports stadiums and training bases, excluding sites dedicated to sports facilities for institutions such as schools;
	Health and hygiene	6	Medical, health care, sanitation, epidemic prevention, rehabilitation and emergency facilities, etc.;
	Social welfare	7	Facilities providing welfare and charitable services to the community, including sites for orphanages, nursing homes, etc.;
	Heritage sites	8	Excluding heritage sites that have been used for other purposes;
	Religious facilities	9	Places of religious activity, including Buddhist temples, Taoist monasteries, churches, mosques, etc.;
Commercial and business facilities	Commercial facilities	10	Service facilities such as retail, catering and hotels;
	Business facilities	11	A comprehensive office land utilities business location for finance and insurance, arts and media, technical services, etc.;
	Recreation facilities	12	A variety of recreational and leisure facilities
Green space		13	Public open spaces such as parks, green belts and squares;
Industrial		14	Production workshops, warehouses and their ancillary facilities of industrial and mining enterprises;
Street and transportation		15	Urban roads, transport facilities, etc., excluding internal roads and car parks on residential and industrial;
Municipal utilities		16	Facilities for supply, environment, safety, etc.
Logistics and warehouse		17	Material storage, transit, distribution, wholesaling, trading, etc.

2.4. Method

2.4.1. Functional mixing degree and equilibrium

The degree of functional mixing is reflected at the urban level in the degree of land use mixing, which is the overall mix of different types of land in the city, which is used in this study to analyze the functional mixing of land use in the historic districts and other areas of the city, and is part of the answer to research question (2). The concept of information entropy was introduced in urban geography to represent this, with a higher entropy value indicating a higher degree of mixing. The formula is as follows:

$$H = -\sum_{j=1}^{k} P_i \ln(P_j)$$

$$J = \frac{H}{H_{max}} = \frac{-\sum_{i=1}^{k} P_j \ln(P_j)}{\ln k}$$

where H is the actual information entropy of the study area, P_j is the share of type j functions in the entire study area, k is the total number of function types in the study area, J is the equilibrium degree, and H_{max} is the maximum information entropy. When $J = 0$, the spatial structure is in the most unbalanced state; when $J = 1$, the spatial structure reaches the ideal equilibrium state. Using the land data mentioned above, the functional equilibrium degree of old Beijing city at each time section was calculated.

The functional mix was depicted at the scale of block and parcel units, using the grid as the unit of calculation and POI as the material for analysis. The equation used is:

$$H = -\sum_{i=1}^{k} A_i \ln(A_i)$$

where H is the information entropy of the unit, A_j is the proportion of POI of function j in this unit, and k is the total number of POI types. Owing to the large size of residential areas and parks, often corresponding to several units that the POI cannot cover, a large number of units have no functional distribution. Therefore, depending on the situation, units without a POI were supplemented with one corresponding functional POI.

2.4.2. Extraction of functional hybrid patterns

Frequency density (FD) is the most common metric used in urban function identification studies, and is used in this study to extract functional organization relationships and adaptation patterns between urban functions and heritage to address the research question (2). The study area was first divided into grid units with a fixed unit size, the total records of POI data in each unit were then obtained, and the FD and ratio metrics were calculated for each type of function in the unit.

$$F_i = \frac{n_i}{N_i}, i \in (1, 2, ..., k)$$
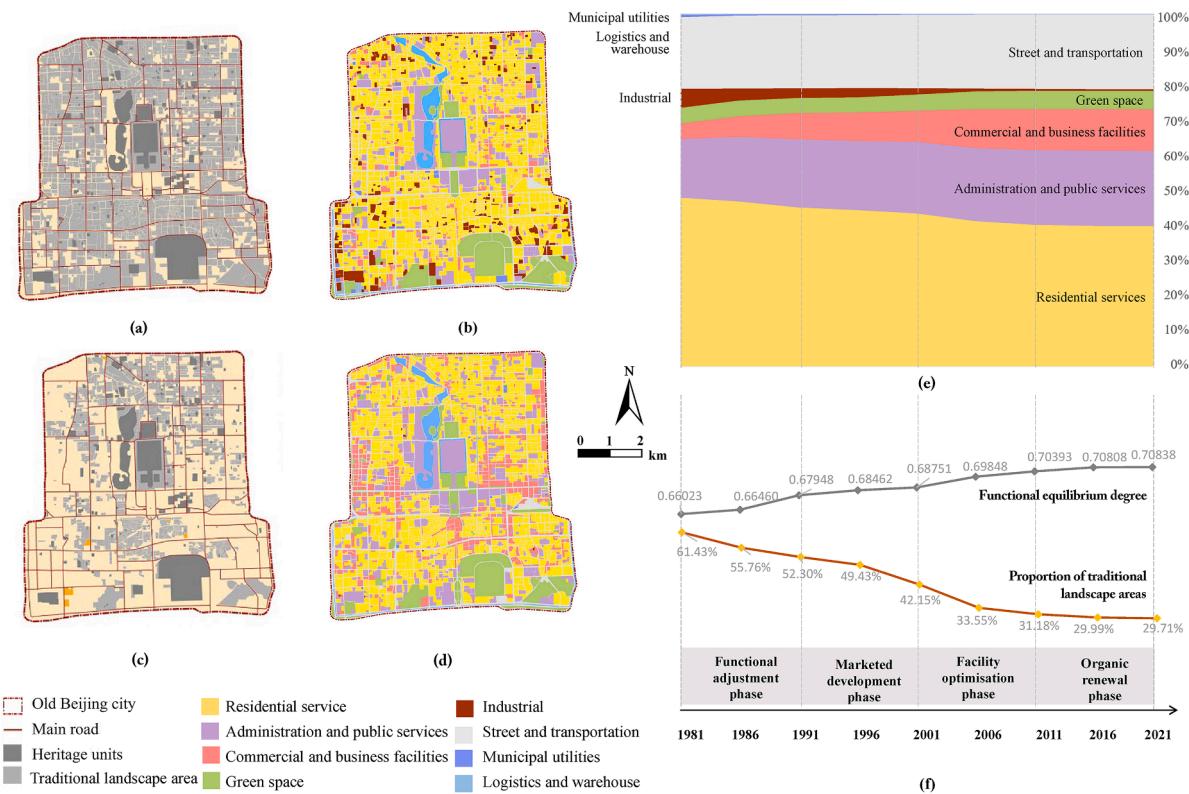
$$C = \frac{F_i \times W_i}{\sum_{i=1}^{k} (F_i \times W_i)} \times 100\%, i \in (1, 2, ..., k)$$

where i denotes the type of POI, k is the total number of POI types, n_i denotes the number of POIs of type i in a unit, N_i is the total number of POIs of type i, F_i is the FD of POIs of type i in a unit, C_i is the proportion of

Table 2
Weight of each function in extraction of functional hybrid patterns.

| Types of function	Weight	Types of function	Weight	Types of function	Weight
Residential services	0.394	Social welfare	0.001	Green space	0.052
Administration and office	0.049	Heritage sites	0.065	Industrial	0.004
Cultural facilities	0.018	Religious facilities	0.002	Street and transportation	0.210
Education and research	0.046	Commercial facilities	0.050	Municipal utilities	0.001
Sports facilities	0.008	Business facilities	0.044	Logistics and warehouse	0.001
Health and hygiene	0.022	Recreation facilities	0.023		

Fig. 3. Landscape and land use change in old Beijing city: (a) Traditional Landscape Areas in 1981; (b) Functional distribution status in 1981; (c) Traditional Landscape Areas in 2021; (d) Functional distribution status in 2021; (e) Changes in the proportion of various functions in old Beijing city; (f) Change in functional equilibrium degree of old Beijing city and proportion of traditional landscape areas.

the FD of POIs of type i in a unit, and W_i denotes the weight of each FD. This study uses area weights, that is, the area proportion of this type in old Beijing city (Table 2).

Functional areas were identified based on the FD and ratio indices, and functions with C_i values >20% were identified. When only one function has a $C_i \geq 80\%$, the unit is considered to have only one function. When only one function has a $C_i \geq 50\%$ and all other functions have a $C_i <20\%$, the unit is considered a mixed functional area dominated by one type of function. When a functional area of category 2, 3, or 4 has $20\% \leq C_i \leq 80\%$ in a unit, the grid unit is identified as a mixed functional area of these types. When the C_i value for each function type is <20%, the unit is considered a mixed multifunctional area.

3. Results

3.1. A review of the regeneration of old Beijing city over the last 40 years

3.1.1. Changes in the function and landscape of the old city

Over the past 40 years, residential land has decreased by approximately 17%, with a significant contraction along the Second Ring Road and other major roads. The highest percentage of residential land has been converted to commercial and business lands, with a small area used for education, research, and green spaces. In 1981, a large amount of industrial land was located in the old city, accounting for approximately 5% of its area. However, with the reorientation of the city's development, industrial facilities have virtually disappeared. Most industrial land has been developed as residential land, with a small proportion converted for commercial and public services. The type of function that has increased significantly is commercial service, with several commercial areas such as Xidan and Wangfujing expanding dramatically,
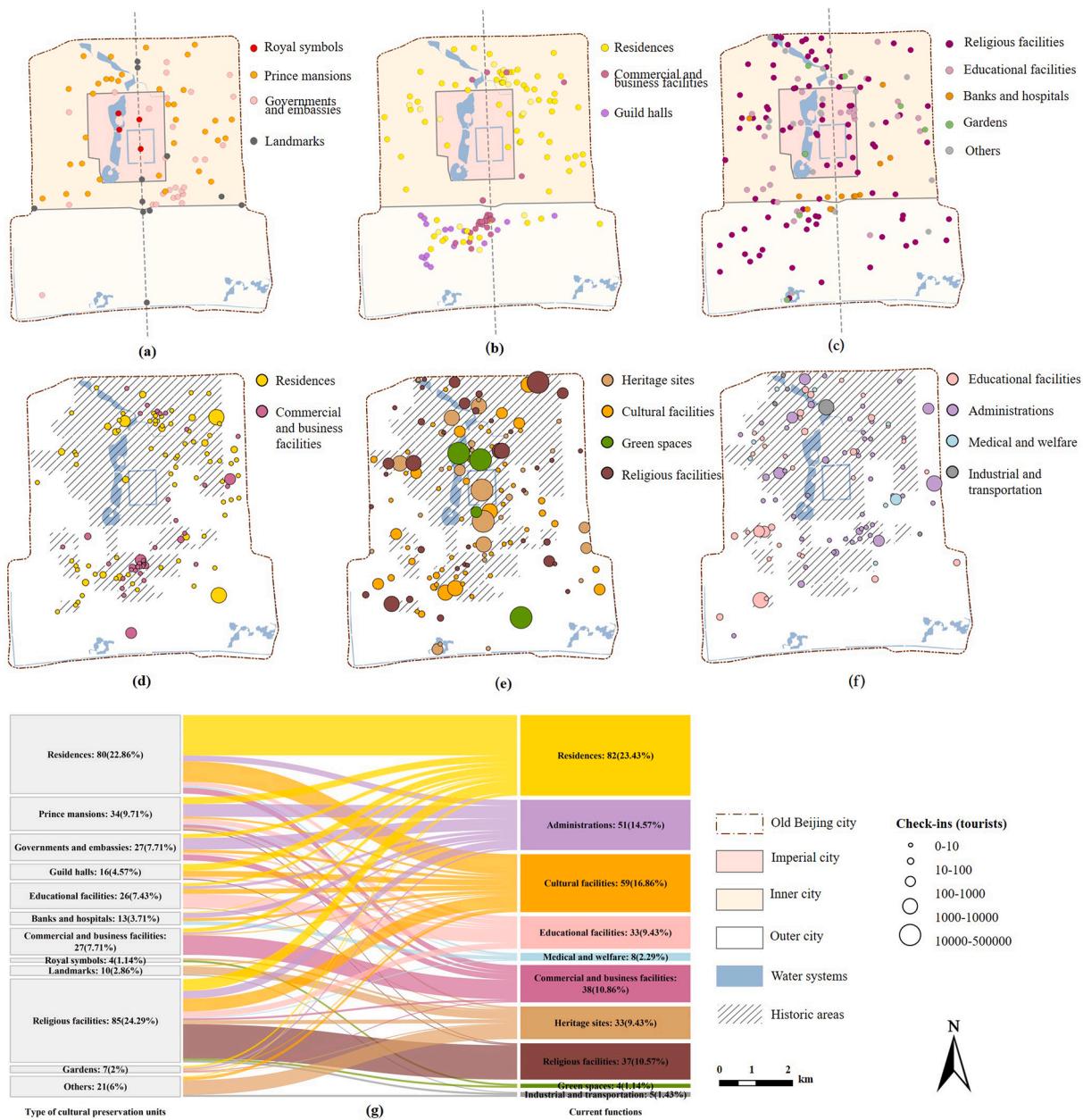
commercial facilities in various blocks becoming more densely distributed, and business land forming several clusters along the East and West Second Ring Roads. In 1981, far fewer facilities were in the southern region compared with the north; however, the situation has changed over the last 40 years, with the area of public services increasing and a more even spatial distribution. Green areas expanded with the addition of several green belts, and the widening of roads led to an expansion in the area of transport facilities.

Based on the calculation of the functional equilibrium of old Beijing city, the periods of 1981–1991 and 2001–2006 exhibited the greatest increase in the overall balance of the old city and the strongest functional changes. Over 40 years of development, the population density of the old city has increased, traditional courtyards have heavily developed into higher-volume housing, and the overall landscape of the old city has changed dramatically. In 1981, 61.4% of the area had a traditional appearance; however, by 2019, only 29.7% of this area remained. In particular, 1996–2006 saw the most rapid landscape changes. Although the function of the old city improved significantly during the decade, approximately 15% of the traditional buildings were replaced by modern buildings throughout the urban renewal process. The historic environment around existing heritage sites has been cleared, and 28% of the heritage sites in old Beijing city are now isolated, presenting a phenomenon of insularity and loss of integrity (Figs. 3a-3e; A1).

3.1.2. Phases of old Beijing city renewal

3.1.2.1. Functional adjustment phase (1981–1990). Since 1980, China has gradually shifted from a planned to a market economy with the development of private and tertiary industries. In 1982, the *Beijing Urban Construction Master Plan (Draft)* was issued to adjust the position
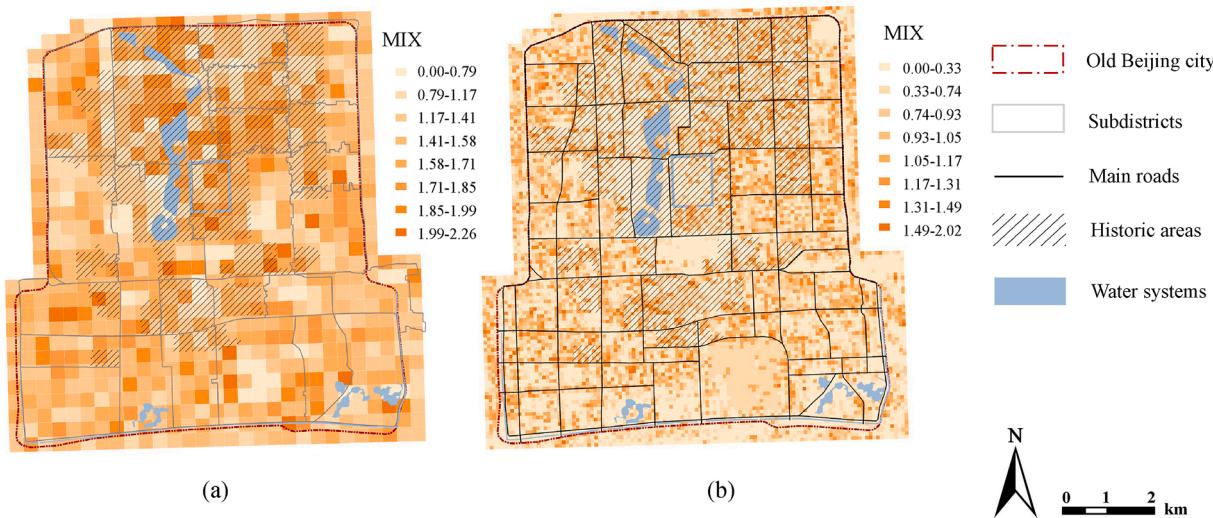
Fig. 4. Historical functions, contemporary functions, and functional transformations of heritage: (a-c) Historical functions and distributions of heritage; (d-f) Contemporary functions and distributions of heritage; (g) Functional transformation of heritage.

of Beijing as "the political and cultural center of the country" and remove "economic center" and "modern industrial base." Consequently, industrial facilities have been gradually evacuated, large-scale construction and renovation have been conducted, and various public services have been greatly improved.

3.1.2.2. Marketed development phase (1991–2001). In the early 1990s, China transitioned to an open-market economy, urban construction changed from being dominated by government investment in social capital, and commercial real estate rapidly developed. Land prices became a major player in the market economy in 1992, when Beijing promulgated the *Provisional Regulations on the Grant and Transfer of State-owned Land Use*, resulting in an inflated demand for land and rising land prices. A large amount of residential land was replaced by commercial and business land, resulting in a higher average land yield.

3.1.2.3. Facility optimization phase (2001–2010). Beijing's successful bid to host the 2008 Olympic Games in 2001 was an opportunity for the local government to invest heavily in improving infrastructure and building cultural facilities in the city. The *Conservation Plan for 25 Historic and Cultural Reserves in Old Beijing City* changed the situation of inadequate funding for heritage conservation and the long-term disrepair of historic buildings. Numerous mixed residential compounds in Old Town were transformed and revitalized into cultural facilities, with an increase in public administration and public service facilities. Conversely, after the full implementation of the "auction and listing" system in 2002, the market became the dominant market for urban land development, with the expansion of land for commercial services.

3.1.2.4. Organic renewal phase (2011–2020). The Beijing Municipal Government implemented a neighborhood improvement plan that

Fig. 5. The degree of functional mix at the (a) block (400 m × 400 m) and (b) parcel (100 m × 100 m) scales.

focused on optimizing functional configurations, adjusting and upgrading business patterns, and shaping landscape characteristics. Actions to vacate and decommission historic buildings and reused spaces were launched. During this period, organic regeneration became dominant, with small-scale spatial transformations occurring in historical and cultural areas, such as Shichahai, Nanluoguxiang, and Xisi. In 2017, the *Beijing Urban Master Plan (2016–2035)* identified the core areas of the capital's functions, with the Old City as its main focus, highlighted the cultural heritage conservation units, essence areas, and historical areas (Fig. 3f).

3.2. Functional adaptation of heritage in old Beijing

3.2.1. Historical functions of heritage
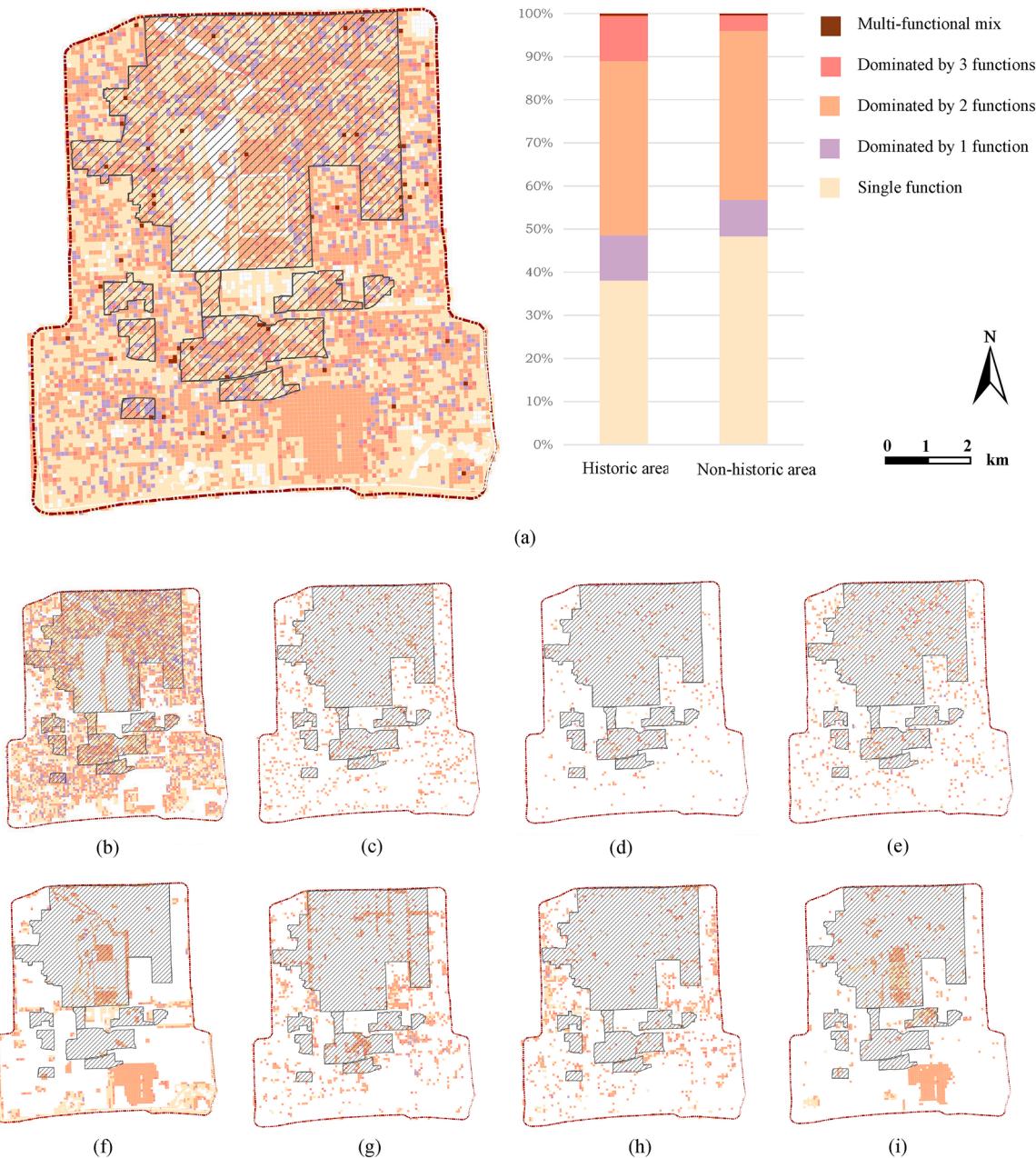
Heritage possesses specific historical conditions and characteristics of the times at the beginning of its birth, carrying the functional needs of the city in historical periods, becoming a carrier of today's memory of history and culture, and reflecting the historical functional pattern and spatial memory of old Beijing city. During the historical period, owing to the urban system of the feudal dynasties, the spatial distribution of different functional heritage sites had a specific pattern (Fig. 4a–c). As symbols of dynastic power, royal palaces and gardens are distributed along the central axis of the city and on both sides, and landmarks such as gates, towers, and walls delineated the central axis and boundaries of the ancient city. The prince's mansions and governments are located in the inner city on the north side, where officials and nobles used to live, while commercial facilities such as guild halls and stores are located in the outer city on the south side, where common people and migrants live. The former residences of celebrities, traditional residences, and other residential properties are mostly located in the center of the inner and outer cities. Religious facilities are evenly distributed throughout old Beijing city.

3.2.2. Functional transformation of heritage

Nowadays, heritage is confronted with a different urban context, transforming its function (Fig. 4g) and becoming a carrier of multiple contemporary urban functions (Fig. 4d–f). Currently, heritage is most commonly a residential function, with approximately 23% of heritage sites comprising numerous celebrity residences and traditional dwellings. This is followed by cultural facilities, about one-third of which come from museums or cultural halls based on the former residences of celebrities. Some religious facilities and guide halls have also been

revitalized and utilized as museums. In addition, numerous princely mansions, governments, and religious facilities are currently used as administrative facilities. Facilities with religious ritual functions in the historical period have almost maintained their original functions and commercial facilities have mostly maintained their commercial attributes from ancient times to the present day. Some former residences of celebrities, prince mansions, and governments are also used for commercial operations. Most educational facilities maintained their original functions during the historical period. The royal palaces and landmarks, on the other hand, are now used as heritage facilities that are open to visitors, and the royal gardens are naturally integrated into modern city parks. In addition, parts of heritage sites are used as medical and social welfare facilities, and although the number of such heritage sites is small, it plays a significant role. Based on the number of visitors, heritage sites of cultural facilities, green spaces, and religious facilities (Fig. 4e) have a higher tourism fervour than heritage sites with other functions (Fig. 4d and f), as they are closely related to their contemporary functions. Consequently, these heritage sites, which are tourist attractions, have higher historical and cultural values and conservation ratings.

Therefore, from the perspective of contemporary functions, heritage can be divided into four functional types: (1) Tourist attractions with high levels of protection because of their outstanding historical and cultural value, becoming city cards and visible carriers of the history and culture of the ancient capital; these are often preserved as heritage sites or revitalized as museums, exhibition halls, and other cultural facilities, such as the Forbidden City, Beihai Park, and other famous attractions in Beijing which interest a large number of tourists. (2) Complements of urban functions which bear the roles of residence, administration, education, medicine and welfare, and industry. Although their level of protection and Weibo check-in quantity may not be high, they are used by a fixed group of people, full contributing to their spatial value, such as the buildings in Dongjiao Minxiang as administrative facilities and the Gunbeizi Garden (a prince mansions) as a hospital. (3) Combined tourist attractions and supplements to urban functional heritage sites with both tourist heat and functions such as green spaces and religious facilities; these often have a high heritage protection level, such as the Temple of Heaven Park and Yonghe (Lama) Temple. (4) Heritage sites that are left vacant or sealed and are not open to the public as they are stock resources which have yet to establish a functional adaptation mode, such as the Jingyong Ancestral Hall and Courtyard No. 3 in Ma Xian Hutong.

(a)

(b)   (c)   (d)   (e)

(f)   (g)   (h)   (i)

Fig. 6. The distribution and mix pattern of functions in old Beijing city: (a) Functional mix pattern of the parcels in old Beijing city; (b) Residence-related functional mix pattern; (c) Administration-related functional mix pattern; (d) Cultural-related functional mix pattern; (e) Education and research-related functional mix pattern; (f) Green space-related functional mix pattern; (g) Commercial-related functional mix pattern; (h). Business-related functional mix pattern; (i) Historic site-related functional mix pattern.

3.3. Functional organizations of old Beijing city

3.3.1. Spatial differences in functional mixing degree

The degree of mixing can indicate the functional diversity within a block. Sustainable cities encourage a mix of land use types, thereby enhancing urban spatial efficiency. To determine the difference in the degree of the functional mix between historical and other areas, the POI were used to calculate the mix of functions on a block scale of 400 m × 400 m. With the exception of a few special zones such as parks, squares, and shopping areas, which are relatively homogeneous in function, all the blocks of the old city have a high degree of functional mix; little difference was found in the degree of functional mix between the

historic areas and other areas. By calculating the spatial autocorrelation, the Moran's index was 0.196, which was close to 0, confirming that the aggregation in the spatial distribution of the mixing degree was not significant. Mixing calculations were performed at a parcel scale of 100 m × 100 m. Moran's index was 0.316, indicating that the mix exhibited a certain spatial agglomeration. As shown in Fig. 5, the high-value areas were located along the main roads, and the differences in the mix of functions were primarily reflected in the variations within the blocks.

3.3.2. Differences in functional mix patterns

To distinguish differences in the patterns of functional combinations between historical and other areas, using a 100 m × 100 m as parcel grid
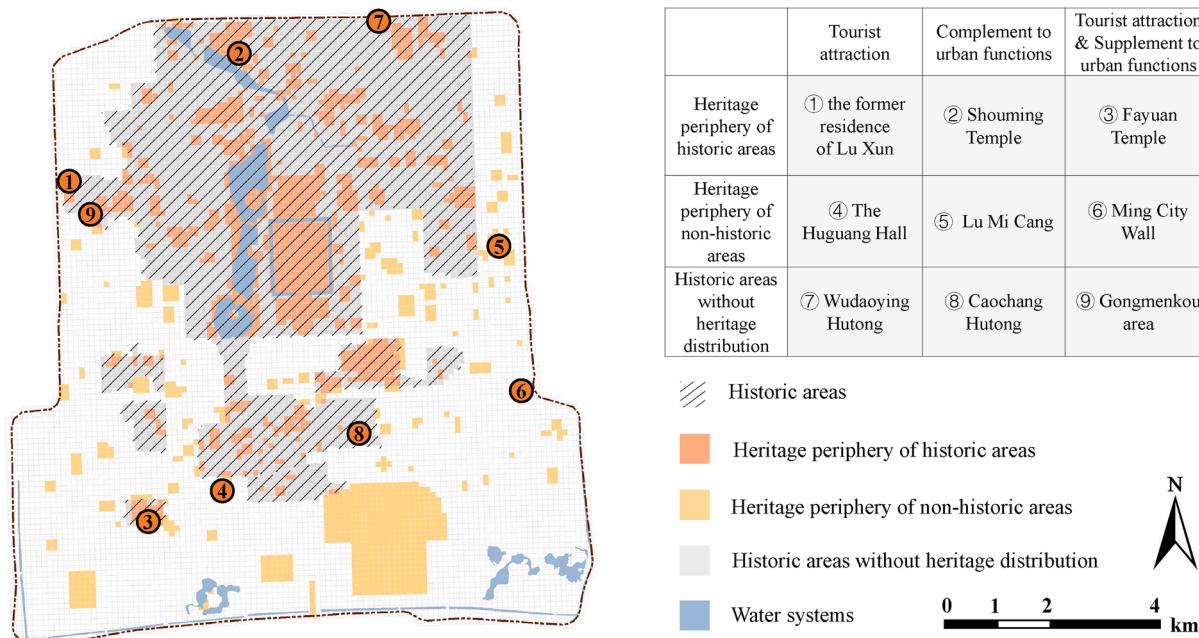
Table 3
Mixed features of various functions.

Functions	Study Area					Historic Aera					Non-historic Area				
	Single function	Dominated by 1 function	Dominated by 2 functions	Dominated by 3 functions	Multi-functional mix	Single function	Dominated by 1 function	Dominated by 2 functions	Dominated by 3 functions	Multi-functional mix	Single function	Dominated by 1 function	Dominated by 2 functions	Dominated by 3 functions	Multi-functional mix
Residential	40.10%	12.32%	42.48%	4.41%	0.68%	38.49%	13.25%	43.25%	4.37%	0.64%	41.46%	11.54%	41.83%	4.45%	0.72%
Administration and office	7.66%	1.84%	74.42%	12.98%	3.10%	4.26%	1.75%	76.44%	15.04%	2.51%	9.79%	1.90%	73.14%	11.69%	3.48%
Cultural facilities	14.74%	4.84%	68.00%	11.79%	0.63%	11.39%	4.46%	72.77%	10.89%	0.50%	17.22%	5.13%	64.47%	12.45%	0.73%
Education and research	4.78%	1.49%	73.13%	19.10%	1.49%	3.39%	0.56%	74.01%	20.34%	1.69%	6.33%	2.53%	72.15%	17.72%	1.27%
Sports facilities	15.18%	2.68%	54.46%	25.89%	1.79%	0.00%	20.00%	40.00%	40.00%	0.00%	15.89%	1.87%	55.14%	25.23%	1.87%
Health and hygiene	10.09%	1.15%	66.06%	16.74%	5.96%	4.11%	1.37%	67.81%	19.18%	7.53%	13.10%	1.03%	65.17%	15.52%	5.17%
Social welfare	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Heritage sites	18.27%	0.26%	74.14%	5.12%	2.21%	23.53%	0.48%	66.93%	6.84%	2.23%	11.71%	0.00%	83.13%	2.98%	2.18%
Religious facilities	0.00%	0.00%	74.51%	15.69%	9.80%	0.00%	0.00%	78.79%	12.12%	9.09%	0.00%	0.00%	66.67%	22.22%	11.11%
Commercial facilities	20.35%	3.35%	49.13%	21.85%	5.32%	4.91%	0.57%	75.28%	15.47%	3.77%	44.78%	7.76%	7.76%	31.94%	7.76%
Business facilities	18.58%	1.53%	61.85%	13.82%	4.22%	8.29%	0.00%	55.80%	24.86%	11.05%	20.58%	1.82%	63.02%	11.68%	2.89%
Recreation facilities	20.83%	0.00%	52.08%	12.50%	14.58%	10.00%	0.00%	60.00%	0.00%	30.00%	23.68%	0.00%	50.00%	15.79%	10.53%
Green space	43.08%	2.11%	50.56%	4.18%	0.08%	27.64%	2.74%	63.36%	6.00%	0.26%	50.24%	1.82%	44.61%	3.33%	0.00%
Industrial	57.69%	0.00%	23.08%	3.30%	15.93%	43.33%	0.00%	23.33%	3.33%	30.00%	60.53%	0.00%	23.03%	3.29%	13.16%
Street and transportation	0.00%	0.00%	71.43%	0.00%	28.57%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	66.67%	0.00%	33.33%
Municipal utilities	50.00%	0.00%	5.00%	5.00%	40.00%	11.11%	0.00%	11.11%	0.00%	77.78%	81.82%	0.00%	0.00%	9.09%	9.09%
Logistics and warehouse	14.29%	0.00%	71.43%	14.29%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	16.67%	0.00%	83.33%	0.00%	0.00%

Table 4

Functional mix patterns in heritage zones.

| (i) historic areas without heritage distribution		(ii) heritage periphery of historic areas		(iii) heritage periphery of non-historic areas	
Patterns of functional mixing	Percentages	Patterns of functional mixing	Percentages	Patterns of functional mixing	Percentages
Residence	0.413	Historic site & Green space	0.398	Residence & Other multi-functional	0.162
Residence & Commercial	0.098	Residence & Other multi-functional	0.115	Historic site	0.124
Residence & Administration	0.084	Historic site & Residence	0.078	Historic site & Residence	0.101
Residence & Other multi-functional	0.079	Historic site	0.061	Historic site & Green space	0.098
Residence & Green space	0.057	Residence & Green space	0.043	Green space	0.095
Green space	0.035	Residence	0.040	Residence & Green space	0.059
Residence & Education and research	0.035	Historic site & Commercial	0.024	Residence & Commercial	0.040
Residence & Business	0.032	Residence & Administration	0.023	Residence	0.037
Residence & Health and hygiene	0.025	Residence & Commercial	0.020	Residence & Cultural	0.033
Residence & Cultural	0.020	Residence & Cultural	0.017	Residence & Education and research	0.028
Commercial	0.009	Historic site & Business	0.014	Residence & Administration	0.026
Business & Commercial	0.009	Multi-functional	0.014	Historic site & Commercial	0.020
Residence & Business & Commercial	0.008	Residence & Education and research	0.013	Historic site & Business	0.017
Administration	0.005	Residence & Health and hygiene	0.010	Green space & Other multi-functional	0.015
Business	0.005	Green space	0.010	Historic site & Cultural	0.013

Fig. 7. Typical cases and their spatial locations.

unit, the functional combination pattern was extracted to examine the mutual compatibility of functions. A total of 164 functional mix patterns were identified, of which 117 were in historic areas and 147 were in non-historic areas. The statistics revealed that single-function units accounted for approximately 44.1%, units dominated by one, two, and three functions accounted for 9.3%, 39.7%, and 6.4%, respectively, units dominated by four functions were not found. Of these, approximately half of the units in non-historic areas have a single-function pattern, whereas historic areas contain a much larger number of units with a mix of functions (approximately 60%). While non-historic areas had a greater variety of functional mix types, historic areas had more mixed functional units (Fig. 6).

In residential functional units, residences often dominated. Among public service facilities, administrative, cultural, educational, and sporting functions are often mixed with one or two other functions, less

often completely dominating the unit and showing a more even scattering in spatial distribution; in contrast, religion and welfare usually play a subordinate role in the units, rarely becoming the dominant function. Heritage sites have a mixed character. Green spaces are often dominant, as they tend to be large and concentrated in old Beijing city. The distribution of most functions inside and outside the historic area is consistent, except for commercial, business, municipal utilities, logistics and warehouse. The distribution of commercial functions is characterized by clear spatial clustering, with a prominent distribution along the roads. Commercial functions were also clearly clustered along the East and West Second Ring Roads, business functions are more distributed outside the historic area (Fig. 6; Table 3).

3.3.3. Functional distribution of heritage-related zones

Of the 350 heritage conservation units in old Beijing city, 251 were
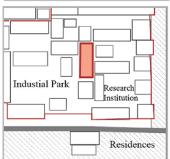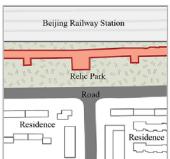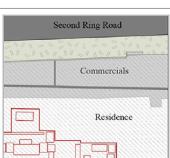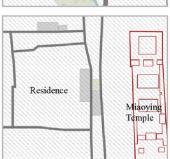
	Types of heritage	Layout plan	The function of heritage	Peripheral functions	Heritage features and ways of adaptive use
Heritage periphery of historic areas	Tourist attraction ① **the former residence of Lu Xun**		Museums and memorials	Museums and traditional residential areas	• National Key Cultural Relics Protection Units • Layout and display of furnishings maintain originality • Integration of surrounding resources as part of the Lu Xun Museum and the New Culture Movement Museum
	Complement to urban functions ② **Shouming Temple**		Cultural service center for the visually impaired	Traditional residential areas and office facilities	• Little tourist attraction compared to the neighbouring Gongwangfu and other heritages • The building is well preserved and in harmony with the surrounding historical landscape • the building has been rented as a cultural service center for the visually impaired
	Tourist attraction & Supplement to urban functions ③ **Fayuan Temple**		Monasteries and Buddhist colleges	Traditional residential and civic areas	• One of the most visited temples by tourists • Compatible with the Chinese Buddhist Institute and the Chinese Buddhist Library and Heritage Museum • The courtyard and front plaza provide a place for the surrounding residents to relax
Heritage periphery of non-historic areas	Tourist attraction ④ **The Huguang Hall**		Museums, theaters and commercial	City roads, subway stations and office buildings	• National Key Cultural Relics Protection Unit with a large scale, forming a building complex • Adjacent to subway stations and city roads • Museum with integrated functions such as theatre performance, exhibition and commerce
	Complement to urban functions ⑤ **Lu Mi Cang**		Exhibition space in the industrial park	Residence and creative industry parks	• Only some of the buildings remain and are not of high grade • Relying on the surrounding resources, such as the Fahua Temple, the area's popularity has been leveraged to integrate the revitalisation of the historical stock of buildings into an industrial park
	Tourist attraction & Supplement to urban functions ⑥ **Ming City Wall**		Heritage park	Residence, green spaces and urban roads	• Extensive area with a high grade • A heritage park with scientific and recreational functions • Ecological services for the surrounding population
Historic areas without heritage distribution	Tourist attraction ⑦ **Wudaoying Hutong**		Creative and cultural business area		• Attracting visitors by relying on the nearby Guozhijian and Yonghe Lama Temple • Implanting creative industries and creating a clustering effect • A literary and artistic atmosphere, unique in the old Beijing city
	Complement to urban functions ⑧ **Caochang Hutong**		Traditional residential area		• There is no tourist attraction in the area • Traditional residential historic area • The main focus is on the improvement and restoration of the historic environment, restoring the historic water system and optimising the living environment
	Tourist attraction & Supplement to urban functions ⑨ **Gongmenkou area**		Mixed commercial and residential area		• The area has become an internet sensation thanks to the nearby White Pagoda Temple • The unification of the street appearance and the addition of commercial services

Fig. 8. Analysis of sustainable patterns in typical cases.

located in historical areas. Accordingly, patterns were extracted for three typical zones associated with heritage sites: (i) historic areas without heritage distribution, (ii) heritage peripheries of historic areas, and (iii) heritage peripheries of non-historic areas (Table 4).

Historic areas, such as regions of old Beijing city with more complete traditional styles, comprise 43% of the units with residential areas as a single-function. The second most common type was a combination of residential and commercial areas such as Nanluoguxiang, Wudaoying Hutong, Dashilanr, and Xianyukou. In addition, a great number of residence-dominated units were mixed with other uses.

Many heritage sites are located in historic areas, and among the units with these heritage sites, the functional combinations are very diversified. Parcels with residence as a single-function are still typical, accounting for the largest proportion (16.2%). In addition, the combinations of historic sites and residences and historic sites and green spaces are also typical patterns. Combinations of housing with culture, science, education, and administration as well as the combination of monuments with commerce and business are also relatively common patterns, reflecting the contribution of the adaptive use of heritage to the enhancement of the neighborhood mix.

Outside historic areas, heritage is detached from the historic environment, and units with a mix of heritage sites and green spaces, such as the Temple of Heaven Park and the City Wall Ruins Park, are the most numerous at 39.8%, followed by units with single-function residences and mixed units with residential and heritage sites.

3.4. Sustainable patterns for coordinating heritage conservation and urban functions

Based on the above research, nine cases of three heritage types distributed in three types of zones were analyzed (Fig. 7) and sustainable patterns of heritage adaptive use were summarized to provide suggestions for the future balance and sustainable development of heritage conservation and urban functional improvement (Fig. 8).

Heritage within a historic area is preserved in its originality and integrity because of the historic environment, and for visitors to have a complete historical and cultural experience. Tourism-attractive cultural heritage sites within historic areas (Type 1) are often integrated with the surrounding heritage resources and cultural facilities, highlighting the originality of their architectural entities and functions. For example, the former residence of Lu Xun is a courtyard located in Gongmenkou Hutong; its layout and furnishings have been preserved as they were when Lu Xun lived there. At present, the former residence of Lu Xun is combined with the neighboring Lu Xun Museum and Museum of the New Culture Movement to display objects and materials related to Lu Xun and famous figures and events of the New Culture Movement. Heritage does not interact with the surrounding traditional residential area in terms of function but is more important in terms of presenting the historical atmosphere. Urban functional heritage within historic areas (Type 2), often with low heritage protection levels, have become environmental backdrops for the surrounding tourism-attractive heritage sites. Shouming Temple, a Han Buddhist temple with a largely intact original layout, is located in the busiest historical district of Shichahai. Since 2003, the building has been rented as a cultural service center for the visually impaired, and their weekly activities have been organized in the building's main hall, allowing them to "watch" movies through audio and visual narration. This is an effective way to use stock in an old city, which is densely populated, and has limited land resources and important social implications. Heritage sites that combine the role of a tourist attraction and urban function (Type 3) provide better services for tourists and local residents. For example, Fayuan Temple, one of the temples most visited by tourists in old Beijing city, is compatible with

the functions of the Chinese Buddhist Academy and Chinese Buddhist Library and Heritage Museum, in addition to its original religious function. It is integrated with the surrounding neighborhood, providing a place for relaxation, especially as a front square for residents to gather and move around, a rare open space in narrow hutongs.

For heritage sites in non-historic areas, the loss of the surrounding historic environment is the biggest dilemma for their conservation. Therefore, fully exploring their intrinsic value or seeking connections with surrounding resources is vital. The tourism-attractive heritage of non-historic areas (Type 4) is in an isolated state surrounded by modern urban functions and environments; hence, maximizing the value of the heritage itself is crucial. During the Qing dynasty, Huguang Hall was a meeting place for people from Hunan and Hubei provinces who travelled to Beijing. The building complex itself is intact and is currently used as a museum with functions such as theater performances, exhibitions, and commerce. It attracts many visitors with its comprehensive and unique functions, as well as with the transportation advantage of being adjacent to the main roads and subway stations of the city. For urban functional heritage in non-historic areas (Type 5), authenticity is only reflected in the physical aspect of the building proper, while the functional aspect is integrated with other resources in the vicinity. For example, Lu Mi Cang, a large-scale storage complex of the Ming and Qing dynasties, of which only some are currently preserved, has integrated the surrounding small Republican and modern Soviet-style buildings in the process of adaptive use. It has become a creative industrial park with an integrated audiovisua science and innovation office area, thematic cultural neighborhood, and vibrant residential area, driving the renewal of the neighborhood in which it is located. Heritage sites outside historic areas also have both tourist attractions and urban functions (Type 6). The site of the Ming City Wall, in the southwest corner of the inner city of Beijing, was restored in 1987 and transformed into a park in conjunction with an urban green space, using the natural environment to separate it from the modern city. This site is an effective urban seam zone (adjacent to the Beijing Railway Station to the north and a dense residential area to the south) that provides ecological space and activities for the surrounding residents.

Historic areas are a type of heritage with a greater emphasis on integrity than independently protected buildings. The historic areas of Beijing also play different roles in terms of function. Blocks with a tourism-attractive function (Type 7) often draw on neighboring tourism resources. For example, Wudaoying Hutong, near Yonghegong and Guozijian, was developed into a new commercial street with creative features unique to the old city of Beijing after many foreigners invested in it in its early days. Nanluoguxiang and Dashilanr, which are also commercially oriented tourism development models, are the most extensively studied historic areas in this category. Another type of historic area was predominantly residential (Type 8), such as Caochang Hutong. The Caochang area launched a renovation and improvement campaign with the goal of creating a harmonious and livable community, mainly to supplement the infrastructure. Based on its historical location and direction, the Sanli River system, which determined the pattern of hutongs in this area, was restored, supplementing the scarce ecological space in the historical block and creating leisure for the residents. In addition, some historic areas have both livelihood and tourism functions (Type 9), such as Gongmenkou area, which is adjacent to the White Pagoda of Miaoying Temple, a national key cultural relic protection unit, and is one of Beijing's online hotspots because of its close view of the White Pagoda when walking through hutongs; it is also a district rich in lifestyle. The area provides residents with many living services and public activity spaces, and the inclusion of special businesses reflects the interweaving of old and new.

4. Conclusions and discussion

This study focused on the relationship between urban function improvement and heritage conservation in the renewal of old Beijing city. From the perspective of historical urban landscape, heritages are placed in the background of urban function, and the theoretical framework is constructed with the value and function of heritages as the link to coordinate protection and urban development. The heritages were innovatively interpreted as an urban stock resource rather than a mere tourist attraction, its multiple roles and identities in modern adaptation were demonstrated. This paper provides a reference for systematic practice of heritages in modern conservation and renewal.

The 40-year renewal process of old Beijing city has experienced free growth and function optimization trade-offs in a market environment. While urban functions have gradually improved and facilities have become more evenly distributed, it comes at the expense of 51.6% of the historic architectural district, with approximately 28% of the heritage sites in old Beijing city currently in an isolated state. Today, urban heritage exists as several types of functions: tourism-attractive heritage as the calling card of the city and explicit carrier of the history and culture of the ancient capital, urban functional heritage as a stock resource to be used rationally, a combination of tourism-attractive and urban functional heritage, and many other heritage sites as stock resources waiting to be utilized. The differences in the functional mix of old Beijing city are mainly reflected at the parcel level; the historic areas have more mixed functional units than other zones, with predominantly residential functions mixed with cultural, scientific, educational, and administrative functions. Based on the above research, a case study was conducted on nine types of typical heritage sites and their surrounding functional organization patterns. Recommendations are presented to balance the optimization of urban functions with heritage conservation and utilization for sustainability.

The role of heritage in modern adaptation processes is not limited to the development of core resources for tourism, nor should attention to its sustainability pattern be based solely on tourism-oriented assessments of its development potential (Worku Tadesse, 2022). Increasing public awareness and economic stability of heritage sites is possible through tourism and the promotion of continuous investment in peripheral systems to maintain optimal services (Kamran, 2022). However, in older parts of the city, where the intensity of plot development is strictly controlled and the effective use of the stock of buildings is an important measure for improving the efficiency of the site, a variety of adaptive uses of heritage in urban functions can also contribute to its spatial and social value. On one hand, multiple heritage functions can balance and complement the overall functions of the district; on the other hand, heritage is not only heritage but also a public service facility that is integrated into the city which can promote the sustainable management of cultural heritage. For example, the heritage site of the embassy district of Dongjiao Minxiang is primarily used as an administrative office; however, the reason for its high visitor rate and evaluation is its unique and intact architectural style. This shows that the historical and artistic values of the heritage site and its intrinsic use are not conflicting. Currently, much of the heritage in old Beijing city exists in a closed and preserved form, without specific use functions, and with a large gap between heritage and urban functions. Therefore, to give heritage the necessary elements of urban functions, these aspects must be considered:

First, the functional placement of urban heritage sites must consider their spatiotemporal adaptability. In the context of continuous urban development and renewal, heritage sites and their surrounding urban environments form an interrelated, interactive, nested, and organic whole (Xie et al., 2011). In this process, the coupling characteristics between various functional elements and heritage in making specific coordination arrangements, such as ensuring the coexistence of cultural, educational, and administrative facilities with heritage and securing the integrity of heritage, should be considered.

Second, the current dilemma of heritage preservation is insularity, which is a legacy of past urban regeneration and a warning to many historic cities being renewed. However, creating a false historical atmosphere is not necessary; instead, the urban evolution that has occurred and the "collage city" of the old and new that has been created should be respected. With this inclusive attitude, "heritage islands" can be made sustainable by looking inward for values and uniqueness and outward for connections to surrounding resources.

Finally, no single sustainable model of urban heritage exists; its sustainability is expressed at three levels. First, heritage itself is an important component of and largely contributes to sustainable urban development (Vileniske, 2008). Second, sustainable solutions must balance the relationship between urban development and heritage conservation (Tan, Kusumo & Widodo, 2023). Although many cases of heritage revitalization have occurred in museums and cultural centers, these types of facilities do not contribute significantly to the overall functional balance and complementarity of the neighborhood. Third, heritage sustainability implies the enhancement of resilience, rational allocation of resources, and synergistic development of the entire sociocultural ecosystem. Therefore, based on the adaptation of heritage values to the surrounding environment, a sustainable pattern that harmonizes urban development and heritage conservation must be a multifaceted and holistic solution.

There are still some limitations to this work. For example, we obtained the number of visitors to heritage from the Weibo platform, but this platform is mostly used by young people and tourists, and the use and interaction of residents with heritage spaces cannot be obtained through online data. Therefore, in the case study section, we can only select typical cases for fieldwork. On the other hand, the ways of heritage adaptive use are becoming more and more diversified, and heritage often has multiple functions, such as cultural, commercial, educational, etc. However, the judgment of heritage functions in this study is still based on its most important function type. In addition, the relationship between the heritage and the city should be coordinated, and future research should also consider the relationship with residents and other stakeholders, to provide criteria for judging the appropriateness and fairness of heritage adaptive use.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

Appendix A

(a) Traditional landscape areas in 1981

(b) Traditional landscape areas in 1986

(c) Traditional landscape areas in 1991

(d) Functional distribution status in 1981

(e) Functional distribution status in 1986

(f) Functional distribution status in 1991

(g) Traditional landscape areas in 1996

(h) Traditional landscape areas in 2001

(i) Traditional landscape areas in 2006

(j) Functional distribution status in 1996

(k) Functional distribution status in 2001

(l) Functional distribution status in 2006

(m) Traditional landscape areas in 2011

(n) Traditional landscape areas in 2016

(o) Traditional landscape areas in 2021

(p) Functional distribution status in 2011

(q) Functional distribution status in 2016

(r) Functional distribution status in 2021

Legend:
- Old Beijing city
- Main road
- Heritage units
- Traditional landscape area
- Residential
- Administration and public services
- Commercial and business facilities
- Green space
- Industrial
- Street and transportation
- Municipal utilities
- Logistics and warehouse

Fig. A1. Functional distribution and traditional landscape areas changes in 1981–2021.

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